VEHICLE AND GEOMETRIC VARIABLES RELATED TO ACCIDENTS IN RURAL NO-PASSING ZONES

by

William C. Taylor, Ph.D.
Matthew DeLong
Gisso Shams

Sponsored by

The Michigan Department of Transportation
The Office of HIghway Safety Planning

November 1985

MICHIGAN STATE UNIVERSITY
1855

COLLEGE OF ENGINEERING

MICHIGAN STATE UNIVERSITY
EAST LANSING, MICHIGAN 48824

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-MI-RD-85-05		

4. Title and Subtitle	5. Report Date
Vehicle and Geometric Variables Related to Accidents in Rural No-Passing Zones	November 1985
	6. Performing Organization Code
7. Author(s) William C. Taylor, Matthew Delong, Gisso Shams	8. Performing Organization Report No.
9. Performing Organization Name and Address Department of Civil and Environmental Engineering, Michigan State University, East Lansing, MI 48824	10. Work Unit No.
	11. Contract or Grant No. HPR 0010 (7)
12. Sponsoring Agency Name and Address The Michigan Department of Transportation, The Office of Highway Safety Planning, Federal Highway Administration	13. Type of Report and Period Covered Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Previous studies on Michigan highways had identified a high rate of accidents in no-passing zones. This study was conducted to identify geometric features, roadside and vehicle characteristics, associated with these higher accident rates. A representative sample of two-lane, two-way rural roads in Michigan, containing 525 no-passing zones (245 with a high accident rate and 280 with zero accidents in three years) was selected for the study. Geometric and roadside environment information (i.e. shoulder and curve type, number of driveways, roadway obstacles and intersections) were gathered for each of these 525 no-passing zones. Regression analysis and discriminant analysis were used to describe the propensity of a no-passing zone to experience a high accident rate. Discriminant models were developed to predict which no-passing zone will experience "high" and "low" accident rates based on these variables.

No evidence was found that the length of no-passing zones or the presence of curve warning signs, chevrons or advisory speed plates are related to the rate of accidents in no-passing zones. The study also failed to find no-passing zones to be particularly hazardous for vehicles for any specific weight class. Small vehicles experience a higher than expected accident rate on rural roads in general, but this does not appear to be exacerbated in no-passing zones.

17. Key Words	18. Distribution Statement
No-passing, rural, safety, roadside environment, models	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-69)

ACKNOWLEDGEMENTS

Prepared in cooperation with the Michigan Office of Highway Safety Planning, the Federal Highway Administration and the National Highway Traffic Safety Administration, through Highway Safety Project #MTR-85-005A, and the Traffic and Safety Division of the Michigan Department of Transportation.

The authors would like to thank Mr. Jack Benac of the Technical Services Unit, Traffic and Safety Division of the Michigan Department of Transportation for his invaluable assistance with this project. Without Mr. Benac's cooperation, knowledge and skill this project would have been extremely difficult, if not impossible, to complete.

VEHICLE AND GEOMETRIC VARIABLES RELATED TO ACCIDENTS IN RURAL NO-PASSING ZONES

INTRODUCTION

A recent study conducted by the Michigan Department of Transportation reported that "accident rates in no-passing zones are over 25 percent higher than in passing zones." (1) This finding was based on the analysis of 10 years of Michigan trunkline accident data. Statistical tests were conducted, and the the difference in accident rates was found to be statistically significant. Head-on accidents were also found to be significantly higher in no-passing zones, and since this type of accident tends to be more severe than the average for all accidents, it was postulated that the magnitude of the safety problem in no-passing zones may be even greater than the difference in accident rates.

Because no-passing zones are generally located coincident with specific geometric features such as vertical curves, horizontal curves and intersections, this higher accident rate should be expected. Thus, the evaluation of the effectiveness of specific no-passing zones can not reasonably be based on the difference between locations where passing is prohibited and those locations where it is allowed. Instead, the evaluation must be based on the differences among accident rates at various no-passing zones.

---

(1) Evaluation of Accidents in Passing and No Passing Zones (preliminary); Michigan Department of Transportation, January 1981.

OBJECTIVES

The ultimate goal of this study was the identification of combinations of geometric features, roadside characteristics and vehicle characteristics that are associated with high accident rates in no-passing zones. Once these combinations are known, traffic safety can be enhanced by controlling locations to avoid combinations of those variables associated with high accident locations, by altering design standards to reduce the risk of particular accident types and/or by warning the driver of potentially dangerous locations.

The first objective of the study was the determination of the magnitude and characteristics of the accident problem at no-passing zone locations on two-lane rural highways in Michigan. The data base used in this analysis included all accidents occurring on Michigan Trunkline highways in 1980, 1981 and 1982.

The second objective was the determination of the geometric features and roadside development variables associated with no-passing zones experiencing a high rate of accidents. The information for this analysis was obtained from the MIDAS accident file, the roadway inventory file and the MDOT photologs.

The third objective was the development of a "model" based on roadway and roadside characteristics to predict which no-passing zones would be expected to experience a high rate of accidents. This modelling analysis was used to determine combinations of geometric features and roadside variables which result in an over-representation of specific accident types.

A fourth objective was the determination of vehicle types that were over (or under) represented in accidents occurring in no-passing zones on two-lane rural highways. This analysis required the use of the VNDCTR file and was based on the exposure measure developed under a previous contract with MDOT.(2)

This report summarizes the results of the studies used to address each of these objectives and contains recommendations for monitoring no-passing zones. The report also includes documentation of all computer programs used in the analysis. Copies of all data tapes used in the analysis are available to the sponsor.

LITERATURE REVIEW

An initial task in this study was the preparation of a literature review of safety in no-passing zones. A major portion of this task had already been included in a report on the feasibility study for this project.(3) In that report, a total of 147 citations were retrieved by the computer search, and the literature summarized as it related to signing, pavement marking, trends in eye height and tort liability. Roadway geometry and the roadside environment were examined in this study, and the literature review expanded to cover these items.

An additional 70 citations related to geometric or roadside features were included in the literature review covering roadway geometry (vertical curves, horizontal curves and intersections) and roadside environment (driveways) and their relationship to accidents. Most of these papers have been reviewed and summarized by the FHWA in a recent publication on highway safety (4).

---

(2) Safety Impacts of Vehicle Design and Highway Geometry, a dissertation by Koji Kuroda, Michigan State University, 1984.

(3) A report on the State-of-the-Practice on No-Passing Zone Signing and Marking (1984).

(4) Synthesis of Safety Research Related to Traffic Control and Roadway Elements, Volume 1, 1982.

Geometric Features

Geometric features, such as intersections, horizontal curves and vertical curves, generally dictate whether a section of roadway will be a passing or no-passing zone. Previous studies have found that each of these alignment features significantly affects accident rates. There is a particularly high concentration of accidents at rural intersections. "In rural areas 24 percent of the total accidents and 17 percent of fatal accidents occurred at intersections."(5)

The relationship between the number of accidents and the radius of horizontal curves has been studied by many researchers. One such relationship developed by Babkok in 1968 showed: "Alignments with curvature less than 3 degrees produce a small decrease in the number of accidents, while alignments with curvature greater than 3 degrees produce a rapid increase in accidents."(6) Figure 1 shows this relationship.

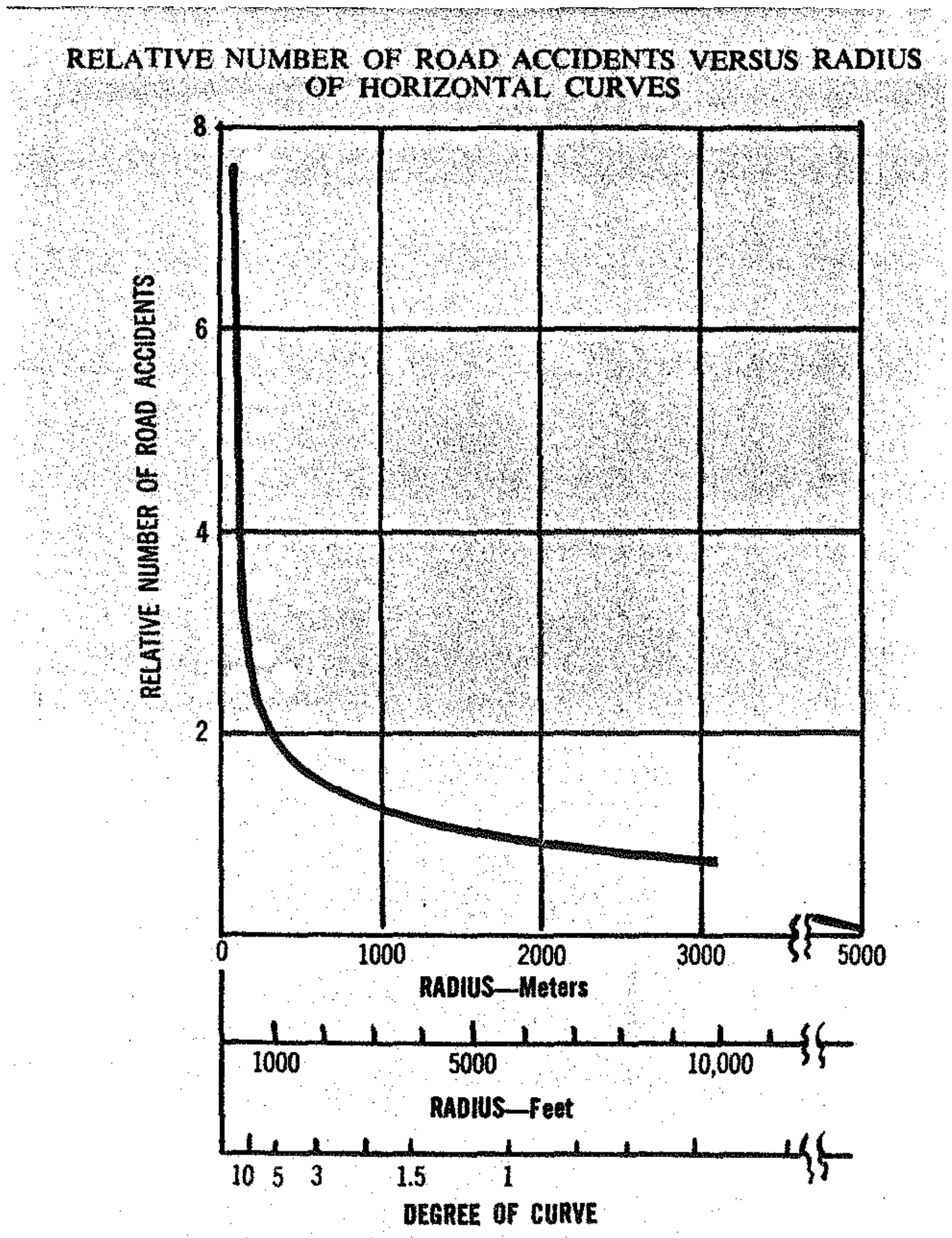
The combined effect of curvature and volume on accident rates has also been reported: "Accident rates increase with increasing curvature at volumes below 5000 vehicles per day (VPD). Sharp curves have lower accident rates than moderate curves at volumes over 5000 VPD" (Raff; 1953). Table 1 shows the combined effect of volume and curvature on accident rates.

On vertical curves, an increase in gradient leads to an increase in the accident rate. Bitzel (1956) studied expressways in Germany and found a positive relationship between gradient and accidents shown in Table 2.

---

(5) Ibid.
(6) Ibid.

FIGURE 1



Source: "Synthesis of Safety Research Related to Traffic Control and Roadway Elements," Volume 1, December 1982.

Table 1. Accident Rate on Two-Lane Curves, by Volume of Traffic and Degree of Curvature

Curvature	0-4,900 vpd		5,000 vpd or more		All Volumes	
Degrees	Number	Per Million Vehicle Miles	Number	Per Million Vehicle Miles	Number	Per Million Vehicle Miles
0-2.9	395	1.6	111	1.9	506	1.66
3.0-5.9	423	2.3	173	3.1	596	2.53
6.0 or more	569	3.2	123	2.8	682	3.13

Source Data From: "Interstate Highway Accident Study," by M.S. Raff, Highway Research Board Bulletin 74, 1953, p. 35 (81).

Table 2. Accident Rates Related to Gradient (German Expressways)

Gradient in Percent	Accident Rate*
0-1.9	0.75
2-3.9	1.09
4-5.9	3.06
6-8.0	3.39

* Accidents/MVM

Source: "Effect of Motorway Design on Accidents in Germany," by I. F. Bitzel, Highways and Bridges and Engineering Works, 1956, p. 4 (12).

Table 3. Freeway Accidents and Vertical Curvature

Type of Vertical Curve and Position	Accident Rate
CRESTS (General)	2.02
On upgrade of crests	2.33
At peak of crests	1.96
On downgrade of crests	1.92
SAGS (General)	2.96
On downgrade of sags	3.57
At bottom of sags	2.45
On upgrade of sags	2.39

* Accidents/MVM

Source: "Freeway Traffic Accident Analysis and Safety Study," by B. F. K. Mullins and C. J. Keese, HRB Bulletin 291, 1961, p. 46 (76).

The type of curve is also apparently an important factor in highway safety, with crest curves experiencing a lower accident rate than sag curves. The reported accident rate per mile for each curve type are as follows:(7)

Curve Type	Accident Rate
Tangents	5.1
Crest	10.7
Sag	12.8

This difference may be due to a limited sight distance provided by headlights, as the researchers also found a positive relationship between sight distance conditions and accident frequency as shown in Table 3.

Roadside Environment

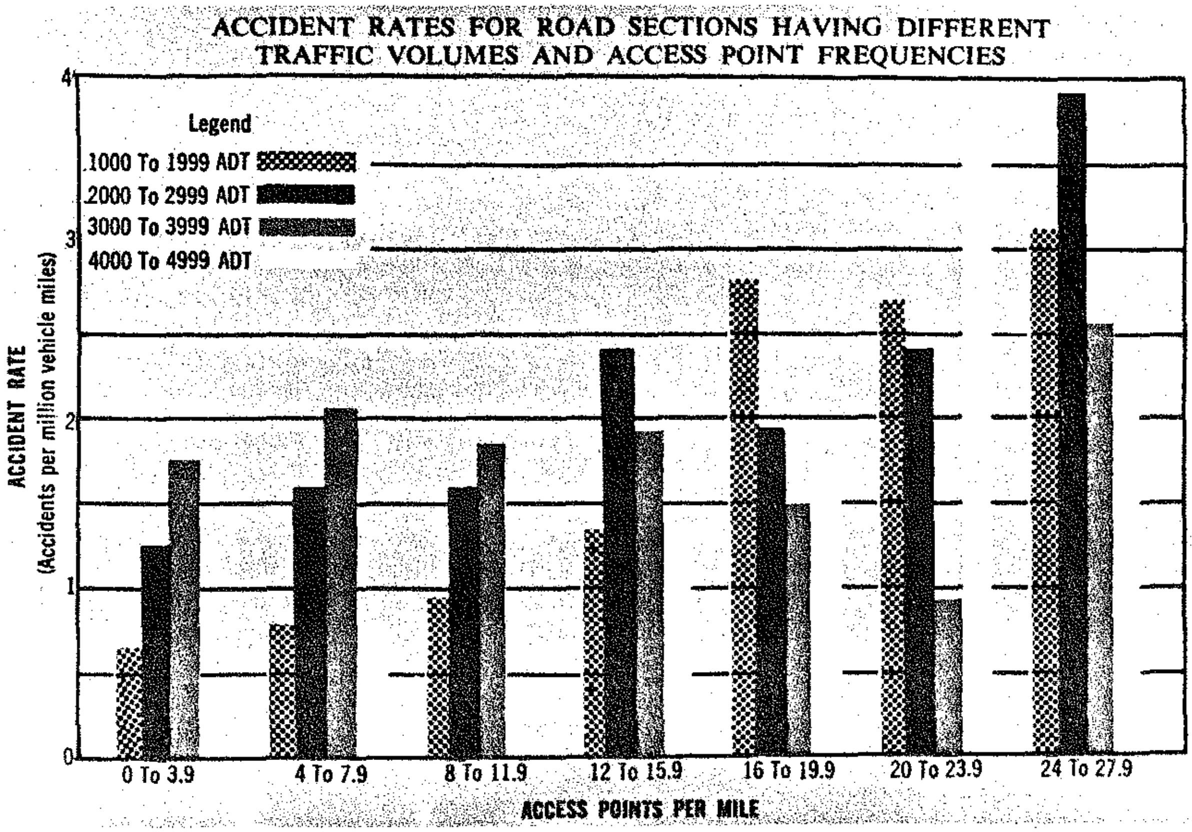
The effect of access along 420 miles of rural, two-lane highway in Minnesota was studied by Staffeld (1953). This 420 miles had an average of 7.7 private driveways per mile. In this study the accident rates were determined for sections with and without driveways. "Accident rates for sections without driveways averaged 1.4 per million vehicle miles (MVM) while those sections with driveways for low volume or residential use averaged 1.5 accidents per MVM" (Staffeld; 1953). The rate of accidents for sections containing one or more commercial driveway, however, was found to be 2.9 accidents per MVM. This difference reflects the greater frequency of use of commercial driveways. Figure 2 shows this relationship.

After analyzing three years of accident data on 1400 miles of rural, two-lane highways in Oregon, Schoppert (1957) concluded that volume,

---

(7) "Freeway Traffic Accident Analysis and Safety Study," by B.F.K. Mullins and C.J. Keese, HRB Bulletin 291, 1961, p. 46 (76).

FIGURE 2



Source: "Synthesis of Safety Research Related to Traffic Control and Roadway Elements," Volume 1, December 1982.

frequency of driveways or intersections and design features such as shoulder width or sight distance are significant factors (in sequence of importance) involved in accident rate predictors. In this analysis, the number of commercial establishments and the number of commercial and residential driveways per mile showed a positive relationship to accidents regardless of the volume grouping involved. For volumes over 2000 ADT, the number of access points was reported to be a good predictive index of the number of accidents, but for volumes under 2000 ADT, no strong relation between roadway elements and accidents was found.

These previously reported results support the conclusion that the accident rate in no-passing zones can be expected to be higher than that where passing is permitted. These studies also substantiate the hypothesis that roadside characteristics contribute to a higher accident rate. This does not imply, however, that the accident rate cannot be reduced with the appropriate signing and/or the use of "forgiving" highway design concepts.

METHODOLOGY

The methodology used in this study is illustrated in Figure 3, and described in the steps which follow.

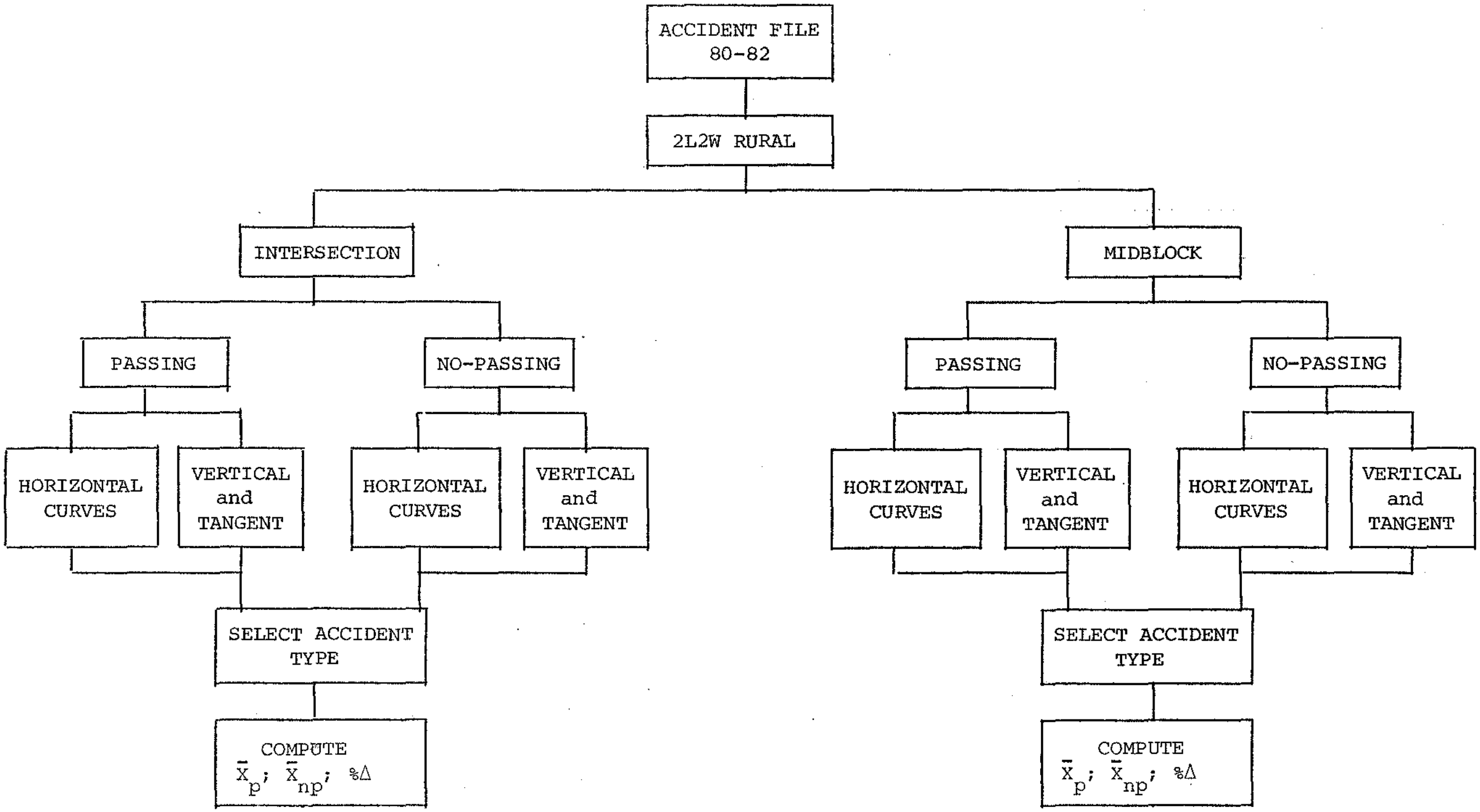


Figure 3. Methodology for Safety Evaluation of No-Passing Zones

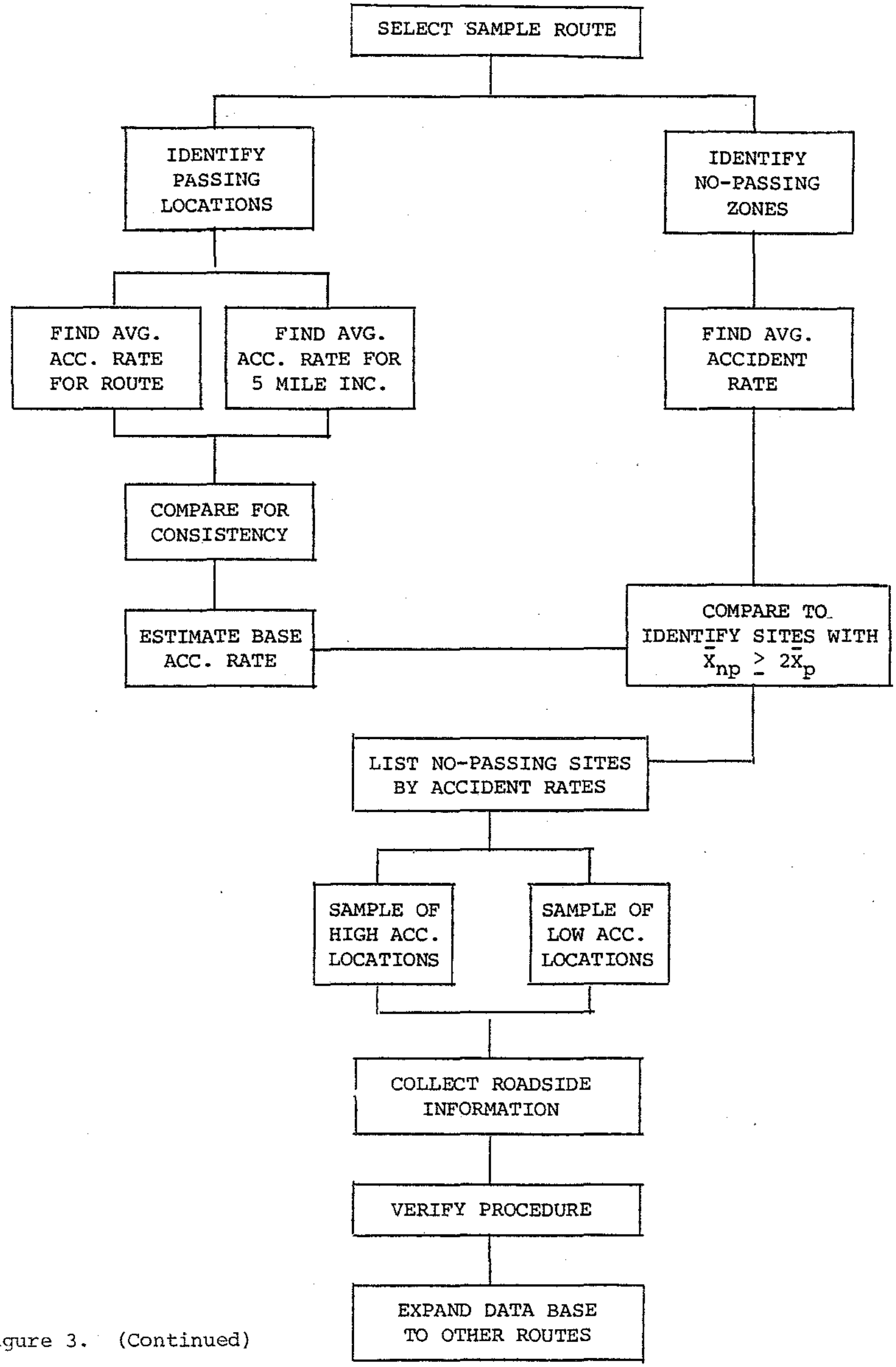


Figure 3. (Continued)

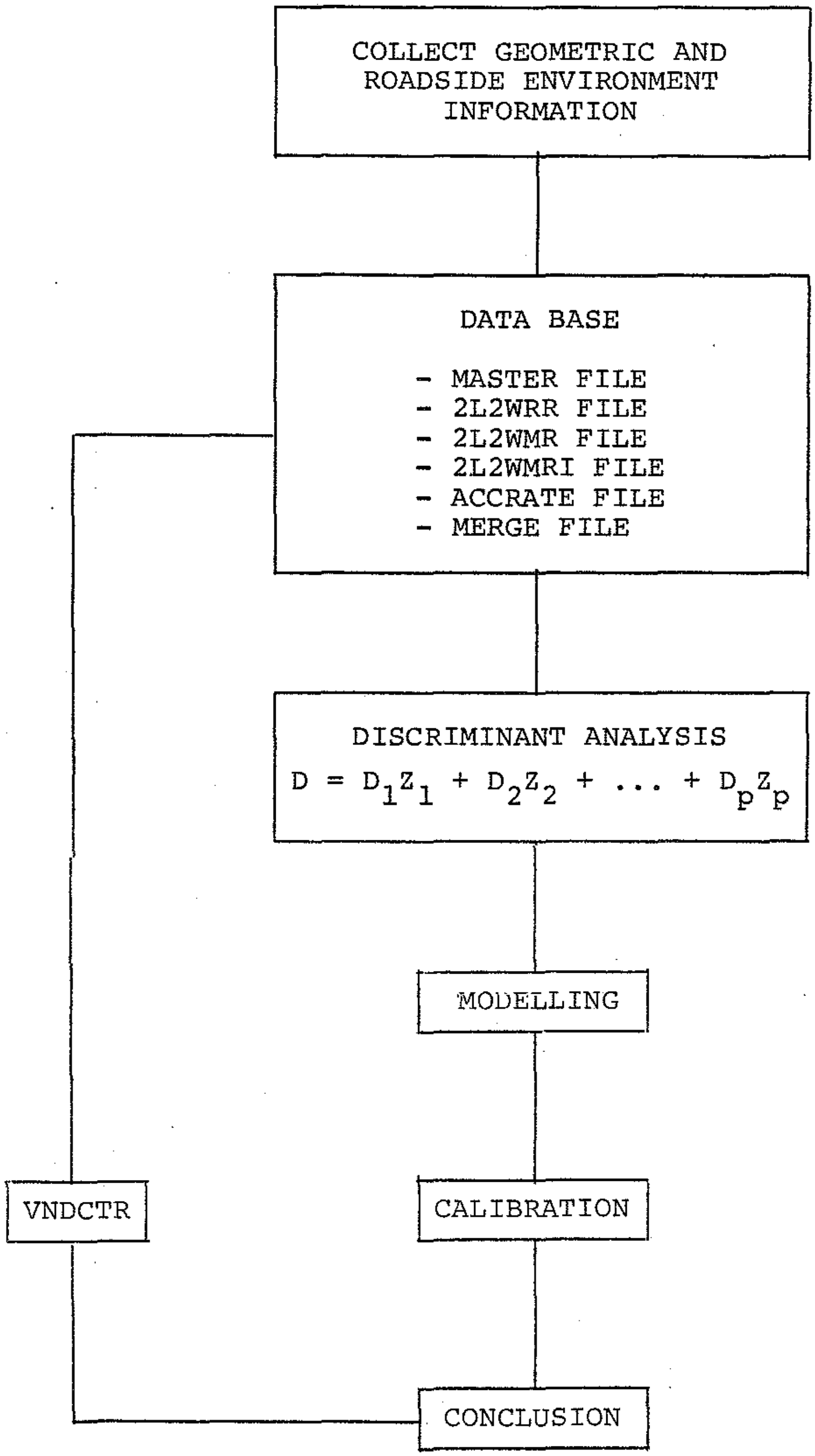
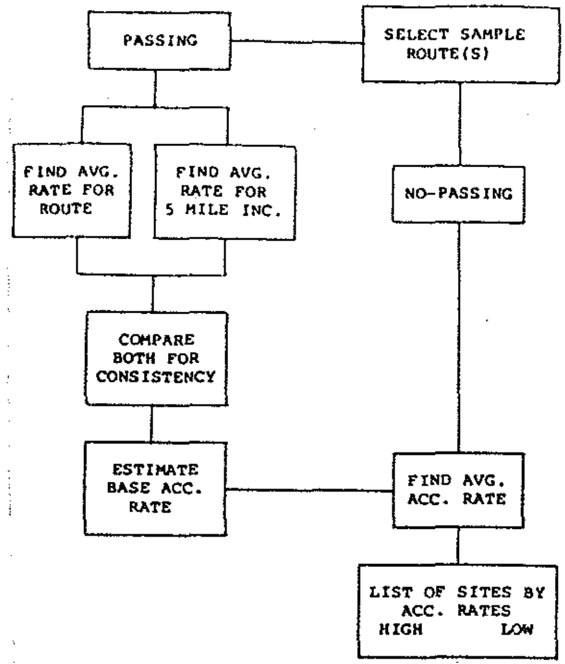


Figure 3. (Continued)

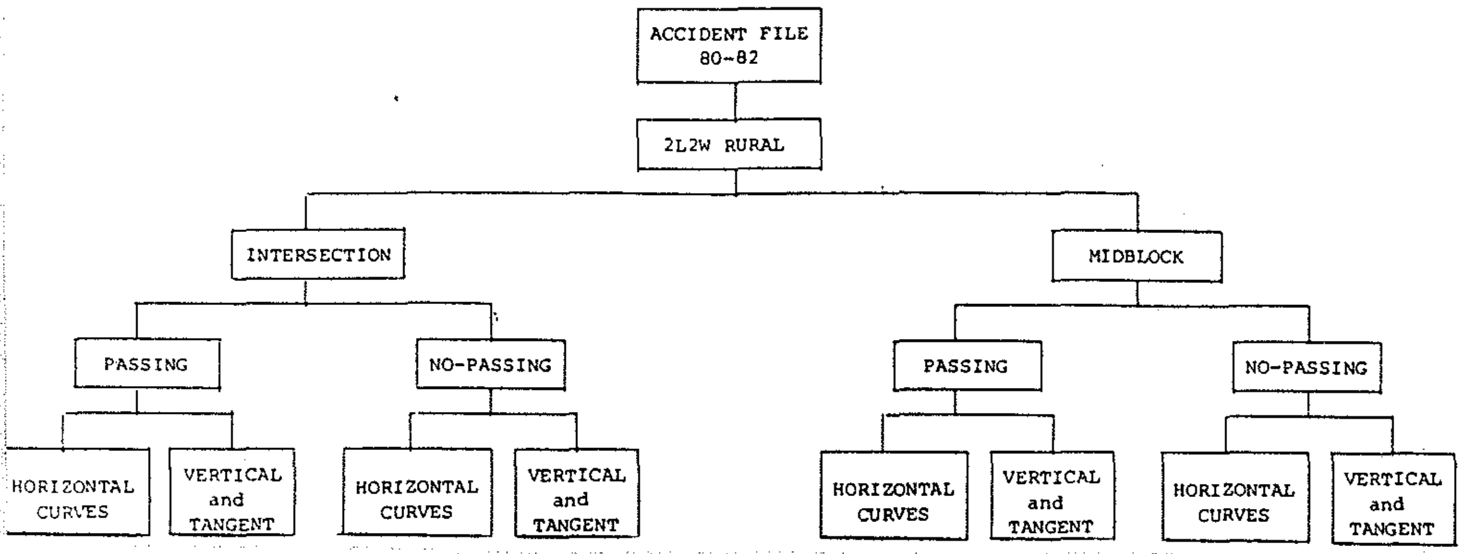
GEOMETRIC FEATURES AND ROADSIDE CHARACTERISTICS

The second objective of this study was the determination of geometric features and roadside characteristics associated with no-passing zones experiencing a high rate of accidents. Since all roadside information is not available on an automated file, this task required the review of photolog film to obtain this data. It was not feasible (nor necessary) to view film for the entire state, so a sample of routes from throughout the State of Michigan was selected for analysis.



The proposed data collection and analysis procedure was tested by selecting a sample route (M-52 from Saginaw to Adrian) and conducting a sample analysis. A separate set of calculations of passing section rates were made using only the nearest five mile lengths of passing sections on either side of each no-passing zone. The entire route rate and these selected section rates were then compared. There was no significant difference between the accident rate using these two methods. Thus, it was decided that accident rates based on the entire route on which each no-passing zone was located would be used in this study.

A listing from highest (7.02 accidents/MVM) to lowest (0 accidents/MVM) accident rates occurring in no-passing zones on M-52 was prepared. A sample of the 15 highest accident locations and 15 locations with zero accidents were selected and roadside information collected for these sites. A discriminate analysis using SPSS was run on these sites, and the results were reviewed. Based on this successful test of a sample route, the data required for the remainder of the study was obtained and coded as described in the following sections.



DATA PREPARATION

Accident data for Michigan Trunkline routes for the years 1980-1982 (which is found in the MIDAS accident file) were used for this study. "Bitstat," an internal program in the State computer system, was used to reduce the master file so that it contained only two-lane two-way rural road information (file 2L2WRR). The 2L2WRR file was then stratified into two files, one containing all intersection accidents and the other containing all midblock accidents.

For this study a no-passing zone is defined as any zone in which passing is restricted in one or both directions. The identified passing and no-passing zones on the 2L2WMR file were not consistent with this definition. Because of other criteria which define the limits of a control section, a zone as defined in this study may comprise several zones on the state files. Bridges, intersections, and changes in cross-section are some of the criteria the State uses for ending one zone and starting a new one. Thus, one long stretch of no-passing zone may be several no-passing zones on the State records. This problem was solved by running the 2L2WMR file through the program "Crunch" to reduce the State zones so that they matched the study definition. This was done by comparing the begin and end mile points of consecutive no-passing zone roadway segments. End mile points which were equal to the begin mile point of the following segment were replaced by the end mile point of that segment. By matching definitions the number of zones on the revised file (2L2WMR1) was approximately one third less than on file 2L2WMR.

Three years of accident data (1980-82) were combined with volume data and the accident rate (in accidents per million vehicle miles) was used as the selection criteria for high and low accident sites. The revised (2L2WMR1) file was run through the program "Accrate" which computed the accident rate for the selected accident types (see accident selection) and created a new file (file ACCRATE).

Geometric and obstacle information gathered from the photolog (see photolog data gathering) was combined with the information on the ACCRATE file for each site selected for analysis. This was accomplished by running both sets of data through the program "MERGE." A new file (file MERGE) was created with each entry having the following information: district code, control section, route number, ADT, lane width, shoulder width, begin mile, end mile, zone type, 3 accident frequencies, 3 accident rates, shoulder surface type, curve information, driveway information, roadside obstacle information, and intersection information. The two files ACCRATE and Merge were the end products of the data base building process.

Each of these files was then divided into files containing no-passing zones and those occuring where passing is allowed. Finally, each of the files was further classified as horizontal curves or other (the other being vertical curves, tangent sections and miscellaneous segments not classified as horizontal curves). This resulted in the following eight data files available for analysis:

a. Intersection accidents occuring on horizontal curves in passing zones.

b. Intersection accidents occuring on vertical curves or tangent sections in passing zones.

c. Intersection accidents occuring on horizontal curves in no-passing zones.

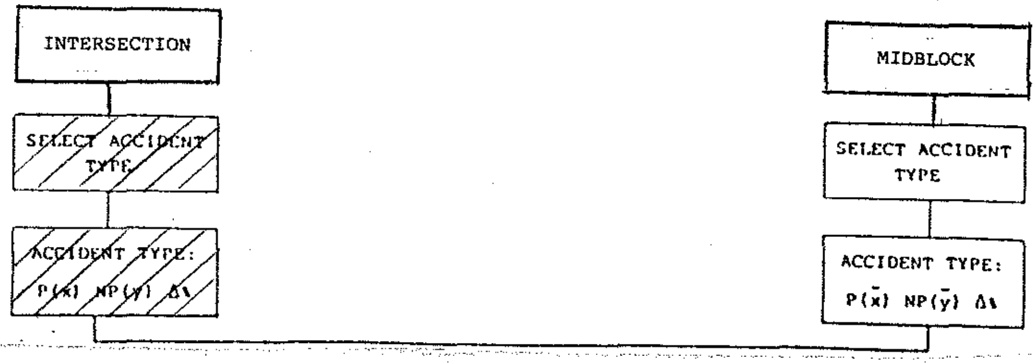
d. Intersection accidents occuring on vertical curves or tangent sections in no-passing zones.

e. Midblock accidents occuring on horizontal curves in passing zones.

f. Midblock accidents occuring on vertical curves or tangent sections in passing zones.

g. Midblock accidents occuring on horizontal curves in no-passing zones.

h. Midblock accidents occuring on vertical curves or tangent sections in no-passing zones.



ACCIDENT SELECTION

The objective of this phase of the study was to identify accident types which occur at a differential rate in passing sections and no-passing zones. Using the data files listed in the preceding section, the mean, standard deviation and variance of each accident type in each data file was calculated. The selection of the relevant intersection and midblock accident types to be used in this study was based on a comparison of data files a and b versus c and d and data files e and f versus g and h. These sets contain the statewide no-passing and passing zone average accident rates at intersections and midblock locations respectively.

The passing and no-passing zone accident rate, standard deviation and variance of 25 accident types (see Table 4) were calculated and compared. At intersections, the difference in total accident rate and the rate for each accident type between passing sections and no-passing zones was quite small. Since (1) the presence of a no-passing zone had little effect on the number or type of intersection accidents; (2) the accident files do not distinguish accidents by approach leg to an intersection, and (3) the accident rate at intersections is difficult to define; the intersection accident file was not used for any further analyses.

The accident rates were significantly different for several accident types at midblock locations. Eight midblock accident categories (total, injury, wet, icy, dark, overturned, fixed object, and head-on) were found to have a statistically significant difference in the accident rate, and

TABLE 4. Accident Rates for rural Trunkline Highways in Michigan.

#	Accident Type	2L2W Rural Intersection		2L2W Rural Midblock	
		No-Pass Acc/MV	Pass Acc/MV	No-Pass Acc Rate	Pass Acc Rate
1	Total	0.42	0.39	1.94	1.73
2	Injury	0.15	0.14	0.49	0.34
3	Fatal	0.00	0.00	0.02	0.02
4	Wet	0.08	0.08	0.31	0.26
5	Icy	0.07	0.07	0.41	0.31
6	Dark	0.15	0.14	1.03	0.96
7	Overturn	0.02	0.02	0.16	0.13
8	Train	0.00	0.00	0.00	0.00
9	Parked	0.01	0.01	0.03	0.02
10	Multi: other	0.02	0.02	0.15	0.15
11	Pedestrian	N/A	N/A	0.01	0.01
12	Fixed Object	0.09	0.07	0.49	0.31
13	On Road Obj.	0.00	0.00	0.01	0.01
14	Animal	N/A	N/A	0.71	0.80
15	Bicycle	N/A	N/A	0.01	0.01
16	Single: other	0.00	0.00	0.02	0.02
17	Head On	0.02	0.01	0.14	0.10
18	SS-Meet	0.00	0.00	0.01	0.01
19	SS-Pass	0.00	0.00	0.01	0.01
20	Angle	0.09	0.09	0.01	0.01
21	Left Turn	0.05	0.06	0.01	0.02
22	Right Turn	0.01	0.01	0.00	0.00
23	Rear End	0.07	0.06	0.15	0.14
24	Backing	N/A	N/A	0.00	0.00
25	Parking	N/A	N/A	0.00	0.00

N/A = Drop before analysis

Figures rounded to two decimals

were identified as potential categories for analysis (see Table 5). The fact that the total accident rate and the injury accident rate were both found to be significantly higher in no-passing zones than in passing zones supports the findings in the previous MDOT report.

Since several of these categories are not mutually exclusive (i.e. a head-on accident could occur on an icy road at night), and many of the variables are not related to the presence of a no-passing zone; icy, wet, dark, injury and total accidents were not subjected to further analysis.

The three remaining accident categories (fixed object, head-on and overturned) are all related to geometrics, and thus are potentially susceptible to change by modifying geometric design standards or traffic control devices. To gain further insight into these accident types, the no-passing zones were separated into two groups, those containing at least one horizontal curve, and those with no horizontal curves, and the accident rates for each group determined.

Table 6 presents the results of this stratification. In all cases, the accident rate in no-passing zones which contain a horizontal curve is higher than in those that were established due to a vertical curve, intersection, railroad approach or some other reason. This could be expected for the three accident types selected, as these accident types are typical of horizontal curve accidents. However, it is also true of the total accident rate.

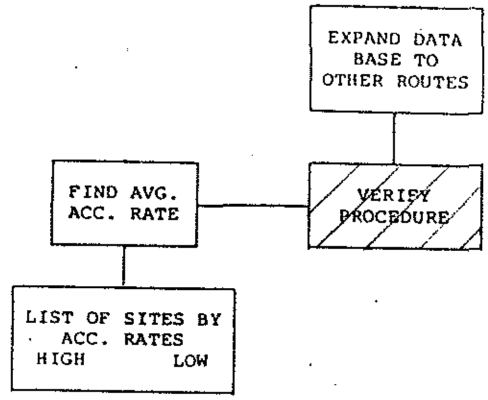
This concluded the first phase of the study, which was the determination of the difference in accident rates between no-passing zones and sections of roadway where passing is allowed. The total accident rate is approximately 10% higher in no-passing zones, with certain types of accidents being as much as 37% higher.

Table 5. Test of difference in accident rates at two lane midblock locations.

Accident Type	No-Pass freq.	X_1	Pass freq.	X_2	Difference X_1-X_2	% Difference	Statistically Significant (α=.80)
Total	12074	1.94	21712	1.73	0.42	10.6	Yes
Injury	3018	0.49	5657	0.34	0.15	30.6	Yes
Fatal	143	0.02	306	0.02	0.00	0.0	No
Wet	1875	0.31	3785	0.26	0.05	16.9	Yes
Icy	2510	0.41	4570	0.31	0.10	24.4	Yes
Dark	6318	1.04	13215	0.96	0.07	7.3	Yes
Overturn*	3018	0.17	5657	0.13	0.04	24.2	Yes
Train	143	0.00	306	0.00	0.00	0.0	No
Parked	1875	0.03	3785	0.02	0.01	14.8	No
Multi: other	941	0.15	2138	0.15	0.00	0.0	No
Pedestrian	59	0.01	145	0.01	0.00	0.0	No
Fixed Object*	2995	0.49	4535	0.31	0.18	37.2	Yes
On Road Obj.	54	0.01	112	0.01	0.00	0.0	No
Animal		N/A		N/A	--	--	--
Bicycle		N/A		N/A	--	--	--
Single: other	112	0.02	220	0.02	0.00	0.0	No
Head-On*	824	0.14	1507	0.10	0.04	23.7	Yes
SS-Meet	35	0.01	88	0.01	0.00	0.0	No
SS-Pass	73	0.01	108	0.01	0.00	0.0	No
Angle	65	0.01	111	0.01	0.00	0.0	No
Left Turn	91	0.02	227	0.02	0.00	0.0	No
Right Turn	12	0.00	22	0.00	0.00	0.0	No
Rear End	942	0.15	2055	0.14	0.01	9.1	No
Backing		N/A		N/A	--	--	--
Parking		N/A		N/A	--	--	--
* Three Acc. Types Used for Analysis		0.79		0.54	0.25	32.2	Yes

TABLE 6. Accident rates in zones with and without horizontal curves (acc. per MVM)

	No Passing Zones	Passing Sections	% Difference
Total Accidents			
Statewide	1.939	1.734	10.6
Zones Containing Horizontal Curves	1.980	1.750	11.6
Zones Without Horizontal Curves	1.922	1.731	9.9
Overturned Accidents			
Statewide	.165	.125	24.2
Zones Containing Horizontal Curves	.193	.146	24.3
Zones Without Horizontal Curves	.153	.121	20.9
Fixed Object Accidents			
Statewide	.491	.308	37.3
Zones Containing Horizontal Curves	.580	.338	41.7
Zones Without Horizontal Curves	.455	.303	33.4
Head-on Accidents			
Statewide	.135	.103	23.7
Zones Containing Horizontal Curves	.151	.126	16.6
Zones Without Horizontal Curves	.129	.100	22.5



Expand Data Base to Other Routes

To obtain a representative sample of all two-lane two-way rural roads in Michigan, approximately 1000 miles of road from the 2L2WRR file were selected representing all regions of the state (see Table 7).

These routes contained 525 no-passing zones with a total length of 227.20 miles. There were 633 of the three selected types of accidents in these zones. An accident rate for the three selected accident types plus one for a combination of head-on, fixed object, and overturned accidents was produced for each no-passing zone and for the passing sections. The no-passing zones were ranked in order from highest to lowest accident rate within each route.

Selection of the sites for the study was based on the accident rate of the three combined accident types. This rate for each zone was compared with the route wide rate, and if the rate for the no-passing zone was at least twice the rate for the passing sections on the route it was selected as a high accident site. There were 245 such sites identified. Those sites which had accident rates lower than the passing zone rates were selected as possible low accident sites. No-passing zones with low rates were more plentiful than those with high rates so to keep an equal balance, 280 sites with an accident rate of zero were selected as low accident sites.

Table 7. Routes selected for analysis.

Zone	Route	Location	Approximate Mileage
1	M-123	Between Moran and Paradise	55 miles
	M-94	Between Manistique and Munising	52 miles
	M-35	Between Escanaba and Menominee	55 miles
	M-28	Between Marquette and Ironwood	133 miles
	M-26	Between Copper Harbor and Mass City	92 miles
2	M-32	Between Gaylord and Alpena	74 miles
	M-72	Between Mio and Harrisville	41 miles
	M-65	Between Rogers City and AuGres	112 miles
	M-115	Between Clare and Frankfort	86 miles
	M-55	Between Cadillac and Manistee	45 miles
	M-73	Between Grayling and Traverse City	50 miles
3	M-52	Between Stockbridge and Hemlock	69 miles
	M-46	Between Saginaw and Muskegon	82 miles
	M-81	Between Saginaw and Cass City	45 miles
	M-25	Between Lexington and Port Austin	65 miles
	M-57	Between Clio and Greenville	76 miles
	M-89	Between Plainwell and Ganges	33 miles
	M-20	Between Midland and Big Rapids	69 miles
	M-50	Between Eaton Rapids and Aito	51 miles
4	M-86	Between Coldwater and Three Rivers	42 miles
	M-50	Between Jackson and Monroe	57 miles
	M-52	Between Adrian and Stockbridge	45 miles
	M-43	Between Kalamazoo and South Haven	35 miles
	M-140	Between South Haven and Niles	40 miles
	M-99	Between Springport and Ransom	57 miles
	M-40	Between Gobles and Long Lake	50 miles

* Zone 1 = State Districts 1 and 2; 2 = Districts 3 and 4; 3 = Districts 5 and 6; 4 = Districts 7 and 8.

Collect Geometric and Roadside Environment Information

COLLECT GEOMETRIC AND ROADSIDE ENVIRONMENT INFORMATION

Geometric and roadside environment information for each of the 525 selected zones were gathered through the use of MDOT's photologs. The film record of each control section was viewed and the beginning and ending mileage for each no-passing zone identified. The following geometric and roadside environment data were obtained for these no-passing zones:

Roadway Geometry

1. Beginning mile point of the no-passing zone.
2. Ending mile point of the no-passing zone.
3. Shoulder Type - paved, unpaved, partially paved.
4. Type of Curve
   - horizontal
     - right
     - left
   - vertical
     - sag
     - crest

Roadside Environment

1. Number of Driveways
   - commercial
     - on vertical curve
     - on horizontal curve
     - on tangent
   - residential
     - on vertical curve
     - on horizonal curve
     - on tangent
2. Number of Roadway Obstacles within 30 feet of the Highway
   - trees
   - poles
   - ditch (%)
   - mailbox
   - guardrail
   - overpass
   - embankment (%)
   - culvert
   - other (fence, etc.)
   - signs

- target
- chevron
- advisory
- other (all highway signs except the 3 previous categories)

3. Presence of Intersection
   - minor
     - with stop
     - with flasher
     - with signal
   - major
     - with stop
     - with flasher
     - with signal

The information described above was collected separately for each side of the road (ascending and descending control section number) and was coded on data sheets. The ascending and descending information was combined for each no-passing zone for analysis purposes.

The beginning and ending photolog mile points (mile point coded through use of photolog) of each individual no-passing zone were compared with the beginning and ending MALI mile points (mile point used in the ACCRATE file) of the same no-passing zone. Since the accident files are based on MALI the mile points obtained from the photologs were changed (where necessary) to match the MALI points. A file was constructed (geometric file) consisting of 525 records, each including route number, control section number, beginning and ending mile point of each no-passing zone and the geometric and roadside environment information. This file was designated as the final work file. The file format is included in Appendix B.

STATISTICAL ANALYSIS OF DATA

DISCRIMINANT ANALYSIS

$$D = D_1Z_1 + D_2Z_2 + \ldots + D_pZ_p$$

The discriminant analysis technique (see Appendix) was used to gain an understanding of the variables that describe the propensity of a no-passing zone to experience a high accident rate. Only sites with "high" and "low" accident rates were used in the analysis in an attempt to accent the difference in the value of the variables. The analysis resulted in a set of "models" which provide a numerical estimate of the relationships being sought.

In any model building process, it is desirable to test the model against a data set different than that used to build the model. Since no comparable data exists, the data contained in the final work files (as described in the previous section) were randomly divided into two files. The first file (containing 50% of the sites) was used in model construction, and the second file (containing the remaining 50% of the sites) was used for model testing.

As in regression analysis, there are several operational options available within discriminate analysis. In this study models were constructed (1) using forward and backward stepwise procedures with all variables included in the final work file, (2) using stepwise procedures with selected variable sets and (3) using the direct method with selected variables. The purpose of the third option was to determine if there were relatively inexpensive countermeasures available that would explain the classification of a given site as "high" or "low."

Model 1

The first model constructed used the forward stepwise procedure with all coded variables to develop the discriminant function. The variables selected for this model (in order of their selection) were:

1. Vertical Curves
2. Other Signs
3. Partially Paved Shoulder
4. Minor Intersections with Flasher Control
5. Mailboxes
6. Trees
7. Major Intersections
8. Unpaved Shoulders

Model 1 correctly categorized 87 of 122 of the high accident locations and 92 of 127 of the low accident locations. Overall, the model correctly classified 71.89% of the 249 sites as belonging to either the high or low group. This perecent correct is referred to as the model accuracy rate in the remainder of this study.

Model 2

Since the order in which variables are used to develop the discriminant function is dependent on their order in the input data, the backward stepwise procedure was used to develop a discriminate function.

The variables included in this analysis were: (The order has no meaning in this technique since variables are being removed instead of added.)

1. Unpaved Shoulders
2. Partially Paved Shoulder
3. Horizontal Curves
4. Vertical Curves
5. Major Intersection
6. Minor Intersections with Flashers
7. Other Signs
8. Trees
9. Mailboxes
10. Embankment
11. Driveways on Horizontal Curves

This model includes horizontal curves, embankment and driveways as new variables not used in model 1. The net results were quite close, with 85 of 122 high accident locations and 91 of 127 low accident locations correctly categorized for an overall accuracy rate of 70.68%. This implies that either these variables add little to the explanatory power of the models, or that they are closely correlated with other variables included in model 1.

Model 3

To test the effect of sample size on the model results, a second model using the backward stepwise procedure was developed with 60% of the sites used to build the model. The variables included in this model were the same as model 2 except that driveways on vertical curves was also included.

Model 3 correctly categorized 105 of 152 high accident location and 114 of 158 low accident locations for an overall accuracy rate of 70.65%. Since the accuracy of the model in correctly categorizing high accident locations or low accident locations did not change significantly, the use of a 50% sample was retained for the remaining model analyses.

Model 4

Since shoulder width and lane width are continuous variables that are descriptive of the entire no-passing zones, and since the presence of guardrail and/or warning signs may be the result rather than a cause of a high accident rate (having already been installed as a countermeasure), a model was constructed with only these four variables. Using the forward stepwise procedure, the variables included in the model were:

1. Signs
2. Guardrail

This model, using only two variables, correctly categorized 73 of 122 high accident locations and 87 of 127 low accident locations for an overall accuracy rate of 64.26%. This is reasonably close to Models 1, 2 and 3. However, the question of whether these zones have high accident rates because of the presence of guardrail and signs, or have guardrail and signs because of the presence of a high accident rate has not been resolved.

Model 5

Model 5 used the backward stepwise procedure with the same four variables as model 4, and the same variables were selected: signs and guardrail. Thus, model 5 correctly categorized the same locations as model 4.

Model 6

Model 6 was run using only total driveways, driveways on vertical curves and driveways on horizontal curves as variables, since previous research has shown driveway density to be related to accident rates. This model selected only driveways on horizontal curves as an explanatory variable. Using this one variable, 41 of 122 high accident locations and 107 of 127 low accident locations were correctly categorized for an overall accuracy rate of 59.44%. This is considerably lower than the previous models, and not too much higher than a random assignment, which would theoretically correctly categorize 50% of the sites. In fact, the only reason the model accuracy is even this high is that it classifies most sites as "low," and this results in a high level of accuracy for low sites.

Model 7

Discriminant analysis techniques assume the variables used in the analysis are normally distributed. Several of the variables included in our data set are classification variables (0,1); and several others were coded into categories (0-3 driveways = 1; 4-7 driveways = 2, etc.). To test the possible effect of data format on the results, model 7 was run using only the values of the continuous variables. The stepwise technique was used, and the following variables were selected:

a. Horizontal curves
b. Major intersections
c. Minor intersections controlled by flashing lights
d. Other signs
e. Driveways on vertical curves
f. Mailboxes
g. Overpasses

Model 7 correctly categorized 68 of 122 high accident locations and 103 of 127 low accident locations for an overall accuracy rate of 68.67%.

The results of the statistical analysis of the data indicate that there is no single variable that can accurately discriminate between high and low accident sites. There are, however, several combinations of variables that can discriminate with almost equal accuracy of 70% for both high and low accident sites.

MODEL VERIFICATION

Each of the 7 models developed in the project was used to predict the classification of the sites previously separated and placed in the verification file. The results of this model verification test is shown in Table 8.

TABLE 8. Results of the model verification analysis.

	High Accident Location Correctly Categorized		Low Accident Location Correctly Categorized		
Model	Number	Percent	Number	Percent	Accuracy
1	88/123	71.5	94/153	61.4	65.9
2	85/123	69.1	95/153	62.1	65.2
3	64/93	68.8	80/122	65.6	66.98
4	81/123	65.9	112/153	73.2	69.3
5	81/123	65.9	112/153	73.2	69.3
6	44/123	64.2	118/153	77.1	58.7
7	71/123	57.7	121/153	79.1	69.6

These numbers are very close to the model calibration results, indicating that the model results are consistent in their ability to categorize locations as "high" or "low" accident sites.

Table 9 lists the variables included in the discriminant functions for each of the seven models developed in this study. Table 10 presents the values of the coefficients for each of these variables and the D^2 values for each model. Statistically, models 1, 2 and 3 should provide the maximum accuracy in placing no-passing zones in their correct category, because they have the highest D^2 value. This means that the centroids of the two groups are separated by a greater difference for these models than for models 4, 5, 6 and 7.

TABLE 9. Discriminant analysis results.

Model	Variables	High	% Correct	Low	% Correct	Overall %
1	a. Vertical Curves b. Other Sign c. Partially Paved Shoulder d. Minor Intersection with Flasher Control e. Mailboxes f. Trees g. Major Intersection h. Unpaved shoulder	87/122	71.3	92/127	72.4	71.89
2	a. Unpaved Shoulder b. Partially Paved Shoulder c. Horizontal Curves d. Vertical Curves e. Major Intersection f. Minor Intersection with Flasher Control g. Other Signs h. Trees i. Mailboxes j. Embankment k. Driveways on Horizontal Curves	85/122	69.7	91/127	71.6	70.68
3	a. Unpaved Shoulder b. Partially Paved Shoulder c. Horizontal Curves d. Vertical Curves e. Major Intersection f. Minor Intersection with Flashers g. Other Signs h. Trees i. Mailboxes j. Embankment k. Driveway on Vertical Curves l. Driveways on Horizontal Curves	101/152	66.4	115/158	72.8	69.68
4	a. Signs b. Guardrail	73/122	59.8	87/127	68.5	64.26
5	a. Signs b. Guardrail	73/122	59.8	87/127	68.5	64.26
6	a. Driveways on Horizontal Curves	41/122	33.6	107/127	84.3	59.44
7	a. Horizontal Curves b. Major Intersections c. Minor Intersections Controlled by Flashing Lights d. Other Signs e. Driveways on Vertical Curves f. Mailboxes g. Overpasses	68/122	55.7	103/127	81.1	68.67

Model Interpretation

Discriminant analysis identifies those variables that contribute most to the separation of the mean score of "high" and "low" accident sites. The contribution of each variable to the difference in the mean value of the two groups is represented by the variable coefficient (Table 10). Since Models 1, 2 and 3 had the highest accuracy rate, the variables used in these models were analyzed.

In model 1, the variables with a positive coefficient contribute to the score of "high" accident sites, while the variables with a negative coefficient contribute to the score of the "low" sites. There are three variables with coefficients significantly larger than the remainder of the variables: the number of vertical curves, the number of signs located in the zone and the presence of partially paved shoulders. The high accident sites had an average of 16.1 other signs per zone, while the low accident sites averaged only 7.2 of these signs per site. The high accident sites had an average of 3.15 curves per zone compared to 1.31 in the sites with a low accident rate. While the coefficient for partially paved shoulders was relatively high, the difference in the mean score for the two categories was not significant (Table 11).

In model 2, the same three variables had the largest coefficients, indicating that these are the three variables which are most effective in discriminating between a high accident location and a low accident location. The negative sign on the coefficients in model 2 are associated with high accident sites, a characteristic that makes discriminant analysis coefficients different than regression coefficients.

In model 3, the major contributors are other signs, partially paved shoulders, and unpaved shoulders. As with partially paved shoulders, the unpaved shoulder variable has an insignificant difference in the mean value between high accident and low accident sites.

It appears that both geometry, as described by the number of vertical curves per zone, and roadside development, as described by the number of other signs per zone contribute to the prediction of accident rates. However, no combination of these variables categorized sites with a satisfactory level of accuracy. Even after selecting sites from two clearly distinct categories, the models only placed about 70% of the sites in the correct category. The accuracy of the models to correctly categorize the marginal sites would probably be lower than this.

To determine whether the model accuracy decreased as the accident rate in the high accident zones approached the average accident rate, the 45 locations with the highest accident rates were selected, and the ability of each of the models to correctly identify these high accident locations recorded in Table 12. Using these sites with very high accident rates did not improve the model accuracy, and it was obvious that the same sites were being missed by all of the models.

One possible explanation for the lack of predictive capability is that we are attempting to predict random events. This is a problem with any accident analysis based on a small number of accidents per site, and is well recognized in the profession. For example, a site with only one accident in three years could be in the high category with an accident rate of 3.65 if the ADT were 1000 vehicles and the length of the no-passing zone was .2 miles. Yet it is possible that the one accident was truly a random event, and none of the variables associated with high accident sites were present at this location.

To test the effect of these low accident frequency sites on the analysis, a model was developed using only sites with at least 3 accidents in the three year analysis period to define high accident sites. This model correctly categorized 31 of 43 high accident sites and 118 of 127 low accident sites for an overall accuracy rate of 87.7%.

The verification test was similarly successful, with an overall accuracy rate of 83.3%. Reducing the influence of random accidents improved the predictive capability of the models, as expected.

The variables with the largest contribution to the discriminant scores in this model are vertical curves, horizontal curves, and the presence of an embankment with coefficients of .68, .45 and .41 respectively. As with shoulder treatment, the embankment variable has virtually the same mean value for high and low accident sites, and thus may have little significance as an independent variable.

Table 10. Discriminant function equations for the seven models.

MODEL 1:

$$D = 0.540\,x_a + 0.573\,x_b + 0.594\,x_c - 0.191\,x_d + 0.194\,x_e - 0.253\,x_f - 0.177\,x_g + 0.301\,x_h$$

$$D^2 = -0.568 - 0.591 = -1.160$$

MODEL 2:

$$D = -0.371\,x_a - 0.618\,x_b + 0.319\,x_c - 0.528\,x_d + 0.211\,x_e + 0.209\,x_f - 0.535\,x_g + 0.249\,x_h - 0.183\,x_i - 0.322\,x_j - 0.172\,x_k$$

$$D^2 = 0.583 - (-0.607) = 1.190$$

MODEL 3:

$$D = -0.439\,x_a - 0.602\,x_b + 0.223\,x_c - 0.387\,x_d + 0.176\,x_c + 0.149\,x_f - 0.560\,x_g + 0.281\,x_h - 0.166\,x_i - 0.300\,x_j - 0.250\,x_k - 0.137\,x_l$$

$$D^2 = 0.579 - (-0.602) = 1.181$$

MODELS 4 AND 5:

$$D = 0.675\,x_a + 0.636\,x_b$$

$$D^2 = -0.321 - 0.334 = -0.655$$

MODEL 6:

$$D = 0.506\,x_a$$

$$D^2 = -0.336 - 0.350 = -0.686$$

MODEL 7:

$$D = 0.515\,x_a + 0.178\,x_b + 0.282\,x_c - 0.721\,x_d - 0.374\,x_e - 0.345\,x_f - 0.406\,x_g$$

$$D^2 = 0.480 - (-0.500) = 0.980$$

* D^2 = Group 1 centroid - Group 2 centroid

Table 11. Mean values of the variables used in discriminant analysis.

Variables		Zero Accident Sites	High Accident Sites
Paved Shoulder	(%)	0.089	0.033
Unpaved Shoulder	"	0.504	0.419
Partially Paved Shoulder	"	0.396	0.527
Horizontal Curve	(Number/Zone)	1.638	3.912
Vertical Curve	"	1.729	3.376
Guardrail	"	2.389	7.596
Signs	"	0.354	1.436
Minor Intersection with Flashers	"	0.016	0.038
Minor Intersections with Stop Signs	"	0.723	1.877
Major Intersection	"	0.083	0.057
Other Signs	"	10.127	20.204
Poles	"	5.171	5.554
Trees	"	14.492	19.265
Driveways on Vertical Curves	"	2.535	6.445
Driveways on Horizontal Curves	"	1.464	2.180
Mailboxes	"	2.600	3.956
Overpass	"	0.529	1.592
Embankment	(%)	0.150	0.380
Ditch	"	0.393	0.984
Culvert	(Number/Zone)	0.500	1.131

Table 12. Sites identified as "high" accident locations by the 7 models.

RANK	ACCIDENT RATE	MODEL NUMBER 1	2	3	4 & 5	6	7
1	12.45	•	•	•	•	•	•
2	10.15	•	•	•			•
3	9.61	•	•	•			
4	8.14	•	•	•	•	•	•
5	7.31						
6	7.02						
7	6.52						
8	6.34						
9	5.89				•		
10	4.68	•	•	•	•	•	•
11	4.57	•	•		•		
12	4.39						
13	4.06	•	•	•			•
14	4.01	•	•	•	•	•	•
15	3.95	•		•			
16	3.90	•	•	•	•	•	•
17	3.90	•	•	•	•	•	•
18	3.65	•	•	•	•	•	•
19	3.51		•				
20	3.31	•					•
21	3.18						
22	3.15						
23	3.13						
24	2.68						
25	2.28				•		
26	2.27	•	•	•	•	•	•
27	2.27	•	•	•	•	•	•
28	2.13	•	•	•			•
29	2.12	•	•	•	•	•	•
30	2.12	•	•	•	•	•	•
31	2.11	•	•	•	•	•	•
32	2.08				•		
33	2.07	•	•	•	•	•	•
34	2.05	•	•	•	•	•	•
35	2.04				•	•	•
36	2.00	•	•	•	•		
37	1.96	•	•				•
38	1.95	•	•	•	•	•	•
39	1.95	•	•	•	•	•	•
40	1.93	•	•	•	•	•	•
41	1.89	•	•	•	•	•	•
42	1.87	•	•	•	•	•	•
43	1.86	•	•	•		•	•
44	1.86						
45	1.83	•					

RATE BASED ANALYSES

The analyses conducted to construct the models presented in Table 10 were based on the frequency with which the independent variables occurred in each of the no-passing zones. Since the mean length of the no-passing zones with zero accidents was only 0.26 miles while the average length of the high accident zones was 0.63 miles, this difference in length could mask the significance of some variables. For example, while the number of trees per zone were 14.5 and 19.3 for zero accident sites and high accident sites respectively (see Table 11), the density of trees were 34.2 and 15.6 respectively.

To determine if the use of rate based variables would alter the results of the analyses, the frequency based variables were divided by the length of the zone in which they occurred, and a new set of variables constructed as shown in Table 13. Regression analysis and discriminate analysis techniques were then used to analyze ths data set.

Examination of the mean values were somewhat surprising in that the density of trees and poles was higher in zero accident sites than in high accident sites. On the other hand, there is little difference in the mean value of vertical curves per mile and other signs per mile, two of the variables identified as significant in the discriminant analysis models.

Two of the variables that appeared to have a significant difference in value for the zero accident sites and high accident sites were driveways on vertical curves and driveways on horizontal curves. These two variables were selected for further analysis since it is reasonable to expect an increase in accidents where the existence of driveways and curves coincide. The 525 analysis zones were categorized by accident frequency, and the mean value of each of these variables calculated for each category. The results of these calculations are shown in Table 14, and Figures 4 and 5. There is an obvious trend in this data, with the frequency of accidents increasing with both the number of driveways per mile on vertical curves and the number of driveways per mile on horizontal curves. Since grouped data were used to construct these curves, it must be remembered that much of the variability in the values of the independent variables is lost in these figures.

Simple and multiple regression techniques were used to determine whether any single variables or combination of variables were statistically significantly related to the total accident rate or the accident rate for the three accident types used in the discriminant analysis models. The simple correlation coefficients are shown in Table 15. The correlation coefficient for the multiple regression equation were only .084 and .080 respectively for the total accident rate and the rate for the three selected accident types.

Scatter diagrams of the number of driveways per mile on horizontal curves, driveways per mile on vertical curves, trees per mile and other signs per mile versus total accident rate and accident rate for the three selected accident types is shown in Figures 6 through 13. It is clear from these diagrams that the variability of the data is too large to develop statistical significance.

Finally, a discriminate analysis was conducted to determine whether a model with better predictive capability than those presented in Table 10 could be developed. The predictive capability of the best model using rates instead of frequencies was only 60.9%. This is lower than those using frequency.

Table 13. Mean Values of the Rate Based Variables
(using 525 sites)

Variables	Zero Accident Sites	Zero Accident Sites
Horizontal Curves (#/mi)	6.30	6.21
Vertical Curves (#/mi)	6.65	5.36
Signs (#/mi)	1.36	2.28
Minor Intersection with Signal (#/mi)	0.06	0.09
Minor Intersection with Stop Sign (#/mi)	2.78	2.98
Minor Intersection with Flasher (#/mi)	0.06	0.06
Major Intersection (#/mi)	0.32	0.09
Other Signs (#/mi)	38.95	32.07
Poles (#/mi)	19.89	15.73
Trees (#/mi)	55.74	30.58
Driveways on Tangent Section (#/mi)	2.95	2.35
Driveways on Vertcal Curves (#/mi)	9.75	10.23
Mailboxes (#/mi)	10.00	6.28
Mean Length of No-Passing Zones (mi)	0.26	0.63

Table 14. Mean number of accidents for various categories of driveway density

# Accidents	Mean Density of driveway, on horizontal curves (#/mi)
0	2.27
1-2	2.26
3-4	1.99
5-6	3.52
7-8	2.28
9-10	4.71
> 10	3.27

# Accidents	Mean Density of driveways on vertical curves (#/mi)
0	3.43
1-2	5.74
3-4	6.47
5-6	8.20
7-8	5.38
9-10	9.50
> 10	8.67

Figure 4. Accident Frequency versus Density of Driveways on Horizontal Curves

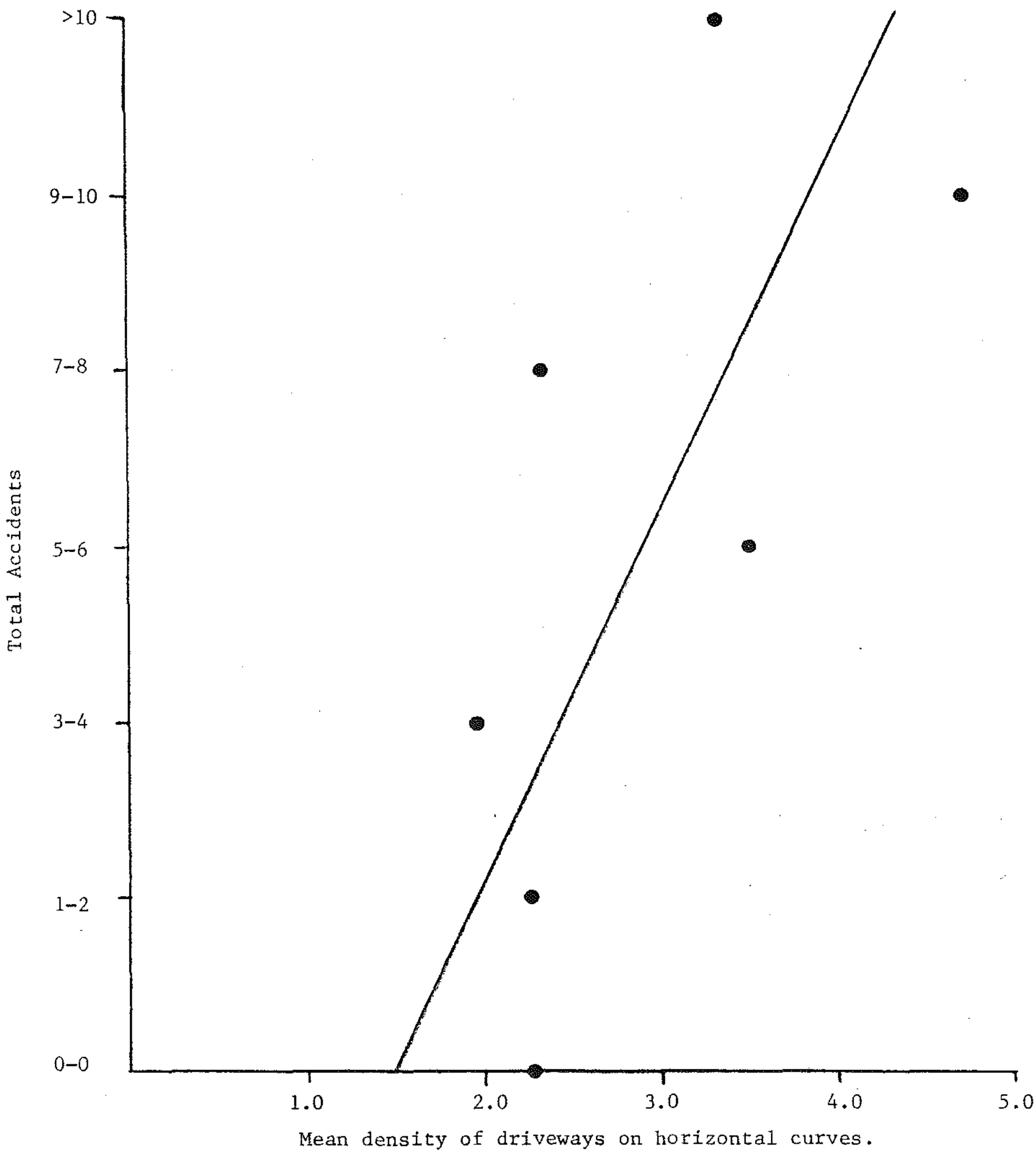


Figure 5. Accident Frequency versus Density of Driveways on Vertical Curves

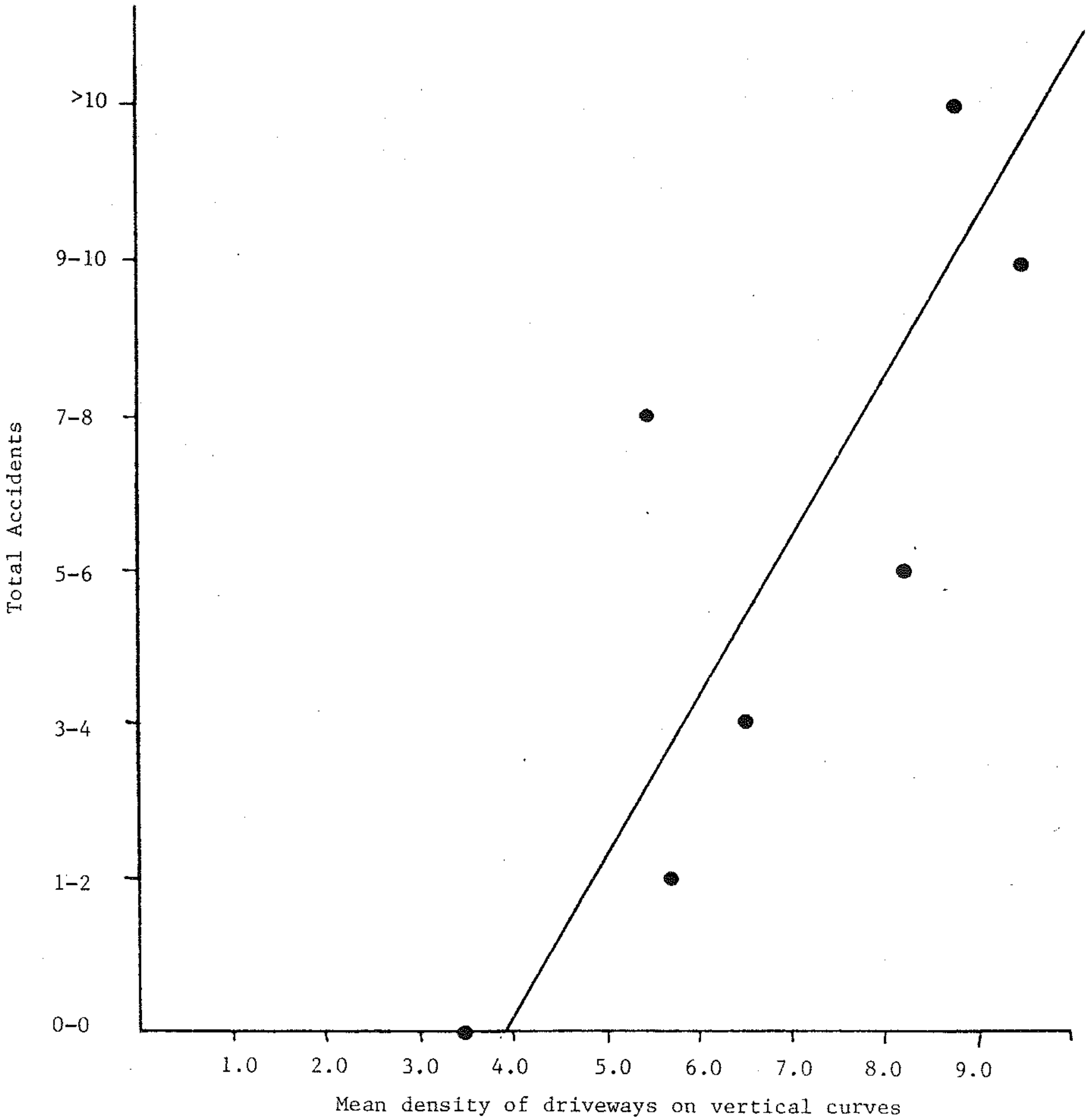


Table 15. Simple Correlation Coefficients

Variable	Total Accident Rate	Three Type Accident Rate
ADT	-.232	-.162
horizontal curve density	-.049	.096
vertical curve density	.017	-.039
sign density	.051	.103
other sign density	.035	-.009
tree density	-.052	.054
pole density	-.009	-.029
minor intersection with signal density	.021	.035
minor intersection with stop sign density	.066	.043
driveway on tangent section density	-.039	-.019
driveway on horizontal curve density	-.052	-.025
driveway on vertical curve density	0.030	0.018
mailbox density	-.055	-.022

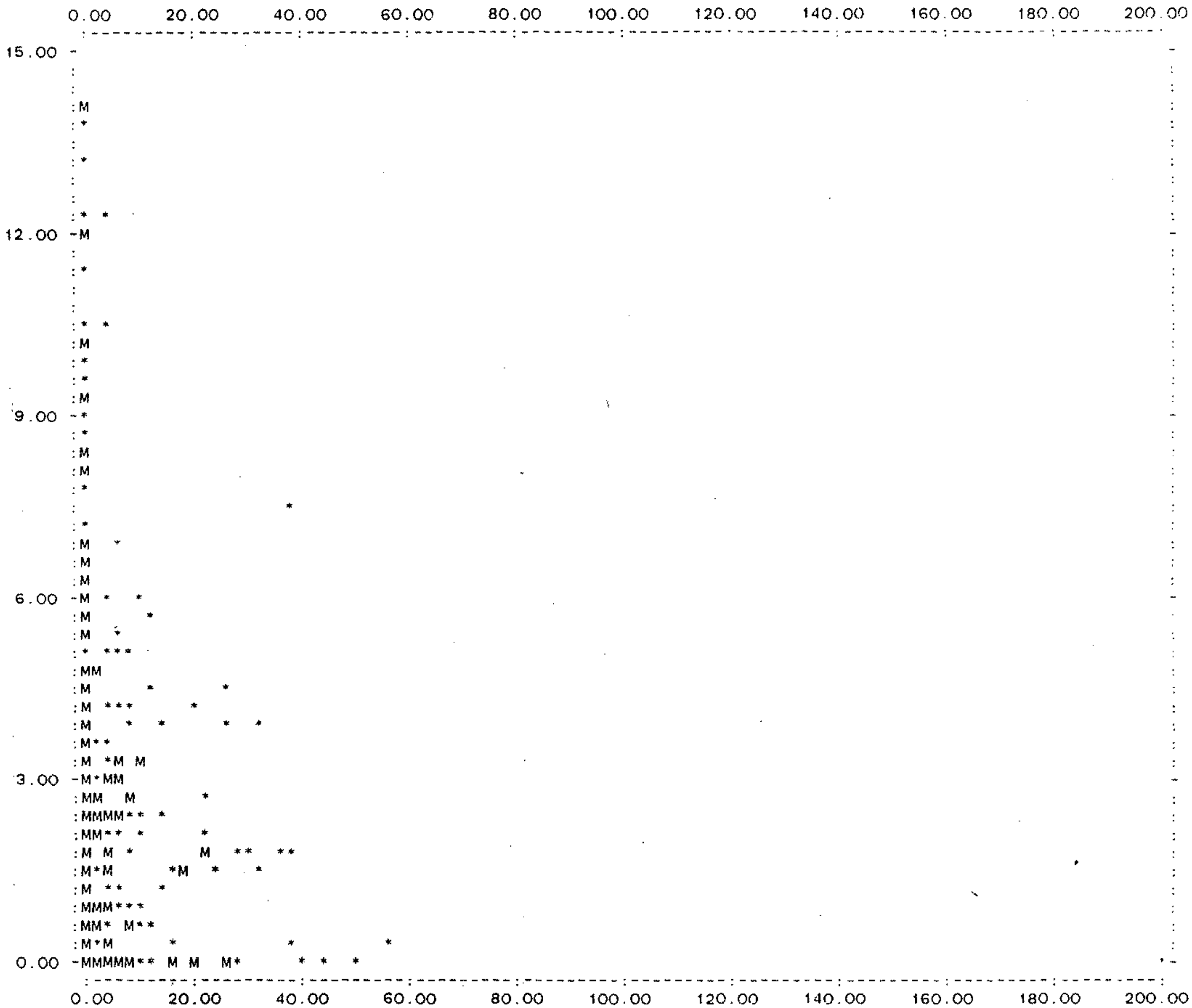


FIGURE 6 Density of Driveways on Horizontal Curves vs Total Accident Rate

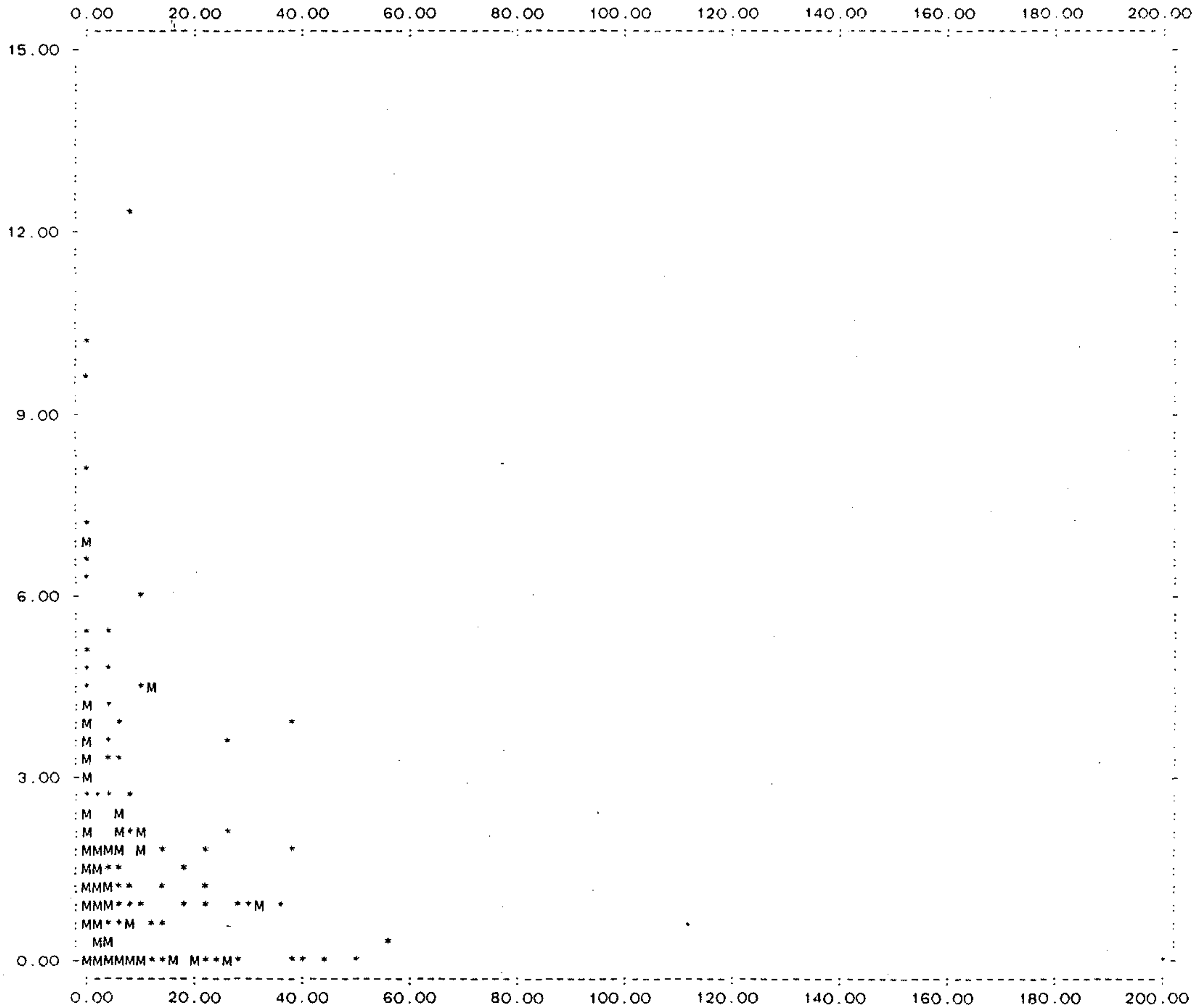


FIGURE 7   Density of Driveways on Horizontal Curves vs the Three Type Total Accident Rate

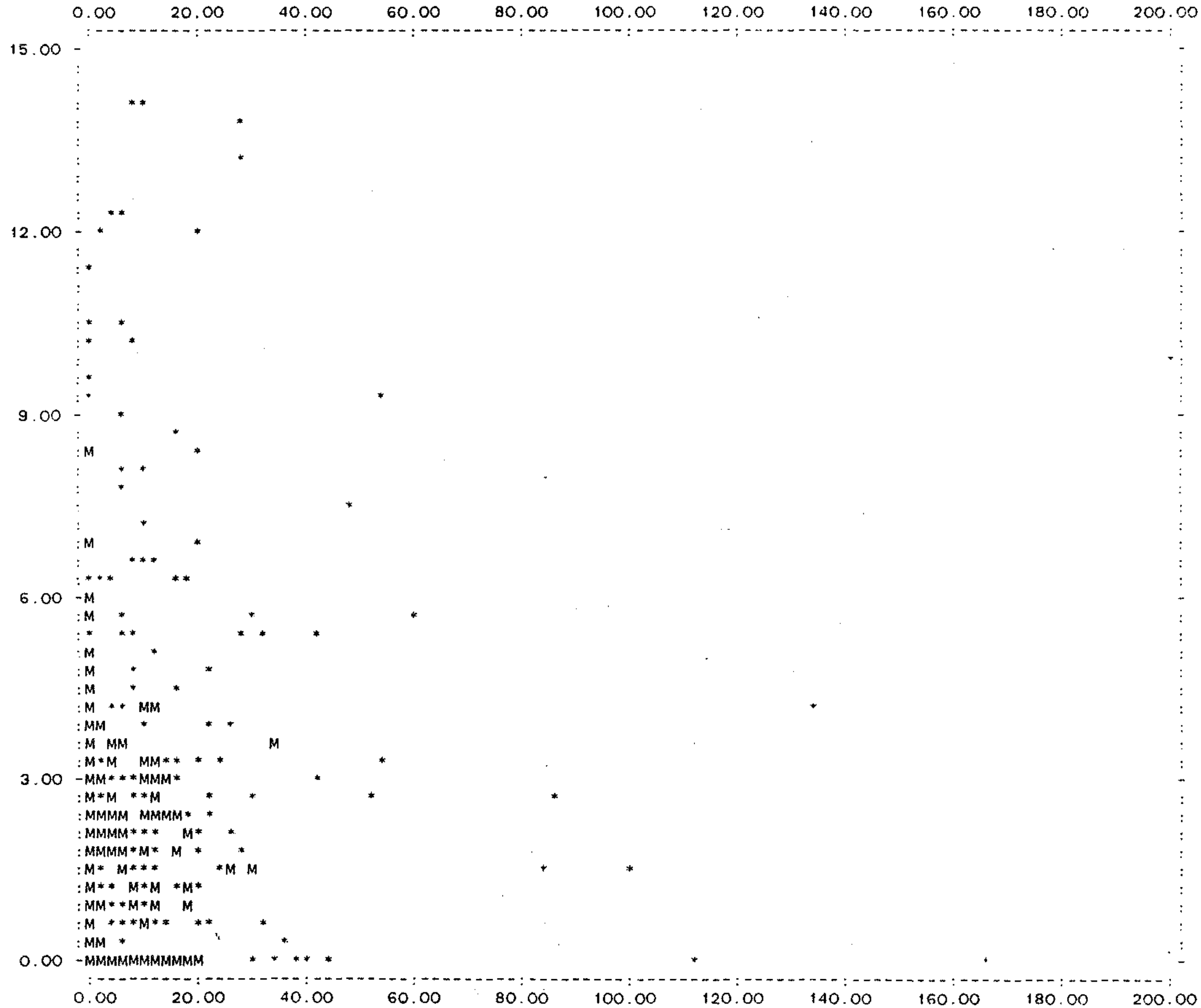


FIGURE 8 Density of Driveways on Vertical Curves vs Total Accident Rate

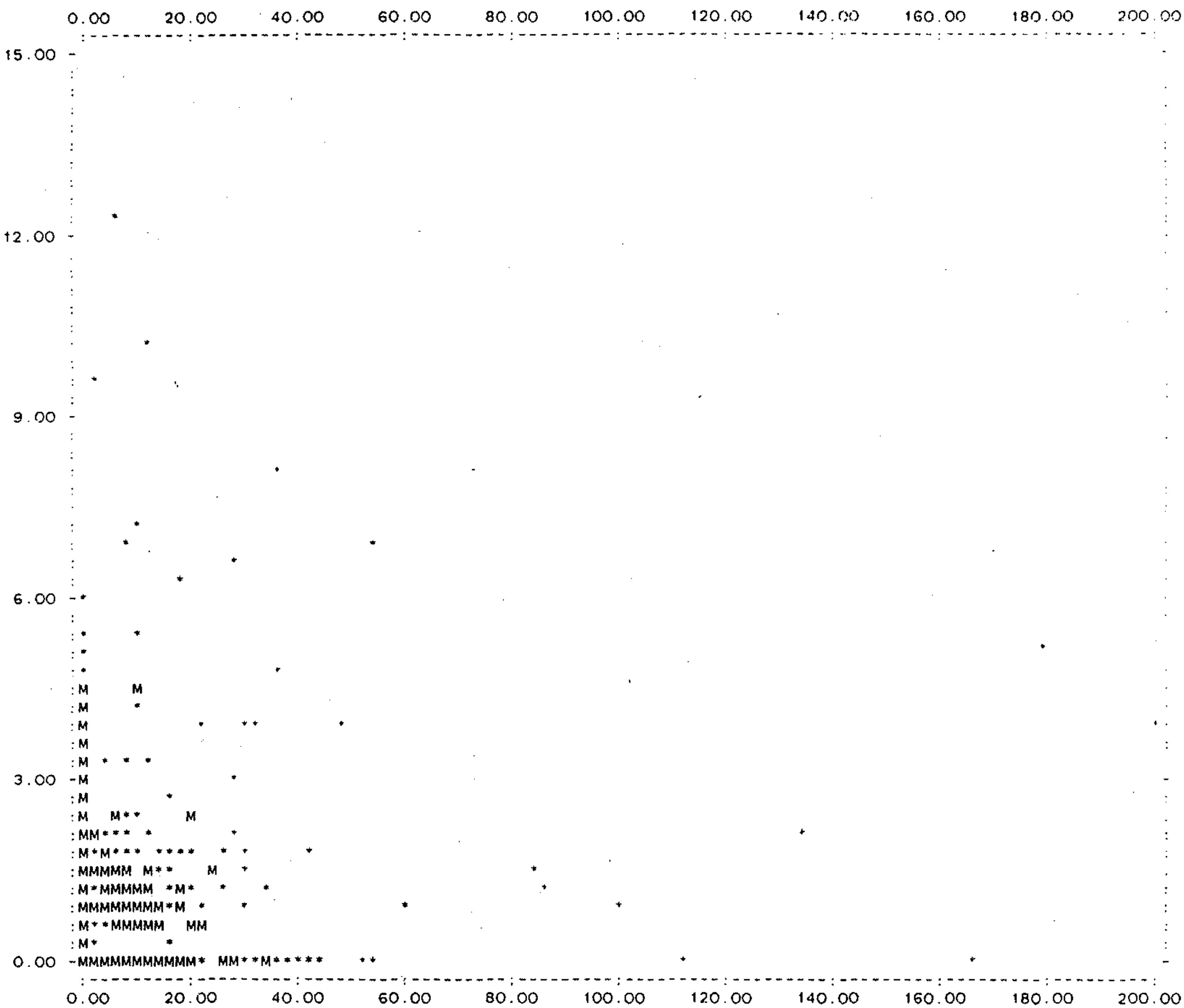


FIGURE 9 Density of Driveways on Vertical Curves vs the Three Type Total Accident Rate.

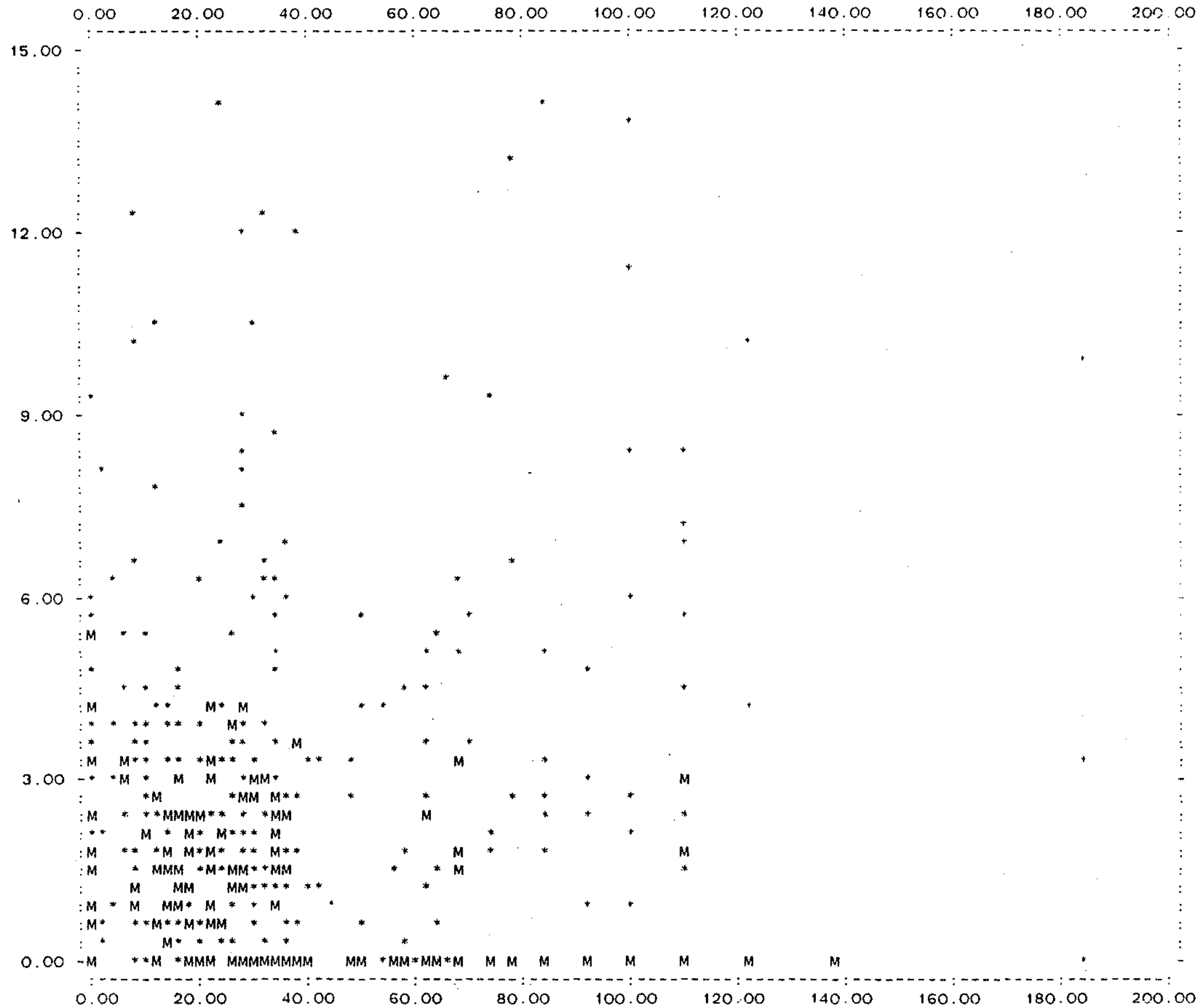


FIGURE 10   Density of Trees vs Total Accident Rate.

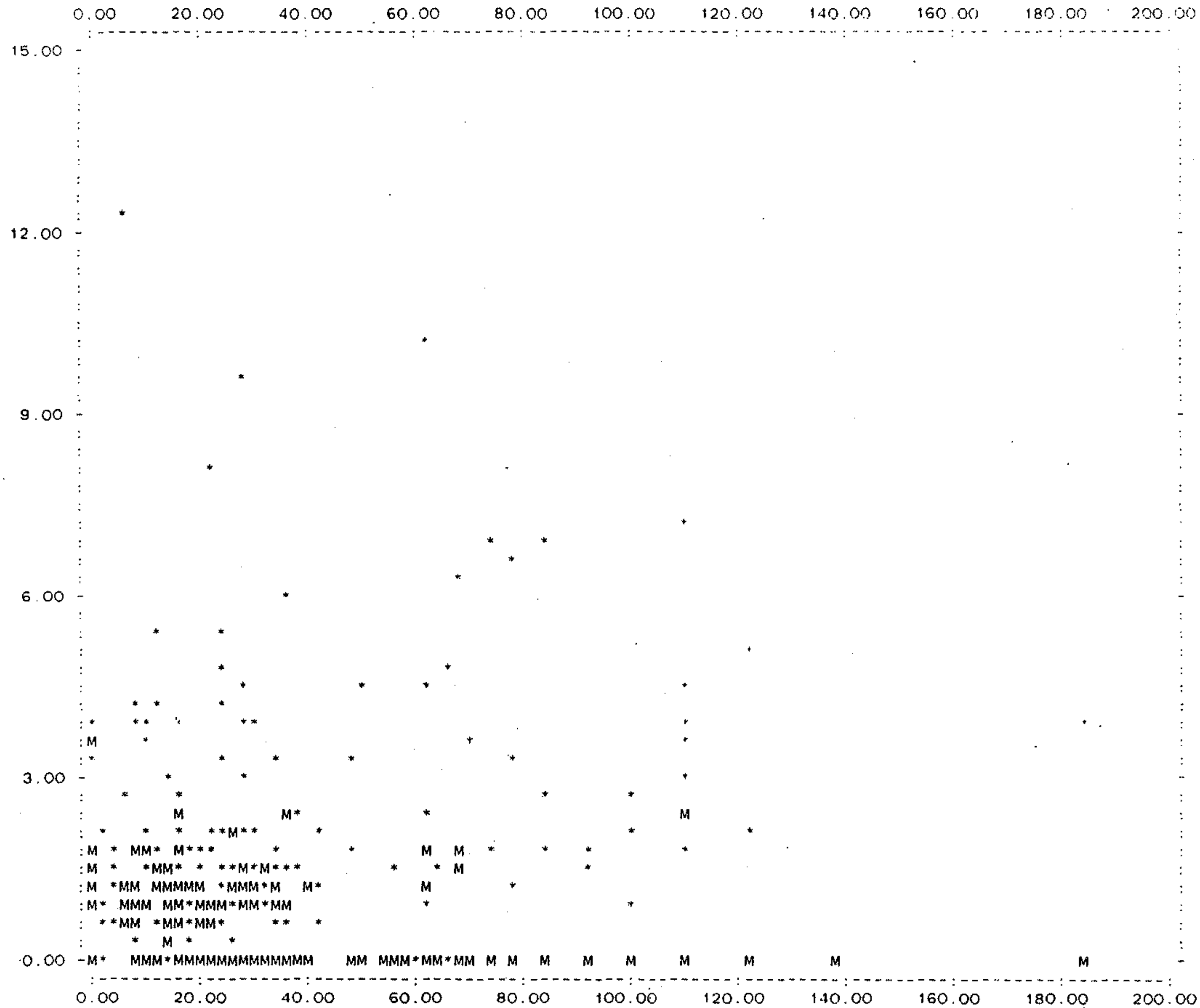


FIGURE 11 Density of Trees vs the Three Type Total Accident Rate.

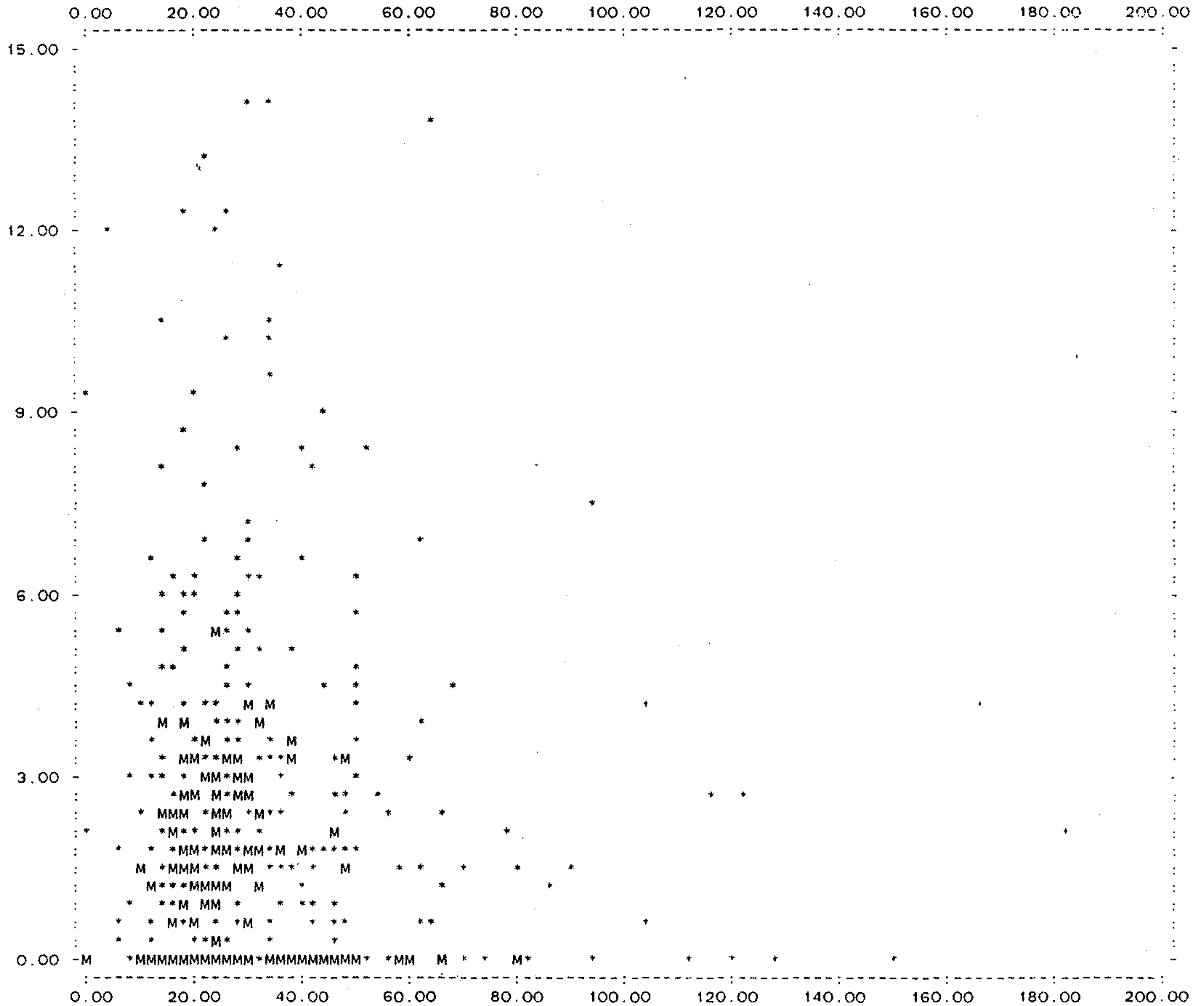


FIGURE 12 Density of Other Signs vs Total Accident Rate

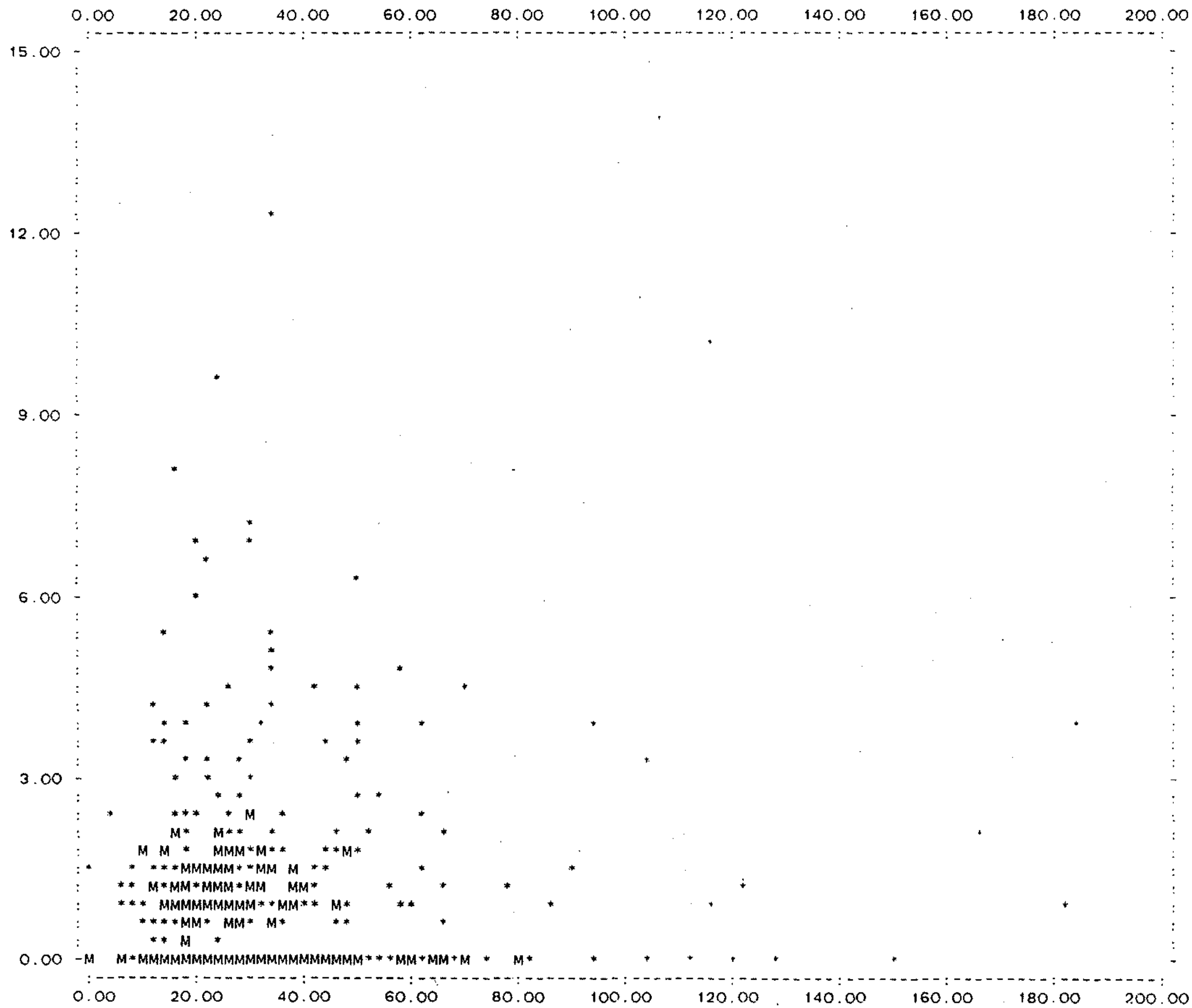


FIGURE 13 Density of Other Signs vs the Three Type Total Accident Rate.

EVALUATION OF HEAD-ON ACCIDENTS

A search of the accident files for the three year period (1980-82) identified a total of 100 accidents coded as head-on accidents in the 525 no-passing zones. Due to a coding change in 1982, hard copies of only 82 of the 100 identified accidents were easily obtainable. These 82 accident reports were obtained and examined. From the information given on the police reports the accidents were classified as horizontal curve accidents, vertical curve accidents, and other. The category "other" includes all accidents not specifially coded by the investigating officer as having occured on a horizontal or vertical curve. This category probably includes the no-passing zone approaches to horizontal and vertical curves as well a no-passing zones related to intersections, railroad crossings, etc.

Most of the accidents (57 of 82) fell into the other category. Thirteen of these accidents were not head-on accidents. This subgroup contains accidents such as "gravel from a dump truck going in the opposite direction broke the windshield," or, "a chair fell off of the northbound vehicle and the southbound vehicle ran into it."

Five of these accidents were caused by impaired drivers. This includes accidents on tangent, level roadway sections where the driver at fault fell asleep at the wheel, was intoxicated, or was distracted in some other way. Another seven of these accidents involved vehicles turning into driveways or intersection accidents classified as midblock.

The remaining 32 "other" accidents were "crossed the centerline" accidents. Of these accidents 11 were weather related (visibility zero, icy roads causing loss of control, etc.) and four were loss of control accidents. Only two accidents were reported as driver disregard for the no-passing zone marking.

A total of 15 of the 82 accidents occurred in no-passing zones on horizontal curves. Of these, four were weather related, three were loss of control accidents, two were intersection or turning accidents, and six were "crossed the centerline" accidents.

Only 10 of the 82 accidents occurred on vertical curves. Of these, four were weather related, three were driver error (too fast for conditions, reckless driving), and three were "crossed the centerline" accidents.

The number of head-on accidents included in the 525 zones was relatively small, with the majority of these accidents occurring on tangent sections. Because of the small number of accidents, no satisfactory analysis of these accidents was possible. Violations of the no-passing zone markings do not appear to contribute to a significant number of accidents, and no particular problems were discovered relative to the length of the no-passing zone marking or the driver eye height. While this study cannot conclusively state that these are not important issues, they do not appear to contribute to a significant number of accidents.

VEHICLE CHARACTERISTICS

The third objective of this study was to determine if certain vehicle classifications, by weight, were over or under represented in accidents at no-passing zones. A previous study (8) had shown that small vehicles are over-represented in rural midblock accidents, but no determination had been made relative to the presence of a no-passing zone.

VNDCTR

Vehicle characteristics were obtained from the "VNDCTR 83" program file. The program "VNDCTR 83" was developed for use in the previous study and was adapted for use in this study. The accident information on the VNDCTR file (file VIN) is from 1983 and 1984. There are more than 36,000 accident records on two-lane two-way rural roads in this file. (For file description see Appendix).

The VNDCTR file was first used to identify the number of vehicles in each of six vehicle weight classes involved in midblock accidents on 2-lane rural highways. This distribution (on a statewide basis) for the selected accident types was determined using the VNDCTR file and the 2L2WMR file. Then the percentage of accidents, by vehicle weight, was determined by separating passing sections from no-passing zones. The results are shown in Table 13.

Figures 4, 5, 6 and 7 show the no-passing to passing accident ratio, by vehicle weight, for overturned, fixed object, head-on, and the total of

---

(8) Safety Impacts of Vehicle Design and Highway Geometry, a dissertation by Koji Kuroda, Michigan State University, 1984.

Table 13. Accidents by Vehicle Weight Class

Accident Type: Vehicle Type: Vehicle Number:	1500–1999	2000–2499	2500–2999	3000–3499	3500–3999	Over 4000	Total Accidents
Overturned No-Passing VEH #1	37 13.7%	80 29.5%	74 27.3%	43 15.9%	21 7.7%	16 5.9%	271 100%
Overturned Passing VEH #1	61 12.9%	134 28.5%	115 24.5%	79 16.8%	48 10.2%	33 7.0%	470 100%
Fixed Object No-Passing VEH #1	50 4.9%	177 17.3%	208 20.3%	254 24.9%	163 15.9%	170 16.6%	1022 100%
Fixed Object Passing VEH #1	69 4.5%	245 15.9%	322 20.9%	382 24.7%	277 17.9%	249 16.1%	1544 100%
Head-on No-Passing VEH #1	19 6.6%	56 19.5%	60 20.9%	71 24.7%	43 15.0%	38 13.2%	287 100%
Head-on Passing VEH #1	29 6.3%	74 16.0%	93 20.1%	110 23.8%	91 19.7%	66 14.3%	463 100%
3 Type Total No-Passing VEH #1	106 6.7%	313 19.8%	342 21.6%	368 23.3%	227 14.4%	224 14.2%	1580 100%
3 Type Total Passing VEH #1	159 6.4%	453 18.3%	530 21.4%	571 23.1%	416 16.8%	348 14.0%	2477 100%
All Accidents No-Passing* VEH #2 (Exposure)	6.15%	15.58%	17.3%	23.85%	19.84%	17.14%	100%
All Accidents Passing* VEH #2 (Exposure)	6.13%	15.6%	17.3%	23.82%	19.83%	17.33%	100%

* Values taken from "Safety Impacts of Vehicle Design and Highway Geometry, a Dissertation by Koji Kuroda, Michigan State University, East Lansing, Michigan, 1984.

these three accident types respectively. These figures represent the vehicle 1 accident experience, where vehicle 1 is the vehicle at fault in an accident. The ratios were computed by dividing the no-passing percentage of each accident type (by vehicle weight) by the passing percentage. A ratio greater than 1.0 means it is more hazardous for the particular weight class in a no-passing zone than in a passing section for the accident type in question. It is clear that there is no greater hazard associated with vehicle size at no-passing zones than in passing sections of 2-lane rural roads.

The ratios of no-passing and passing accident experience, by vehicle weight, to the vehicle weight exposure measure (developed in the Kuroda study) are shown in Figures 8, 9, 10 and 11. These ratios are the percentage of vehicle 1 accidents to the percentage of vehicle exposure by vehicle weight. These results were consistent with both Mr. Kuroda's findings and those in the preceding paragraph. Small vehicles are over-represented in rural 2-lane 2-way midblock accidents, and this over-representation occurs nearly equally in passing and no-passing areas.

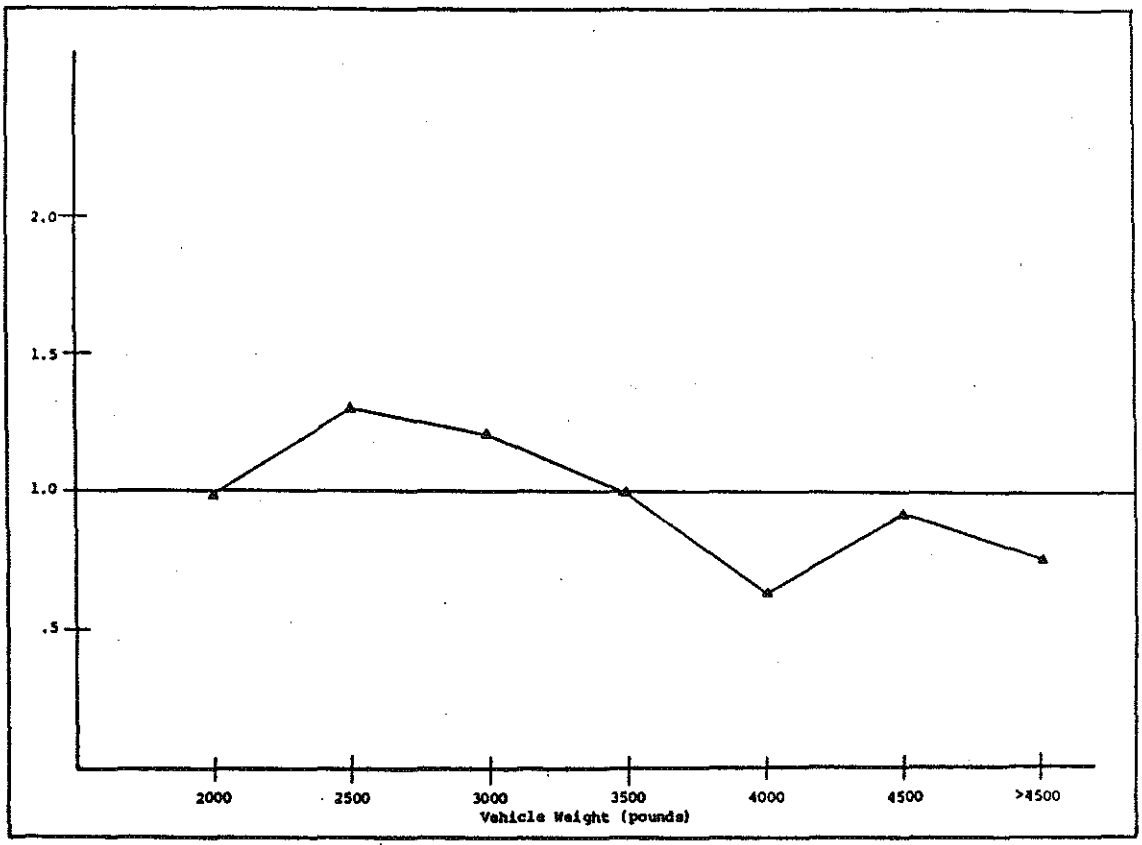


Figure 4. Head-on. No-Passing/Passing - VWT 1.

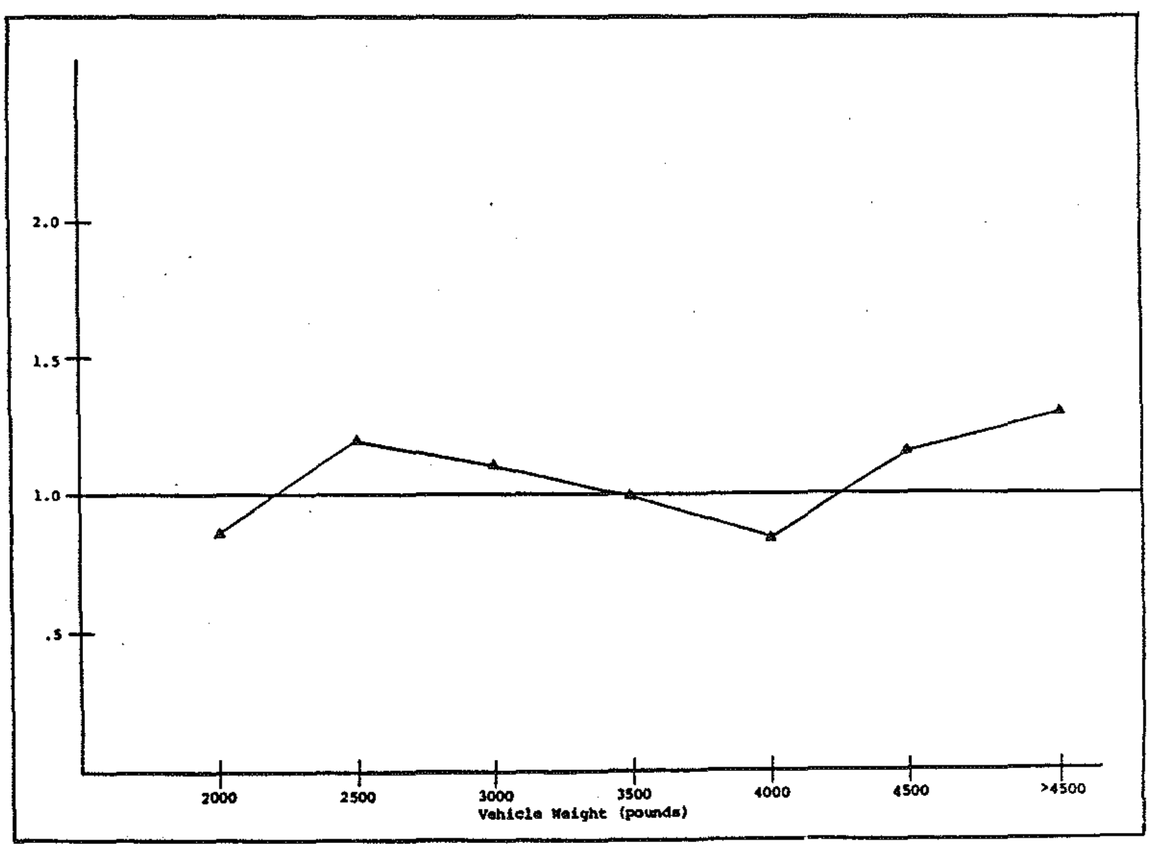


Figure 5. Overturned. No-Passing/Passing - VWT 1.

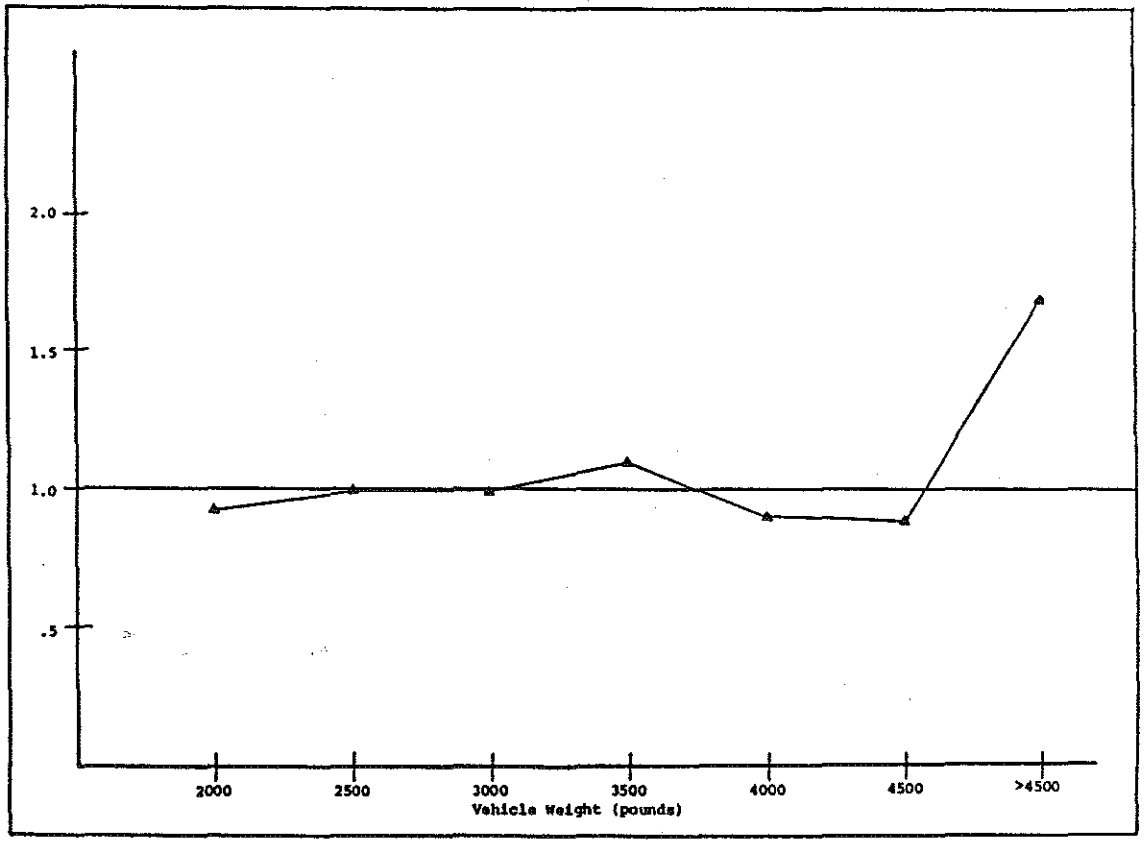


Figure 6. Fixed Object. No-Passing/Passing - VWT 1.

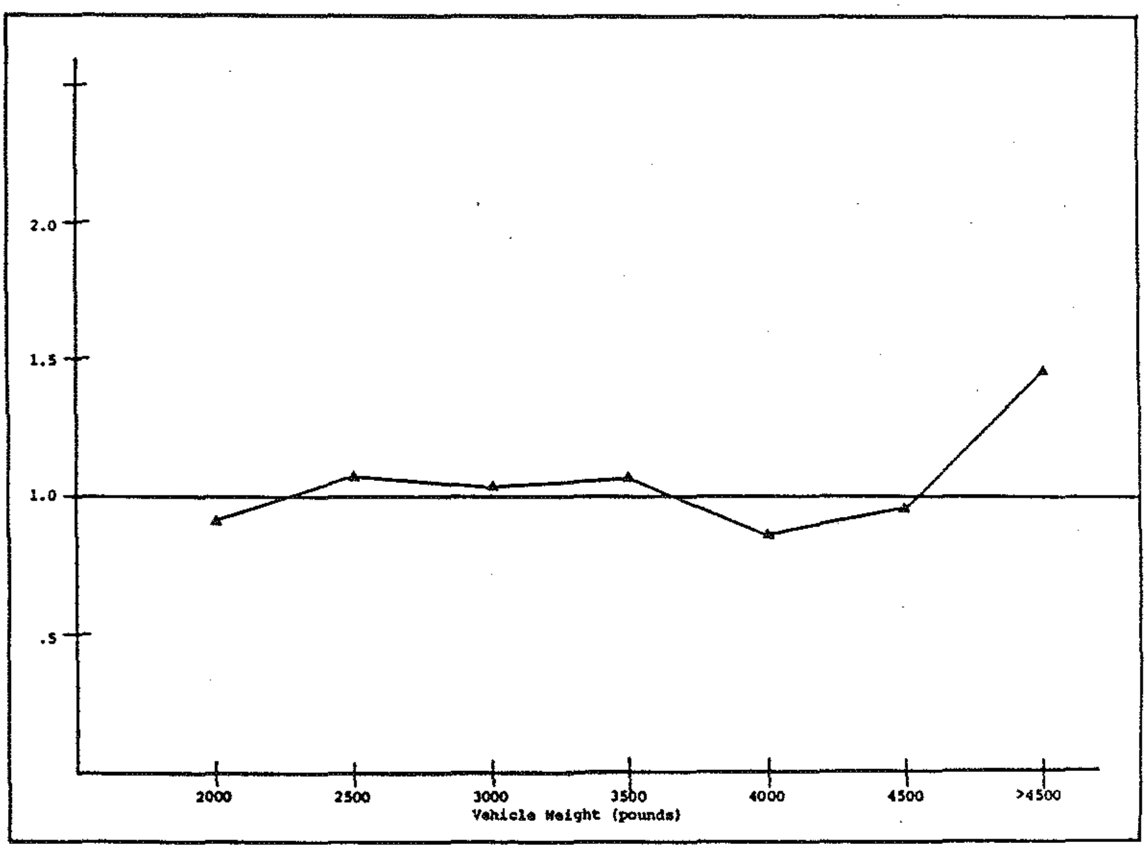


Figure 7. Three Type Total. No-Passing/Passing - VWT 1.

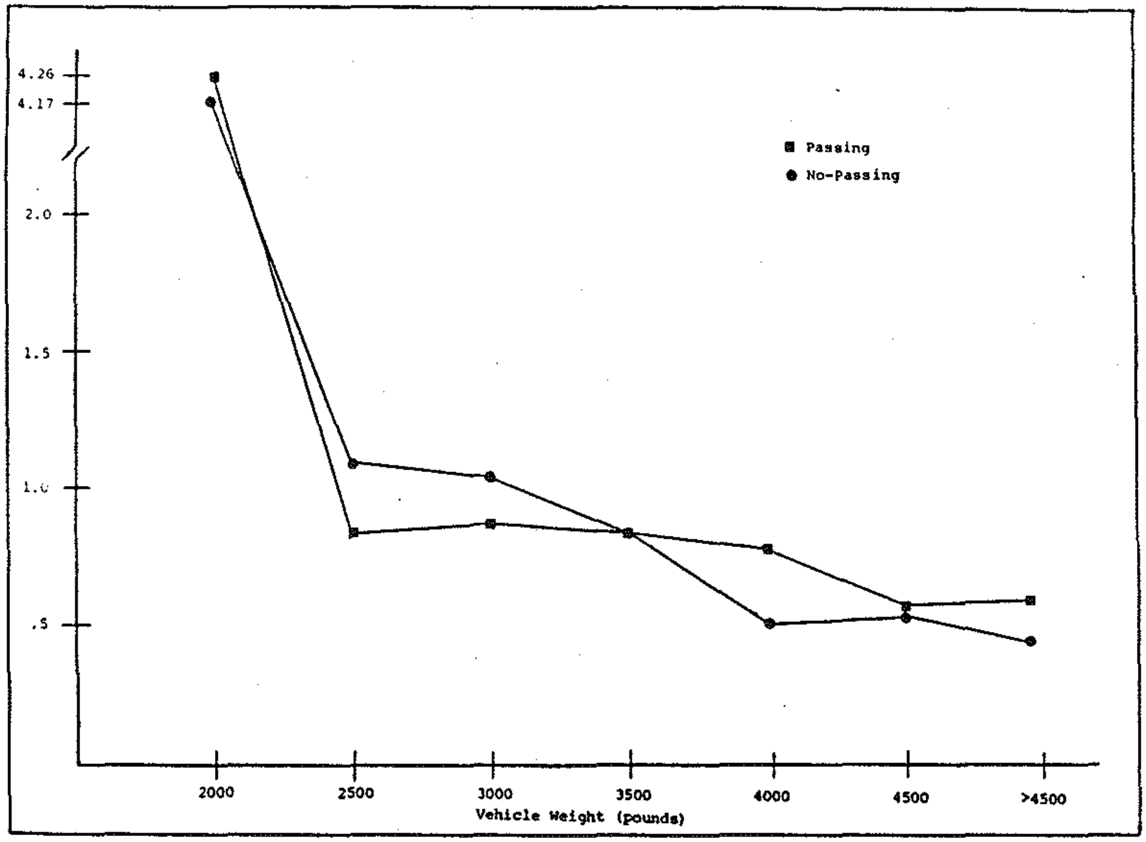


Figure 8. Head-on. No-Passing and Passing - VWT 1/VWT 2 Exposure.

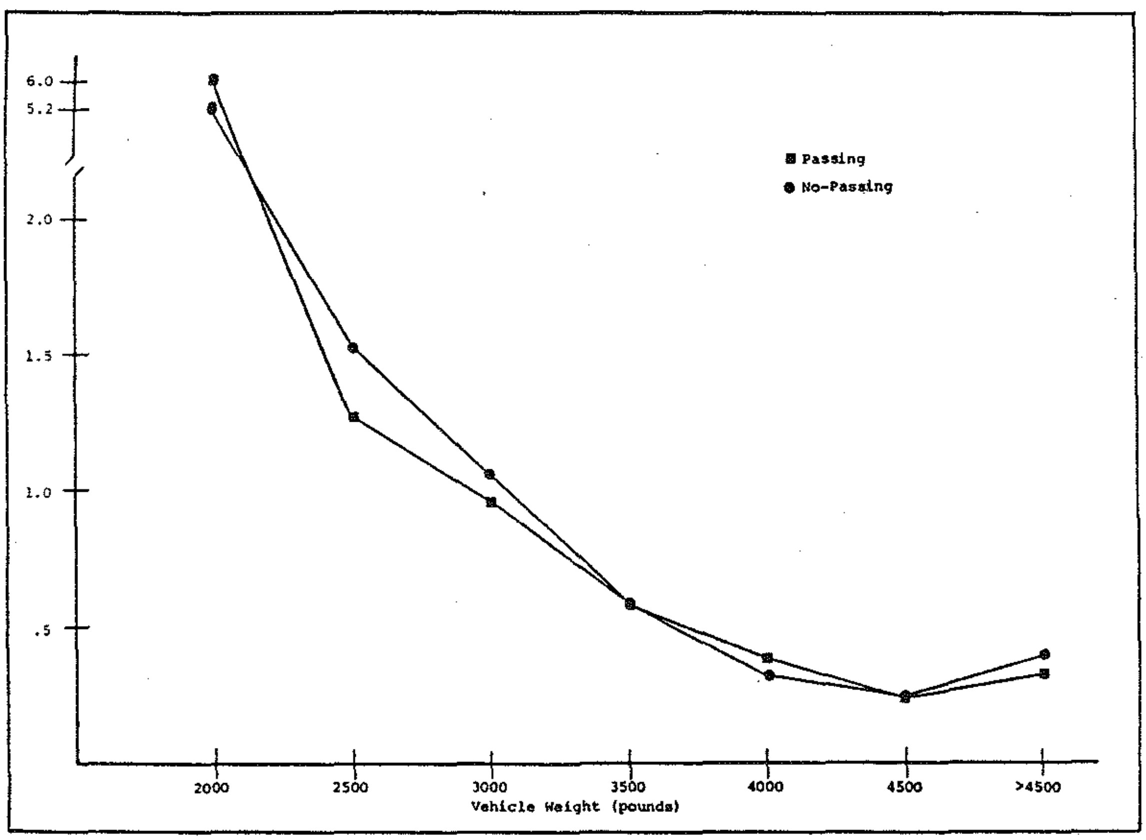


Figure 9. Overturned. No-Passing and Passing - VWT 1/VWT 2 Exposure.

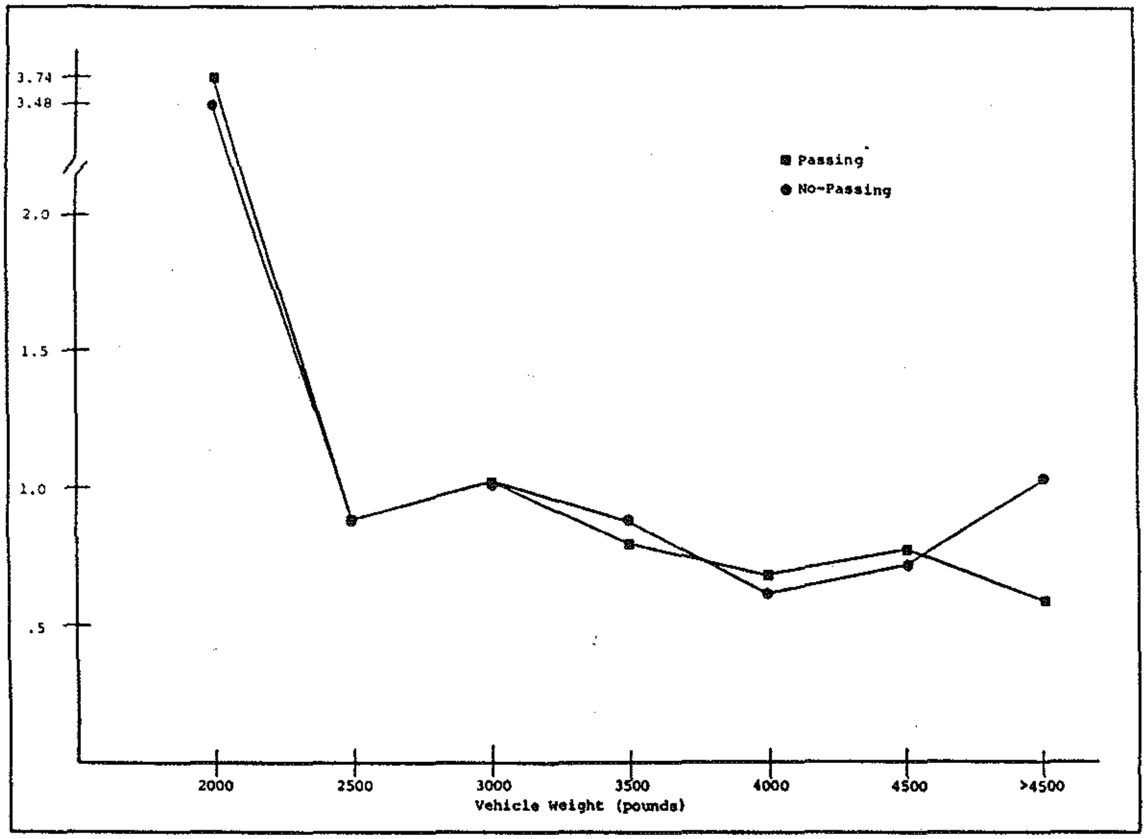


Figure 10. Fixed Object. No-Passing and Passing - VWT 1/VWT 2 Exposure.

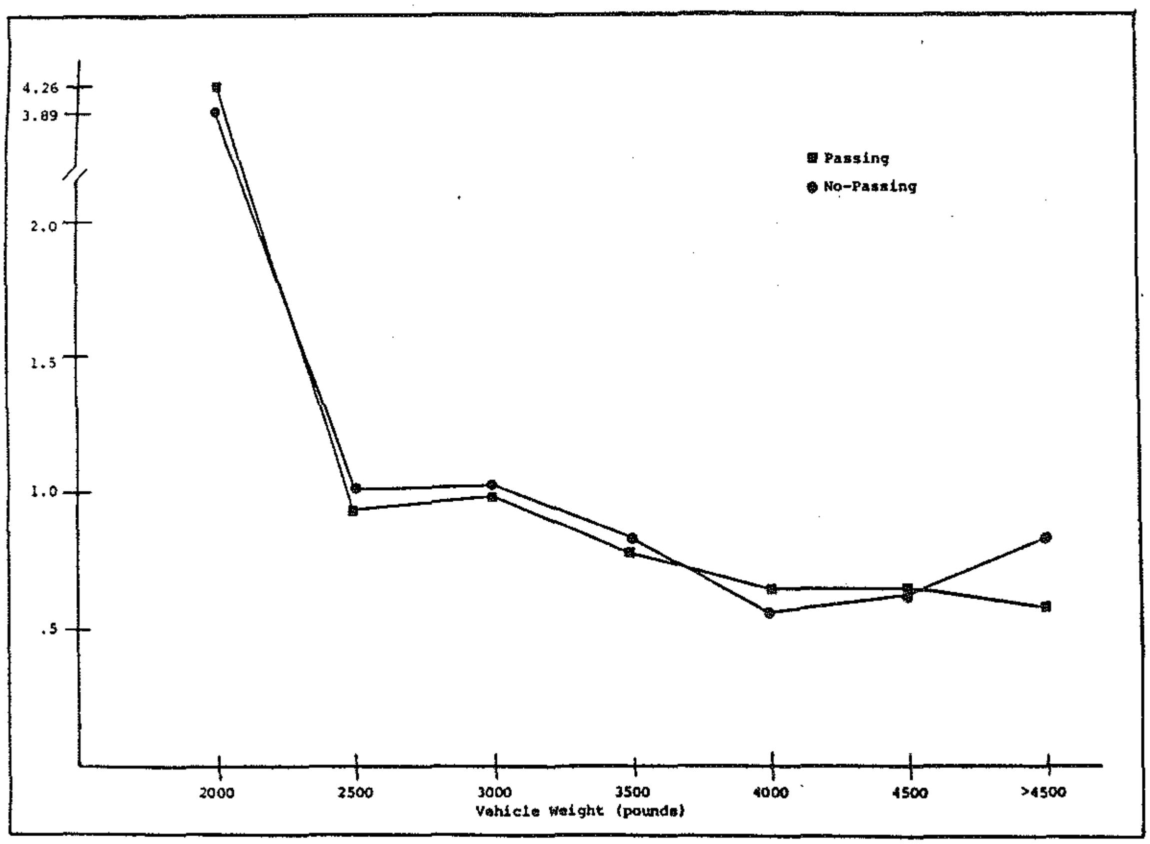


Figure 11. Three Type Total. No-Passing and Passing - VWT 1/VWT 2 Exposure.

SUMMARY

The major findings of this study can be summarized as follows:

1. This study confirmed the previous Michigan Department of Transportation study conclusion that the accident rate in no-passing zones is significantly higher than that in passing sections on the same route. We found the total accident rate to be 10.6% higher in rural midblock locations (1.94 versus 1.73 acc/MVM) and 7.1% higher at rural intersections (0.42 versus 0.39 acc/MV).

The fact that this difference is significantly lower than that reported in the previous MDOT study may be explained by several factors: a) Continuous no-passing zones were combined into single zones for this study; b) traffic volumes for the specific locations being studied were used to determine accident rates in this study, while a statewide average rate was used in the previous study; and c) intersection accidents were segregated before accident rates were calculated, as these records include accidents on all approach legs of the intersection, not just the approaches in which no-passing zones exist.

2. These differences in accident rates are not uniformly distributed across all accident types. At midblock locations, overturned accidents are 24.2% higher; fixed object accidents are 37.3% higher and head-on accidents are 23.7% higher in no-passing zones. Accident severity is also significantly different, with injury accidents being 44.1% higher in no-passing zones. Icy road accidents and wet road accidents were higher by 24.5% and 16.9% respectively. This could be expected because no-passing zones are normally coincident with horizontal and/or vertical

curves.

3. The frequency of head-on accidents is relatively small, and these accidents are not concentrated at horizontal and/or vertical curves. These accidents are more often related to loss of control than to a violation of the no-passing zone marking.

4. There are certain roadway geometry variables and roadside characteristics which are distributed differently between those no-passing zones with a high accident rate and those with a low accident rate. These include number of horizontal curves per zone; number of vertical curves per zone; presence of guardrail, poles, signs and culverts; and the number of driveways per zone.

However, no single variable explains a significant amount of the variance in accident rates among the no-passing zones. There is a large range of values for each variable among both the high and low accident rate sites.

5. Through the use of Discriminant Analysis, it is possible to construct multivariate predictive equations (models) that successfully categorize most no-passing zones into "high" and "low" accident categories. The accuracy of the classification is about 70% when the sample contains only sites with an accident rate at least twice the average for the route on which the zone is located, and sites with zero accidents in three years.

6. It is easier to predict "low" accident locations than it is to predict "high" accident locations. The single variable model correctly categorized 84% of the low accident sites and only 34% of the high

accident sites. This is due to the tendency of this model to categorize most sites as "low." As additional variables are introduced in the equations, a more balanced prediction capability is achieved.

7. The distribution of vehicles involved in accidents in rural midblock locations (by weight class) is similar in passing areas and in no-passing zones. However, small vehicles are overrepresented in both locations. Those vehicles weighing less than 2500 pounds are overrepresented by a factor of 2.

CONCLUSIONS AND RECOMMENDATIONS

There is a clear, and expected, difference in the type and frequency of accidents which occur in no-passing zones when compared to the remainder of a given route. This study has demonstrated that it is possible to construct models which predict which no-passing zones will experience "high" and "low" accident rates based on geometric and roadside variables.

The number of routes used in this study represented about 12 percent of the Michigan Trunkline system. It would be beneficial if a list of no-passing zones could be prepared indicating the accident rate and the grouping predicted by the model for the remainder of the Michigan Trunkline system. Since the models are operational on the Department computers, no additional contract work need be undertaken to complete this task.

No evidence was found that the length of the no-passing zone or the presence of curve warning signs, chevrons or advisory speed plates is related to the accident rate in no-passing zones. Perhaps such a relationship will emerge from looking at the list of sites where the accident rate is higher than predicted. However, at the current time, no change in the marking or signing policy of the Department is indicated.

It is recommended that the department begin coding no-passing zones by direction. In our analysis, all accidents occurring within the mile points in which either direction has restricted passing were coded as having occurred in a no-passing zone. Since it is reasonable to assume that some of these accidents involved vehicles travelling in the direction in which passing was allowed, the results may be biased.

No-passing zones do not appear to be particularly hazardous for vehicles of any specific weight class. While small vehicles do experience a higher than expected accident rate in rural midblock locations, this does not appear to be exacerbated in no-passing zones.

APPENDIX A

DISCRIMINANT ANALYSIS

APPENDIX A

DISCRIMINANT ANALYSIS

Introduction

When a population can be divided into K distinct groups G_1, G_2, ..., G_k, given that an observation $X = (x_1, x_2, \ldots, x_n)$ is known to belong to one of these groups, but it is unknown to which group it belongs, discriminant analysis can be used to develop a rule for assigning x in a way that the chance of misclassification is minimized. In building the function, samples should be taken directly from G_1, G_2, ..., G_n with the assumption that they are correctly classified. The two or more group used in this analysis should be considerably different in some manner which can be described by a multitude of independent variables. In this study the two groups are "high" and "low" accident rate no-passing zones.

A large number of methods of discriminant analysis exist. The most widely used in practice is the Linear Discriminant Function Method of Fisher. Fishers method of discriminant analysis assumes linearity and finds the decision surface which best separates the groups. For two normal distributions with identical covarience matrices the optimal decision surface is linear and if the mean and covarience estimators are chosen properly the Fisher method will converge to this optimal decision surface.

Discriminant Analysis between Two Groups

Berenson, Levine and Goldstein (1983) described the procedure involved in Fisher's Linear Discriminant Analysis between two groups:

1) the variables involved in the analysis are selected based on their significance; 2) the mean of each variable within each of the two groups is calculated; 3) discriminant coefficients, interpreted as a measure of a variable's worthiness (as a discriminator) are found.

This leads to a discriminator function;

$$D = d_1x_1 + d_2x_2 + \dots + d_nx_n$$

where: D is a discriminant score which is non-dimensional; x's are standardized values of the selected variables; and $d_1, d_2, \dots, d_n$ are discriminant coefficients.

A discriminant score D for each observation within both groups will be calculated and the mean values of these discriminant scores for each group will be found. These are commonly referred to as group centroids (D). Then the point of separation, or cutting score, will be determined. This is the score against which each individual's discriminant score is judged to determine into which group the individual should be classified. Based on the type of existing sample sizes - that is, the samples either being equal or unequal in sizes, two different procedures should be followed: In the case of equal sample sizes, the point of separation between groups will be halfway between the two group centroids - i.e., $D^*=(D_1+D_2/2)$. In the case of unequal sample sizes the point of separation would be the weighted average of the group centroids - i.e., $D^*=(n_2D_1+n_1D_2/n_1+n_2)$.

In order to determine if the between group differences are statistically significant in the sense of mean separation, the sample estimate of the difference in the group centroids can be found.

$$D^2 = D_1 - D_2$$

Large values of D^2 would give us some comfort that future observations can, on the basis of the characteristic measured, be successfully classified.

Validation Methods

Hair et al. (1979) proposed two methods for assessing how well a discriminant rule functions. These are:

1) Confusion Matrix: This is a matrix which shows the actual group and the predicted group memberships. This will identify the percent of the cases that are correctly classified. (Referred to as the accuracy rate in this study.) Although this method of assessment is a common procedure, it does have an overly optimistic nature. Since the data being classified and the data that are used in constructing the discriminant function are precisely the same, there is an optimistic bias built into the calculation.

2) Split Sample Validation: (This is the validation technique used in this study.) The second method for estimating the probability of correct classification without bias is to split the available sample in two parts (50-50, 70-30, 60-40), with one part being used to generate the discriminant function, and the other used to assess its worth. This method seems to give a more precise estimate for the probability of correct classification since it uses independent samples.

REFERENCES

1. Berenson, Mark L., Levine, David M., Goldstein, Mathew. Intermediate Statistical Methods and Applications, pp. 508-525, 1983.

2. Hair, Joseph F., Anderson, Rolph E., Tatham, Ronald L., Grablowsky, Bernie. Multivariate Data Analysis, pp. 94-97, 1979.

3. Hand, D. J. Kernel Discriminant Analysis, pp. 2-15, 1982.

4. Klecka, Williams R. Discriminant Analysis, pp. 43-60, 1980.

5. Neuman, Timothy R. "Discriminant Analysis as a Tool for Investigating Highway Safety Relationships," ITE Journal, pp. 16-22, 1984.

APPENDIX B

MASTER FILE

FILE POSITION	DESCRIPTION	CODE (IF ANY)
1	District	1 = Crystal Falls 2 = Newberry 3 = Cadillac 4 = Alpena 5 = Grand Rapids 6 = Saginaw 7 = Kalamazoo 8 = Jackson 9 = Southfield (Metro)
2-6	Control Section	
13	Data Flag	00 = Midblock 10 = Intersection 20 = Trunkline-Trunkline Intersection 30 = Trunkline-Trunkline Minor Leg
23-26	Begin Mile Point	
27-30	End Mile Point	
31-32	Laneage Code	1 2 Lane 2-way 2 3 Lane 2-way 3 4 Lane 2-way 4 5 Lane 2-way 5 6 Lane 2-way 6 7 Lane 2-way 7 2 Lane 1-way 8 3 Lane 1-way 9 4 Lane 1-way 10 4 Lane Divided 11 6 Lane Divided 12 8 Lane Divided 13 Other
33-34	Lane Width	Measured in Feet
35-36	Shoulder Width	0 Curb 4 0-4 ft 8 4-8 ft 10 8-10 ft 12 10-12 ft
39	Roadside Development	1 Rural 2 Strip-Fringe 3 Urban
40	No-Passing Zone	0 Passing 1 No-Passing

MASTER FILE (continued)

FILE POSITION	DESCRIPTION	CODE (IF ANY)
49-52	Degree of Curve	Degree and Minute
137-142	ADT	
143-145	Total Accidents	
146-148	Injury Accidents	
149-151	Fatal Accidents	
152-154	Wet Accidents	
155-157	Icy Accidents	
158-160	Dark Accidents	
161-163	Overturned Accidents	
164-166	Train Accidents	
167-169	Parked Veh. Accidents	
170-172	Multi: Other Accidents	
173-175	Pedestrian Accidents	
176-178	Fixed Object Accidents	
179-181	On Road Object Accidents	
182-184	Animal Accidents	
185-187	Bicycle Accidents	
188-190	Single: Other Accidents	
191-193	Head-on Accidents	
193-196	SS-Meet Accidents	
197-199	SS-Pass Accidents	
200-202	Angle Accidents	
203-205	Left Turn Accidents	
206-208	Right Turn Accidents	
209-211	Rear End Accidents	
212-214	Backing Accidents	
215-217	Parking Accidents	

2L2WRR FILE

This file is identical to the Master File with the following exceptions:

FILE POSITION	DESCRIPTION	CODE (IF ANY)
13	Data Flag	00 = Midblock
		10 = Intersection
31-32	Laneage Code	1 2 Lane 2-way
39	Roadside Development	1 Rural

ACCRATE FILE

This information was added to the 2L2WRR File.

FILE POSITION	DESCRIPTION	CODE (IF ANY)
218-224	Total Accident Rate (4/MVM)	F(7.2) Field
225-231	Injury Accident Rate	For Accident Rates
232-238	Fatal Accident	
239-245	Wet Accident	
246-252	Icy Accident	
253-259	Dark Accident	
260-266	Overturned Accident	
267-273	Train Accident	
274-280	Parked Accident	
281-287	Multi: Other Accident	
288-294	Pedestrian Accident	
295-301	Fixed Object Accident	
302-308	On Road Object Accident	
309-315	Animal Accident	
316-322	Bicycle Accident	
323-329	Single: Other Accident	
330-336	Head-On Accident	
337-343	SS-Meet Accident	
344-350	SS-Pass Accident	
351-356	Angle Accident	
357-363	Left Turn Accident	
364-370	Right Turn Accident	
371-377	Rear End Accident	
378-384	Backing Accident	
385-391	Parking Accident	
392-398	Combined Rate for Head-On + Fixed Object + Overturned Accidents	

FILE MERGE

FILE POSITION	DESCRIPTION	CODE (IF ANY)
1-5	Control Section	
6-9	Beginning Mile Pont	
10-13	End Mile Poiint	
14-18	ADT	
19-20	Lane Width	
21-22	Shoulder Width	
23-43	Accident Frequencies	
44-92	Accident Rates	
93-94	Paved Shoulder	0 = No 1 = Yes
95-96	Unpaved Shoulder	0 = No 1 = Yes
97-98	Partially Paved Shoulder	0 = No 1 = Yes
99-100	Right Horizontal Curve	Column 99-182
101-102	Left Horizontal Curve	
103-104	Crest Vertical Curve	The data in columns
105-106	Sag Vertical Curve	99-182 are frequency
107-108	Restricted Commercial Driveway on Vertical Curve	of the variable e.g. number of
109-110	Normal Commercial Driveway on Vertical Curve	restricted commer- cial driveways or
111-112	Extended Commercial Driveway on Vertical Curve	vertical curves.
113-114	Restricted Commercial Driveway on Horizontal Curve	
115-116	Normal Commercial Driveway on Horizontall Curve	
117-118	Extended Commercial Driveway on Horizontal Curve	
119-120	Restricted Commercial Driveway on a Tangent	
121-122	Normal Commercial Driveway on a Tangent	
123-124	Extended Commercial Driveway on Tangent	
126-126	Restricted Residential Driveway on Vertical Curve	
127-128	Normal Residential Driveway on Veretical Curve	
129-130	Extended Residential Driveway on Vertical Curve	
131-132	Restricted Residential Driveway on Horizontal Curve	
133-134	Normal Residential Driveway on Horizontal Curve	
135-136	Extended Residential Driveway on Horizontal Curve	

FILE MERGE (continued)

FILE POSITION	DESCRIPTION	CODE (IF ANY)
137-138	Restricted Residential Driveway on a Tangent	
135-140	Normal Residential Driveway on a Tangent	
141-142	Extended Residential Driveway on a Tangent	
143-144	Trees	11 = Greater than 10
145-146	Poles	
147-148	Mailbox	
149-150	Guardrail	
151-152	Overpass	
153-154	Embankments	
155-156	Ditches	
157-158	Culverts	
159-160	Other Objects	
161-162	Tangent Signs	
163-164	Chevrons	
165-166	Advisory Speed Signs	
167-168	Other Signs	
169-170	Major Intersections with Signals	
171-172	Major Intersections with Flashers	
173-174	Major Intersections with Stop Signs	
175-176	Minor Intersections with Signals	
177-178	Minor Intersections with Flashers	
179-180	Minor Intersections with Stop Signs	
181-182	Number of Intersection Legs	
183	District Code	

mple Data Sheet

Control section	MALI		PHOTOLOG		Film Date		
	Begin Mile Point	End Mile Point	Begin Mile Point	End Mile Point	Day	Year	Zone:
							Route:
							Dist:

Page:

No-pass zone	Shoulder			Curves				Driveways																	
				Hor.		Vert.		Commercial									Residential								
								On Vert			On Hor			On Tang			On Vert			On Hor			On Tang		
Begin Mile Point	Paved	[illegible]	[illegible]	R	L	C	S	RE	N	EX	RE	N	EX	RE	N	EX	RE	N	EX	RE	N	EX	RE	N	EX

Road obstacle													Intersection							No-pass zone
									Signs				Major			Minor			#	
Trees	Poles	Ditch	Mail Box	Guard Rail	Over Pass	Embank	Culvert	Other	Target	Chev	Adv. [illegible]	Other	Sign	Flash	Stop	Sign	Flash	Stop	of legs	End Mile Point

VIN FILE

FILE POSITION	DESCRIPTION	CODE (IF ANY)
1-2	Highway District	(See Master File)
3-7	Control Section	
8-11	Mile Point	F(5.3)
12	Highway Area	1 Interchange 2 Intersection 3 Non-above 4 Non-traffic
13-14	County	
15-16	Township	
17-19	Route Number	
20-21	Accident Type (MSP)	1 Overturned 2 Railroad Train 3 Parked Vehicle 4 Another Vehicle 5 Pedestrian 6 Fixed Object 7 Other Object 8 Animal 9 Pedal Cycle 10 Not Known
22	Accident Type (HWY)	1 Head-on 2 Sideswipe - same direct. 3 Sideswipe - opposite direction 4 Angle 5 Left Turn 6 Right Turn 7 Rear-end 8 Backed Into 9 Parking 10 Other
23-24	Number of Vehicles	
25-26	Vehicle Type (V1)	1 Passenger Car 2 Truck 3 Motorcycle 4 School Bus 5 Commercial Bus 6 Farm Equipment 7 Construction Equipment 8 Other Vehicle

VIN FILE (continued)

FILE POSITION	DESCRIPTION	CODE (IF ANY)
		9 Pedestrian 10 Pedalcycle 11 Other
27-28	Vehicle Make (V1)	1 American Motors 2 Buick 3 Cadillac 4 Chevrolet 5 Chrysler 6 Dodge 7 Ford 8 Imperial 9 Jeep 10 Lincoln 11 Mercury 12 Oldsmobile 13 Plymouth 14 Pontiac 15 Volkswagen 16 GMC 17 International 18 Blank 19 Other Foreign 20 Other Domestic
29-30	Age of Driver (V1)	Actual age given in years 98 98 yrs. of age or above 99 Not Known
31	Sex of Driver (V1)	1 Male 2 Female
32	Degree of Injury (V1)	1 Fatal Injury 2 A Injury 3 B Injury 4 C Injury 5 No Injury
33-34	Object Hit	1 No Object Hit 2 Guardrail, Post 3 Highway Sign 4 Utility Pole 5 Culvert 6 Ditch, Embankment 7 Bridge Pier or Abutment

VIN FILE (continued)

FILE POSITION	DESCRIPTION	CODE (IF ANY)
		8 Bridge Rail or Deck
		9 Tree
		10 Signal
		11 Building
		12 Mailbox
		13 Fence
		14 Island or Curb
35-36	Vehicle Characteristic (V1)	1 Under 1500 lbs.
		2 1500-2499 lbs.
		3 2500-3500 lbs.
		4 More than 3500 lbs.
		5 Carryall
		6 Jeep
		7 Pickup Truck
		8 Dump Truck
		9 Truck Tractor
		10 Non-Vehicle
37-38	Vehicle Type (V2)	For File Positions 37-46 see codes for V1 (above)
39-40	Vehicle Make (V2)	
41-42	Age of Driver (V2)	
43	Sex of Driver (V2)	
44	Degree of Injury (V2)	
45-46	Vehicle Characteristics (V2)	
47-48	Vehicle Make (V1)	File Positions 47-78 contain an interpretation of the Veh. ID No. of VEH #1 by the "Vindicator 83" program. For a list of the codes for these positions, the Vindicator 83 guide should be consulted.
49-52	First Year (V1)	
53-56	Last Year (V1)	
57-58	Series (V1)	
59-60	Model (V1)	
61-62	Body (V1)	
63	Restrn (V1)	
64-65	Engine (V1)	
66-69	Weight (V1)	
70-72	Wheelbase (V1)	
73-75	Max Horsepower (V1)	
76-78	Min Horsepower (V1)	
79-80	Vehicle Make (V2)	File Positions 79-110 contain an interpretation of the Vehicle ID No. of VEH #2 by the "Vindicator 83" program. For a list of the codes
81-84	First Year (V2)	
85-88	Last Year (V2)	
89-90	Series (V2)	
91-92	Model (V2)	
93-94	Body (V2)	
95	Restrn (V2)	
96-97	Engine (V2)	

VIN FILE (Continued)

FILE POSITION	DESCRIPTION	CODE (IF ANY)
98-101	Weight (V2)	for these file
102-104	Wheelbase (V2)	positions, the
105-107	Max Horsepower (V2)	Vindicator 83 should
108-110	Min Horsepower (V2)	be consulted.
111-112	Laneage Code	(See Master File)
113-114	Lane Width	In Feet
115-116	Shoulder Width Code	(See Master File)
117-118	Posted Speed	
119	Roadside Development Code	(See Master File)
120	No-Passing Zone Code	0 = Yes 1 = No
121	Curve Code	1 R 2 L
122-123	Degree of Curve	In Degrees
124	Signalization	0 Unknown 1 No Signal 2 Flasher 3 Signal
125	INT Type	0 Unknown 1 Cross 2 Tee 5 Offset 6 Wye 7 Other 8 Freeway Centerline 9 Directional Cross
126	Number of Legs	
127	Number Aux Lanes Right	
128	Number Aux Lanes Left	
129	No Turn on Red	0 All Turns Allowed 1 No Turns on Red Allowed
130	All Red Clearance	0 No Clearance Phase 1 Clearance Phase
131	Left Turn Signal	0 No Control 1 Left Turn Phase 2 No Left Turn Phase

APPENDIX C

PROGRAMMING

PROGRAM

CRUNCH

```
$RESET FREE
FILE  1(TITLE="BENAC/TEMP ON PACK",BLOCKSIZE=7378,
     *MAXRECSIZE=217,UNITS=CHARACTERS)
FILE  2(TITLE="BENAC/2L2WMR/OLD ON MIDAS",BLOCKSIZE=2170,
     *MAXRECSIZE=217,UNITS=CHARACTERS,NEWFILE=TRUE)
      DIMENSION ISEG(2,52)
      DO 81 JK=1,99999
    6 READ (1,100,END=99)(ISEG(1,J),J=1,52)
    7 READ(1,100,END=99)(ISEG(2,J),J=1,52)
C**   IF(ISEG(1,1).NE.8.OR.ISEG(2,1).NE.8)GO TO 6
      IF(ISEG(1,2).NE.ISEG(2,2))GO TO 82
  100 FORMAT(I1,I5,I6,I1,I9,2I4,17A6,A5,I5,25I3,T40,I1)
      IF (ISEG(1,52).NE.ISEG(2,52))GOTO 82
      IF (ISEG(1,52).EQ.ISEG(2,52))GOTO 80
   82 WRITE (2,100)(ISEG(1,JK),JK=1,51)
      DO 84 K=1,52
      ISEG(1,K)=ISEG(2,K)
   84 CONTINUE
      GOTO 7
   80 ISEG(1,7)=ISEG(2,7)
      DO 85 I=27,51
      ISEG(1,I)=ISEG(1,I)+ISEG(2,I)
   85 CONTINUE
      GOTO 7
   81 CONTINUE
   99 WRITE(2,100)(ISEG(1,JK),JK=1,51)
      LOCK 2
      STOP
      END
```

PROGRAM

ACCRATE

```
$RESET FREE
FILE  1(TITLE="MIDAS/TAB/8082 ON MIDAS",FILETYPE=7)
FILE  2(TITLE="BENAC/2L2WMR/RATE/OLD ON PACK",BLOCKSIZE=4220,
     *MAXRECSIZE=422,UNITS=CHARACTERS,AREAS=100,AREASIZE=1000)
FILE  3(KIND=PRINTER)
FILE  4(KIND=REMOTE,MAXRECSIZE=22)
      DIMENSION Q(25),RSUM(25),RSQ(25),SSUM(25),R(25),STD(25),
     *RTOT(25),VARP(25),VARN(25),IACC(25),SEG(18),TACC(25)
      DO 70 I=1,25
      RSQ(I)=0.0
      RSUM(I)=0.0
      SSUM(I)=0.0
   70 CONTINUE
      DO 250 J=1,99999
      READ(1,100,END=99)IDIST,ICS,IFIL,IDATA,IFILL,IBEG,IEND,
     *SEG,IADT,IACC,IPASS
      IF(IDATA.NE.0)GO TO 250
      IF(IPASS.EQ.0)GO TO 250
  100 FORMAT(I1,I5,I6,I1,I9,2I4,17A6,A5,I5,25I3,T40,I1)
      XLGT=FLOAT(IEND)/100-FLOAT(IBEG)/100
      RMVM=XLGT * FLOAT(IADT) * 365 * 30 / 1000000
      TMVM=TMVM+RMVM
      DO 240 L=1,25
C**   IF(IADT.EQ.0.OR.XLGT.EQ.0)WRITE(4,400)IADT,XLGT,IBEG,IEND
      IF(IADT.EQ.0)GO TO 250
      IF(XLGT.EQ.0.0)GO TO 250
  400 FORMAT(2X,I5,2X,F5.2,2X,I4,2X,I4)
      R(L) = FLOAT (IACC(L)) / RMVM
      TACC(L)=TACC(L)+IACC(L)
      RSUM(L) = RSUM (L) + R(L)
      RSQ(L) = RSQ (L) + R(L) * * 2
      SSUM (L) = SSUM (L) + 1
  240 CONTINUE
      TOR=(IACC(7)+IACC(12)+IACC(17)) / RMVM
      WRITE(2,150)IDIST,ICS,IFIL,IDATA,IFILL,IBEG,IEND,
     *SEG,IADT,IACC,R,TOR
  150 FORMAT(I1,I5,I6,I1,I9,2I4,17A6,A4,I6,25I3,26F7.2)
  250 CONTINUE
   99 CONTINUE
      WRITE(3,305)
  305 FORMAT(3X,"2L2W RUR MIDBLOCK NO PASSING ZONES"//,
     *X,"# SITES",3X,"ACC RATE",3X,"STD DEV",7X,"VARP",
     *5X,"VARN")
      DO 330 M=1,25
      STD(M)=SQRT(((RSQ(M)-RSUM(M)**2/SSUM(M)))/(SSUM(M)-1))
      RTOT(M) = TACC(M) / TMVM
      VARP(M) = RTOT (M) + 1.96 * (STD(M)/SQRT(SSUM(M)))
      VARN(M) = RTOT (M) - 1.96 * (STD(M)/SQRT(SSUM(M)))
      WRITE(3,300)SSUM(M),RTOT(M),STD(M),VARP(M),VARN(M)
  300 FORMAT(2X,F6.0,4(2X,F9.5))
  330 CONTINUE
      CLOSE(2,DISP=CRUNCH)
      STOP
      END
```

PROGRAM

MERGE

```
$ RESET FREE
FILE  1(TITLE="BENAC/2L2WMR/RATE/OLDNEW ON MIDAS",FILETYPE=7)
FILE  2(TITLE="(TRAFFIC)BENAC/MSU ON TRAFFIC",FILETYPE=7)
FILE  3(KIND=REMOTE,MAXRECSIZE=22)
FILE  4(TITLE="BENAC/2L2WMR/MERGE ON PACK",MAXRECSIZE=183,
     *BLOCKSIZE=1830,UNITS=CHARACTERS,NEWFILE=TRUE)
      DIMENSION IBEG(7920),IEND(7920),ICS(7920),IADT(7920),LW(7920),
     * ISW(7920),IFREQ(7,7920),RATE(7,7920),IIBEG(7920),IIEND(7920),
     * DR(6,7920),OBJ(5,7920),AINT(3,7920),IISHO(7920),IICUR(2,7920),
     * IDI(7920),IICS(7920)
      ISEL=0
      IFLOP=0
  100 ISEL=ISEL+1
  105 READ(1,101,END=98)IDIS,ICS(ISEL),IBEG(ISEL),IEND(ISEL),LW(ISEL),
     *ISW(ISEL),NOP,IADT(ISEL),(IFREQ(I,ISEL),I=1,7),
     *(RATE(I,ISEL),I=1,7)
  101 FORMAT(I1,I5,T23,2I4,2X,2I2,T40,I1,T138,I5,
     *T143,I3,T152,4I3,T176,I3,T191,I3,
     *T218,F7.2,T239,4F7.2,T295,F7.2,T393,F7.2)
      IF(IDIS.EQ.1.OR.IDIS.EQ.2)IDI(ISEL)=1
      IF(IDIS.EQ.3.OR.IDIS.EQ.4)IDI(ISEL)=2
      IF(IDIS.EQ.5.OR.IDIS.EQ.6)IDI(ISEL)=3
      IF(IDIS.EQ.7.OR.IDIS.EQ.8)IDI(ISEL)=4
      IF(NOP.NE.1)GO TO 105
  330 FORMAT(2X,"ICS= ",I5,"IBEG= ",I4,"IEND= ",I4)
      GO TO 100
   98 CONTINUE
  102 IFLOP=IFLOP+1
      READ(2,103,END=99)IICS(IFLOP),IIBEG(IFLOP),IISHO(IFLOP),
     *(IICUR(J1,IFLOP),J1=1,2),(DR(I,IFLOP),I=1,6),
     *(OBJ(I,IFLOP),I=1,5),(AINT(I,IFLOP),I=1,3),IIEND(IFLOP)
C**   WRITE(3,335)IICS(IFLOP),IIBEG(IFLOP),IIEND(IFLOP)
  335 FORMAT(2X,"IICS=",I5,"IIBEG=",I4,"IIEND=",I4)
  103 FORMAT(3X,I5,I4,A6,A6,A2,6A6,4A6,A2,2A6,A2,I4)
      GO TO 102
   99 CONTINUE
      DO 3 J=1,ISEL
      DO 4 J1=1,IFLOP
      IF(ICS(J).EQ.IICS(J1))GOTO 5
      GOTO 4
    5 IF(IBEG(J).EQ.IIBEG(J1))GOTO 6
      GOTO 4
    6 IF(IEND(J).EQ.IIEND(J1))GOTO 7
      GOTO 4
    7 WRITE(4,200)ICS(J),IBEG(J),IEND(J),
     *IADT(J),LW(J),ISW(J),
     *(IFREQ(J3,J),J3=1,7),(RATE(J4,J),J4=1,7),IISHO(J1),
     *(IICUR(I,J1),I=1,2),(DR(J3,J1),J3=1,6),(OBJ(J3,J1),J3=1,5),
     *(AINT(J3,J1),J3=1,3),IDI(J)
  200 FORMAT(I5,2I4,I5,2I2,7I3,7F7.2,A6,A6,A2,6A6,4A6,A2,2A6,A2,
     *I1)
      WRITE(3,330)ICS(J),IBEG(J),IEND(J)
      GO TO 3
    4 CONTINUE
    3 CONTINUE
      LOCK 4
      STOP
      END
```

PROGRAM

SPSS/VNDCTR

```
RUN NAME        VIN/SPSS
FILE NAME       (MIDAS)BENAC/DELONG/FILE2 ON MIDAS
VARIABLE LIST   DIST,CS,MILE,AREA,RNUM,MSPACC,HWYACC,
                NUMVEH,TYP1,DOIV1,OBHIT,TYP2,DOIV2,VWT1,VWT2,LC,RD,ZONE/
INPUT FORMATS   FIXED (F2.0,F5.0,F4.0,F1.0,4X,F3.0,F2.0,F1.0,2F2.0,5X,F1.0,
                       F2.0,2X,F2.0,5X,F1.0,21X,F4.0,28X,F4.0,9X,F2.0,
                       6X,2F1.0)
VAR LABELS      DIST,HIGHWAY DISTRICT/
                CS,CONTROL SECTION/
                 MILE,MILE POINT/
                AREA,INT OR MID/
                RNUM,ROUTE NUMBER/
                MSPACC,MSP ACCIDENT/
                HWYACC,HIGHWAY ACCIDENT/
                NUMVEH,NUMBER OF VEHICLES/
                TYP1,VEH 1 TYPE/
                DOIV1,DEGREE OF INJURY VEHICLE 1/
                OBHIT,OBJECT HIT/
                TYP2,VEH 2 TYPE/
                DOIV2,DEGREE OF INJURY VEHICLE 2/
                VWT1,VEH WT 1/
                VWT2,VEH WT 2/
VAR LABELS      LC,LANEAGE CODE/
                RD,ROADSIDE DEVELOPMENT/
                ZONE,PASSING OR NOPASSING/
RECODE          DIST(1 THRU 2=1)(3 THRU 4=2)(5 THRU 6=3)(7 THRU 8=4)/
RECODE          VWT1(0=1)(1 THRU 1499=2)(1500 THRU 1999=3)
                    (2000 THRU 2499=4)(2500 THRU 2999=5)
                    (3000 THRU 3499=6)(3500 THRU 3999=7)
                    (4000 THRU 4499=8)(4500 THRU 1000000=9)/
RECODE          VWT2(0 THRU 1499=1)(1500 THRU 1999=2)
                    (2000 THRU 2499=3)(2500 THRU 2999=4)
                    (3000 THRU 3499=5)(3500 THRU 3999=6)
                    (4000 THRU 4499=7)(4500 THRU 1000000=8)/
VALUE LABELS    DIST(1) 1-2
                    (2) 3-4
                    (3) 5-6
                    (4) 7-8/
VALUE LABELS    VWT1(1) 0 LBS
                    (2) LESS THAN 1500 LBS
                    (3) 1500-1999 LBS
                    (4) 2000-2499 LBS
                    (5) 2500-2999 LBS
                    (6) 3000-3499 LBS
                    (7) 3500-3999 LBS
                    (8) 4000-4499 LBS
                    (9) OVER 4500 LBS/
VALUE LABELS    VWT2(1) LESS THAN 1500 LBS
                    (2) 1500-1999 LBS
                    (3) 2000-2499 LBS
                    (4) 2500-2999 LBS
                    (5) 3000-3499 LBS
                    (6) 3500-3999 LBS
                    (7) 4000-4499 LBS
                    (8) OVER 4500 LBS/
VALUE LABEL     TYP1(1) PASSENGER CAR
```

```
                    (2) TRUCK
                    (3) MOTORCYCLE
                    (4) SCHOOL BUS
                    (5) COMMERCIAL BUS
                    (6) FARM EQUIPMENT
                    (7) CONSTRUCTION EQUIPMENT
                    (8) OTHER VEHICLE
                    (9) PEDESTRIAN
                    (10) PEDACYCLE
                    (11) OTHERS/
VALUE LABEL    TYP2(1)PASSENGER CAR
                    (2) TRUCK
                    (3) MOTORCYCLE
                    (4) SCHOOL BUS
                    (5) COMMERCIAL BUS
                    (6) FARM EQUIPMENT
                    (7) CONSTRUCTION EQUIPMENT
                    (8) OTHER VEHICLE
                    (9) PEDESTRIAN
                    (10) PEDACYCLE
                    (11) OTHERS/
INPUT MEDIUM   DISK
N OF CASES     UNKNOWN
*SELECT IF     (AREA EQ 3 AND TYP1 EQ 1 AND ZONE EQ 0 AND MSPACC EQ 1)
TASK NAME      FREQUENCY OF VWT1 ACCIDENTS IN PASSING ZONES
CROSSTABS      TABLES=VWT1 BY MSPACC/
READ INPUT DATA
*SELECT IF     (AREA EQ 3 AND TYP2 EQ 1 AND ZONE EQ 0 AND MSPACC EQ 1)
CROSSTABS      TABLES=VWT2 BY MSPACC/
*SELECT IF     (AREA EQ 3 AND TYP1 EQ 1 AND ZONE EQ 0 AND MSPACC EQ 6)
CROSSTABS      TABLES=VWT1 BY MSPACC/
*SELECT IF     (AREA EQ 3 AND TYP2 EQ 1 AND ZONE EQ 0 AND MSPACC EQ 6)
CROSSTABS      TABLES=VWT2 BY MSPACC/
*SELECT IF     (AREA EQ 3 AND TYP1 EQ 1 AND ZONE EQ 0 AND HWYACC EQ 1)
CROSSTABS      TABLES=VWT1 BY HWYACC/
*SELECT IF     (AREA EQ 3 AND TYP2 EQ 1 AND ZONE EQ 0 AND HWYACC EQ 1)
CROSSTABS      TABLES=VWT2 BY HWYACC/
*SELECT IF     (AREA EQ 3 AND TYP1 EQ 1 AND ZONE EQ 1 AND MSPACC EQ 1)
TASK NAME      FREQUENCY OF VWT1&VWT2 ACCIDENTS IN NO-PASSING ZONES
CROSSTABS      TABLES=VWT1 BY MSPACC/
*SELECT IF     (AREA EQ 3 AND TYP2 EQ 1 AND ZONE EQ 1 AND MSPACC EQ 1)
CROSSTABS      TABLES=VWT2 BY MSPACC/
*SELECT IF     (AREA EQ 3 AND TYP1 EQ 1 AND ZONE EQ 1 AND MSPACC EQ 6)
CROSSTABS      TABLES=VWT1 BY MSPACC/
*SELECT IF     (AREA EQ 3 AND TYP2 EQ 1 AND ZONE EQ 1 AND MSPACC EQ 6)
CROSSTABS      TABLES=VWT2 BY MSPACC/
*SELECT IF     (AREA EQ 3 AND TYP1 EQ 1 AND ZONE EQ 1 AND HWYACC EQ 1)
CROSSTABS      TABLES=VWT1 BY HWYACC/
*SELECT IF     (AREA EQ 3 AND TYP2 EQ 1 AND ZONE EQ 1 AND HWYACC EQ 1)
CROSSTABS      TABLES=VWT2 BY HWYACC/
FINISH
```

PROGRAM

SPSS/DISCRIMINANT

```
RUN NAME        SPSS TEST ON M-52
FILE NAME       SPSS/MERGE
VARIABLE LIST   CS,ADT,LW,SW,FREQ,RATE,PSHOULD,UPSHOULD,PPSHOULD,RCURVE,
                LCURVE,CCURVE,SCURVE,RCDV,NCDV,ECDV,RCDH,NCDH,ECDH,RCDT,
                NCDT,ECDT,RRDV,NRDV,ERDV,RRDH,NRDH,ERDH,RRDT,NRDT,ERDT,
                 TREES,POLES,MAILBOX,GUARDRAIL,OVERPASS,EMBANK,DITCH,CULVERT,
                 OTHEROB,TANS,CHEVS,ADVSP,OTHERS,MAJINTS,MAJINTF,MAJINTST,
                 MININTS,MININTF,MININTST,INTLEG
INPUT FORMATS   FIXED (F5.0,8X,F5.0,2F2.0,18X,F3.0,42X,F7.2,45F2.0)
VAR LABELS      CS, CONTROL SECTION/
                LW, LANE WIDTH/
                SW, SHOULDER WIDTH/
                PSHOULD, PAVED SHOULDER/
                UPSHOULD, UNPAVED SHOULDER/
                PPSHOULD, PARTPAVEDSHOULD/
                RCURVE, RIGHT CURVE/
                LCURVE, LEFT CURVE/
                CCURVE,SAG CURVE/
                SCURVE,CRESTCURVE/
                RCDV,RES COMM DRIVE VERT/
                NCDV,NORM COMM DRIVE VERT/
                ECDV,EXT COMM DRIVE VERT/
                RCDH,RES COMM DRIVE HOR/
                NCDH,NORM COMM DRIVE HOR/
                ECDH, EXT COMM DRIVE HOR/
                RCDT,RES COMM DRIVE TAN/
                NCDT,NORM COMM DRIVE TAN/
                ECDT,EXT COMM DRIVE TAN/
                RRDV,RES RES DRIVE VERT/
                NRDV,NORM RES DRIVE VERT/
                ERDV,EXT RES DRIVE VERT/
                RRDH,RES RES DRIVE HOR/
                NRDH,NORM RES DRIVE HOR/
                ERDH,EXT RES DRIVE HOR/
                RRDT,RES RES DRIVE TAN/
                NRDT,NORM RES DRIVE TAN/
                ERDT,EXT RES DRIVE TAN/
                TANS,TANGENT SIGNS/
                CHEVS,CHEVRONS/
                ADVSP,ADVISORY SPEED/
                OTHERS, OTHER SIGNS/
                MAJINTS,MAJOR INT SIGNAL/
                MAJINTF,MAJOR INT FLASHER/
                MAJINTST,MAJOR INT STOP/
                MININTS,MIN INT SIGNAL/
                MININTF,MIN INT FLASHER/
                MININTST,MIN INT STOP/
                OTHEROB,OTHER OBJECTS/
                INTLEG,INTERSECTION LEGS/
ALLOCATE        TRANSPACE=3500
COMPUTE         CDRIVE=RCDV+NCDV+ECDV+RCDH+NCDH+ECDH+RCDT+NCDT+ECDT
COMPUTE         RDRIVE=RRDV+NRDV+ERDV+RRDH+NRDH+ERDH+RRDT+NRDT+ERDT
COMPUTE         CDV=RCDV+NCDV+ECDV
COMPUTE         CDH=RCDH+NCDH+ECDH
COMPUTE         CDT=RCDT+NCDT+ECDT
COMPUTE         RDV=RRDV+NRDV+ERDV
COMPUTE         RDH=RRDH+NRDH+ERDH
COMPUTE         RDT=RRDT+NRDT+ERDT
COMPUTE         VD=CDV+RDV
COMPUTE         HD=CDH+RDH
COMPUTE         TD=CDT+RDT
COMPUTE         TDRIVE=VD+HD+TD
COMPUTE         SIGNS=TANS+CHEVS+ADVSP
COMPUTE         OBSTP=TREES+POLES
COMPUTE         OBSDE=DITCH+EMBANK
COMPUTE         MAJINT=MAJINTS+MAJINTST+MAJINTF
COMPUTE.        MININT=MININTS+MININTST+MININTF
RECODE          ADT(0 THRU 50=1)(51 THRU 150=2)
                    (151 THRU 250=3)(251 THRU 350=4)
                    (351 THRU 450=5)(451 THRU 550=6)
                    (551 THRU 650=7)(651 THRU 750=8)
                    (751 THRU 2000=9)/
RECODE          RATE(000.00=1)(000.01 THRU 100.00=2)/
RECODE          FREQ(0=1)(1=2)(2=3)(3=4)(4=5)(5=6)(6=7)
                    (7 THRU 100=8)/
RECODE          RCURVE(0 THRU 1=1)(2 THRU 3=2)(4 THRU 5=3)
```

```
                (6 THRU 7=4)(8 THRU 9=5)(10 THRU 50=6)/
RECODE        LCURVE(0 THRU 1=1)(2 THRU 3=2)(4 THRU 5=3)
                (6 THRU 7=4)(8 THRU 9=5)(10 THRU 50=6)/
RECODE        CCURVE(0 THRU 1=1)(2 THRU 3=2)(4 THRU 5=3)
                (6 THRU 7=4)(8 THRU 9=5)(10 THRU 50=6)/
RECODE        SCURVE(0 THRU 1=1)(2 THRU 3=2)(4 THRU 5=3)
                (6 THRU 7=4)(8 THRU 9=5)(10 THRU 50=6)/
RECODE        LW(0 THRU 7=1)(8 THRU 10=2)(11 THRU 12=3)
                (13 THRU 14=4)(15 THRU 20=5)/
RECODE        SW(0 THRU 2=1)(3 THRU 4=2)(5 THRU 6=3)(7 THRU 8=4)
                (9 THRU 10=5)(11 THRU 20=6)/
RECODE        CDRIVE(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 15=7)
                (16 THRU 20=8)(21 THRU 25=9)(26 THRU 100=10)/
RECODE        RDRIVE(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)(7 THRU 8=5)
                (9 THRU 10=6)(11 THRU 15=7)(16 THRU 20=8)
                (21 THRU 25=9)(26 THRU 100=10)/
RECODE        CDV(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 15=7)
                (16 THRU 20=8)(21 THRU 25=9)(26 THRU 100=10)/
RECODE        CDH(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 15=7)
                (16 THRU 20=8)(21 THRU 25=9)(26 THRU 100=10)/
RECODE        CDT(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 15=7)
                (16 THRU 20=8)(21 THRU 25=9)(26 THRU 100=10)/
RECODE        RDV(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 15=7)
                (16 THRU 20=8)(21 THRU 25=9)(26 THRU 100=10)/
RECODE        RDH(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 15=7)
                (16 THRU 20=8)(21 THRU 25=9)(26 THRU 100=10)/
RECODE        TDRIVE(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 15=7)
                (16 THRU 20=8)(21 THRU 25=9)(26 THRU 100=10)/
RECODE        VD(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 15=7)
                (16 THRU 20=8)(21 THRU 25=9)(26 THRU 100=10)/
RECODE        HD(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 15=7)
                (16 THRU 20=8)(21 THRU 25=9)(26 THRU 100=10)/
RECODE        TD(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 15=7)
                (16 THRU 20=8)(21 THRU 25=9)(26 THRU 100=10)/
RECODE        TREES(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 10=4)
                (11 THRU 99=5)/
RECODE        POLES(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 10=4)
                (11 THRU 99=5)/
RECODE        DITCH(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 10=4)/
RECODE        MAILBOX(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 100=7)/
RECODE        GUARDRAIL(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 99=4)/
RECODE        OVERPASS(0=1)(1 THRU 2=2)(3 THRU 4=3)
                (5 THRU 6=4)(7 THRU 8=5)(9 THRU 99=6)/
RECODE        CULVERT(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 99=6)/
RECODE        OTHEROB(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 99=6)/
RECODE        OTHERS(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 99=6)/
RECODE        SIGNS(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 15=7)
                (16 THRU 20=8)(21 THRU 25=9)(26 THRU 100=10)/
RECODE        MAJINT(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 100=7)/
RECODE        MININT(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 15=7)
                (16 THRU 20=8)(21 THRU 100=9)/
RECODE        MININTS(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 15=7)
                (16 THRU 20=8)(21 THRU 100=9)/
RECODE        MININTST(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 15=7)
                (16 THRU 20=8)(21 THRU 100=9)/
              MININTF(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 6=4)
                (7 THRU 8=5)(9 THRU 10=6)(11 THRU 15=7)
                (16 THRU 20=8)(21 THRU 100=9)/
RECODE        INTLEG(0=1)(1 THRU 2=2)(3 THRU 4=3)(5 THRU 55=4)/
RECODE        PSHOULD(0=1)(1=2)/
RECODE        UPSHOULD(0=1)(1=2)/
```

```
RECODE          PPSHOULD(0=1)(1=2)/
VALUE LABELS    PSHOULD (1) 0
                        (2) 1/
VALUE LABELS    UPSHOULD (1) 0
                         (2) 1/
VALUE LABELS    PPSHOULD (1) 0
                         (2) 1/
VALUE LABELS    ADT (1) 0-500
                    (2) 501-1500
                    (3) 1501-2500
                    (4) 2501-3500
                    (5) 3501-4500
                    (6) 4501-5500
                    (7) 5501-6500
                    (8) 6501-7500
                    (9) 7501-20000/
                RATE (1) LOW
                     (2) HIGH/
                FREQ (1) 0
                     (2) 1
                     (3) 2
                     (4) 3
                     (5) 4
                     (6) 5
                     (7) 6
                     (8) 7-100/
                RCURVE (1) 0-1
                       (2) 2-3
                       (3) 4-5
                       (4) 6-7
                       (5) 8-9
                       (6) 10-50/
                LCURVE (1) 0-1
                       (2) 2-3
                       (3) 4-5
                       (4) 6-7
                       (5) 8-9
                       (6) 10-50/
                SCURVE (1) 0-1
                       (2) 2-3
                       (3) 4-5
                       (4) 6-7
                       (5) 8-9
                       (6) 10-50/
                CCURVE (1) 0-1
                       (2) 2-3
                       (3) 4-5
                       (4) 6-7
                       (5) 8-9
                       (6) 10-50/
VALUE LABELS    LW (1) 0-7
                   (2) 8-10
                   (3) 11-12
                   (4) 13-14
                   (5) 15-20/
                SW (1) 0-2
                   (2) 3-4
                   (3) 5-6
                   (4) 7-8
                   (5) 9-10
                   (6) 11-20/
                CDRIVE(1) 0
                      (2) 1-2
                      (3) 3-4
                      (4) 5-6
                      (5) 7-8
                      (6) 9-10
                      (7) 11-15
                      (8) 16-20
                      (9) 21-25
                      (10) 26-100/
                RDRIVE(1) 0
                   (2) 1-2
                   (3) 3-4
                   (4) 5-6
                   (5) 7-8
                   (6) 9-10
                   (7) 11-15
                   (8) 16-20
                   (9) 21-25
```

```
            (10) 26-100/
          TDRIVE(1) 0
            (2) 1-2
            (3) 3-4
            (4) 5-6
            (5) 7-8
            (6) 9-10
            (7) 11-15
            (8) 16-20
            (9) 21-25
            (10) 26-100/
          VD(1) 0
            (2) 1-2
            (3) 3-4
            (4) 5-6
            (5) 7-8
            (6) 9-10
            (7) 11-15
            (8) 16-20
            (9) 21-25
            (10) 26-100/
          HD(1) 0
            (2) 1-2
            (3) 3-4
            (4) 5-6
            (5) 7-8
            (6) 9-10
            (7) 11-15
            (8) 16-20
            (9) 21-25
            (10) 26-100/
VALUE LABEL TD(1) 0
            (2) 1-2
            (3) 3-4
            (4) 5-6
            (5) 7-8
            (6) 9-10
            (7) 11-15
            (8) 16-20
            (9) 21-25
            (10) 26-100/
          CDV(1) 0
            (2) 1-2
            (3) 3-4
            (4) 5-6
            (5) 7-8
            (6) 9-10
            (7) 11-15
            (8) 16-20
            (9) 21-25
            (10) 26-100/
          CDH(1) 0
            (2) 1-2
            (3) 3-4
            (4) 5-6
            (5) 7-8
            (6) 9-10
            (7) 11-15
            (8) 16-20
            (9) 21-25
            (10) 26-100/
VALUE LABEL CDT(1) 0
            (2) 1-2
            (3) 3-4
            (4) 5-6
            (5) 7-8
            (6) 9-10
            (7) 11-15
            (8) 16-20
            (9) 21-25
            (10) 26-100/
          RDV(1) 0
            (2) 1-2
            (3) 3-4
            (4) 5-6
            (5) 7-8
            (6) 9-10
            (7) 11-15
            (8) 16-20
            (9) 21-25
```

```
      (10) 26-100/
   RDH(1) 0
      (2) 1-2
      (3) 3-4
      (4) 5-6
      (5) 7-8
      (6) 9-10
      (7) 11-15
      (8) 16-20
      (9) 21-25
      (10) 26-100/
VALUE LABELS    TREES (1) 0
         (3) 3-4
         (4) 5-10
         (5) 11-50/
   POLES (1) 0
        (2) 1-2
        (3) 3-4
        (4) 5-10
        (5) 11-50/
   DITCH (1) 0
        (2) 1-2
        (3) 3-4
        (4) 5-10
        (5) 11-50/
   MAILBOX (1) 0
          (2) 1-2
          (3) 3-4
          (4) 5-10
          (5) 11-50/
   GUARDRAIL (1) 0
            (2) 1-2
            (3) 3-4
            (4) 5-99/
   OVERPASS (1) 0
           (2) 1-2
           (3) 3-99/
   CULVERT (1) 0
          (2) 1-2
          (3) 3-4
          (4) 5-6
          (5) 7-8
          (6) 9-99/
   OTHEROB (1) 0
          (2) 1-2
          (3) 3-4
          (4) 5-6
          (5) 7-8
          (6) 9-99/
   SIGNS (1) 0
        (2) 1-2
        (3) 3-4
        (4) 5-6
        (5) 7-8
        (6) 9-10
        (7) 11-15
        (8) 16-20
        (9) 21-25
         (10) 26-100/
   OTHERS (1) 0
         (2) 1-2
         (3) 3-4
         (4) 5-6
         (5) 7-8
         (6) 9-99/
   MAJINT(1) 0
        (2) 1-2
        (3) 3-4
        (4) 5-6
        (5) 7-8
        (6) 9-10
        (7) 11-100/
   MININT(1) 0
        (2) 1-2
        (3) 3-4
        (4) 5-6
        (5) 7-8
        (6) 9-10
        (7) 11-15
        (8) 16-20
```

```
                (9) 21-100/
         MININTS(1) 0
                (2) 1-2
                (3) 3-4
                (5) 7-8
                (6) 9-10
                (7) 11-15
                (8) 16-20
                (9) 21-100/
         MININTST(1) 0
                 (2) 1-2
                 (3) 3-4
                 (4) 5-6
                 (5) 7-8
                 (6) 9-10
                 (7) 11-15
                 (8) 16-20
                 (9) 21-100/
         MININTF(1) 0
                (2) 1-2
                (3) 3-4
                (4) 5-6
                (5) 7-8
                (6) 9-10
                (7) 11-15
                (8) 16-20
                (9) 21-100/
           INTLEG (1) 0
                   (2) 1-2
                  (3) 3-4
                  (4) 5-55/
INPUT MEDIUM    DISK
N OF CASES      UNKNOWN
CROSSTABS       TABLES=RATE BY TREES,POLES,SIGNS,ADVSP,TANS,CHEVS/
CROSSTABS       TABLES=RATE BY TREES BY SIGNS/
OPTIONS         3,4,5
READ INPUT DATA
FINISH
```