ACCIDENT EXPERIENCE IN RELATION TO ROAD AND ROADSIDE FEATURES

FINAL REPORT ON THE MICHIGAN STUDY

MICHIGAN STATE HIGHWAY DEPARTMENT

CHARLES M. ZIEGLER, STATE HIGHWAY COMMISSIONER

MICHIGAN
STATE HIGHWAY DEPARTMENT
Charles M. Ziegler
State Highway Commissioner

ACCIDENT EXPERIENCE IN RELATION TO ROAD AND ROADSIDE FEATURES

Final Report on the Michigan Study

Cooperating Agencies:

Michigan State Police

U. S. Department of Commerce
Bureau of Public Roads

Prepared by
Planning and Traffic Division
March, 1952

TABLE OF CONTENTS

List of Tables

Figures

ACCIDENT EXPERIENCE IN RELATION TO ROAD AND ROADSIDE FEATURES

Final Report on the Michigan Study

There are two ways of approaching the problems of highway accidents.

The first of these is to make an intensive study of the characteristics of an individual accident or of a series of accidents in an individual location, in relation to attendant circumstances or features. This is the approach of the enforcement officer investigating a crash for the purpose of setting up an official record and possibly of assessing responsibility. It is also the approach of the traffic engineer studying a high-accident location for the purpose of finding causes and devising a remedy.

It is an accepted fact that even such intensive investigations fall far short of getting all the elements of the accident situation under study; deep psychological factors are seldom touched and factors closer to the observable surface are frequently missed. Nevertheless, such studies produce answers that are usually sufficient for their immediate purposes, and the results of a series of such studies may provide the material for analyses which will give solutions of wider scope. However, the greater the number of such individual studies which are combined, the more general and the less specific are the conclusions which can be drawn from their accumulated findings.

The second way is a much broader and more objective approach to the accident problems. It consists of gathering as large a collection of accident data as possible, and of then analyzing these data in their entirety with reference to selected conditions or features whose relationship to accident occurrence is to be investigated. The validity of this method rests on the belief that the distribution of a large number of instances will create an informative pattern.

The findings of studies of this kind are usually of a very general character. This is bound to be the case because, although a large number of accidents are used in the analysis, by the nature of the study only those characteristics become significant which are more than ordinarily prevalent.

The study here reported is of the latter type. It has resulted in some very general findings about certain basic elements of the accident situations which have developed on highways which traverse suburban areas. In most cases these findings are really substantiations of conclusions which previously had been reached tentatively on the basis of rather casual observations of conditions. In addition, new light has been thrown on important angles of the accident problems and certain vital relationships have been clearly defined.

The Michigan Study

The study of Accident Experience in Relation to Road and Roadside Features was an outgrowth of the countrywide program launched in 1945 by the National Safety Council with the interested support of the Bureau of Public Roads. The Council proposed that the several states make comparative analyses of 1941 traffic accidents on the interstate routes within their borders. The analyses were to segregate the accidents in relation to highway types and certain specified design features.

Michigan cooperated in this program but, because of its experience in working with accident reports, no surprise was felt when the specific information supplied by the accident reports was found to lack sufficient detail and accuracy for the purpose. A program for obtaining more exact data was then set up, and the Bureau of Public Roads' participation in carrying it out was secured.

Like the parent project, the Michigan study aimed to measure the relationship between accidents and highway design features and, in addition, roadside development features which, at the Bureau's request, included advertising signs. It aimed to determine, if possible, the relative importance of individual types of features in creating conditions of hazard.

PREPARATIONS FOR STUDY

The really significant elements of the project, are the means that were adopted to secure sound, detailed facts, and the statistical methods that were employed to analyze these facts.

Since existing accident reports did not yield adequately precise data for such a study, the first step was to obtain data of the type required. This involved selecting a section of highway for study and initiating a system of reporting which would locate the accidents more accurately.

The Study Road and Collection of Data

The selected study section was a 70-mile stretch of highway on US-24 from the Ohio state line to the intersection with M-58 just south of Pontiac, and on M-58 from that intersection to its junction with US-10 northwest of the city. (Figure 1) This study section, part of which is on Telegraph Road along the west edge of the Detroit urban area, includes many different roadside conditions and a considerable variety of design features. It carries heavy volumes made up of large local movements and of through trunkline traffic between Toledo and Detroit, and on the Telegraph Road section a considerable movement by-passing the latter city. There is a high percentage of commercial vehicles.

Carefully considered measures were taken to obtain accurate data concerning the types and location of both features and accidents. A comprehensive inventory was made of all design and roadside features and these were carefully located in relation to consecutively numbered station markers which had been installed at 1000-foot intervals along the road. Arrangements were made with state and local enforcement agencies to report all accidents in definite relation to these markers.

These preparations were completed in 1946, and beginning on January 1, 1947, accidents were reported on the study road according to the prescribed methods. By the end of 1949, 3,025 accidents of all kinds had been reported. These are the accidents used in most of the analyses in this study, although in certain phases only the 1,968 accidents which were reported in 1947 and 1948 were used. All data -- design and roadside features and accidents -- were first correctly located and recorded on a strip map of the study road. (Figure 2)

Methods of Analysis

For analysis, accident data were punched onto two different tabulating card forms. Of the first form, one card was punched for each accident and carried items regarding the distance in hundreds of feet from various features, the volume of 1948 traffic, and a few others. Of the second card form, one was punched for each section and included the section number, the number of accidents, the number of features of each kind, the daily traffic, and the section length.

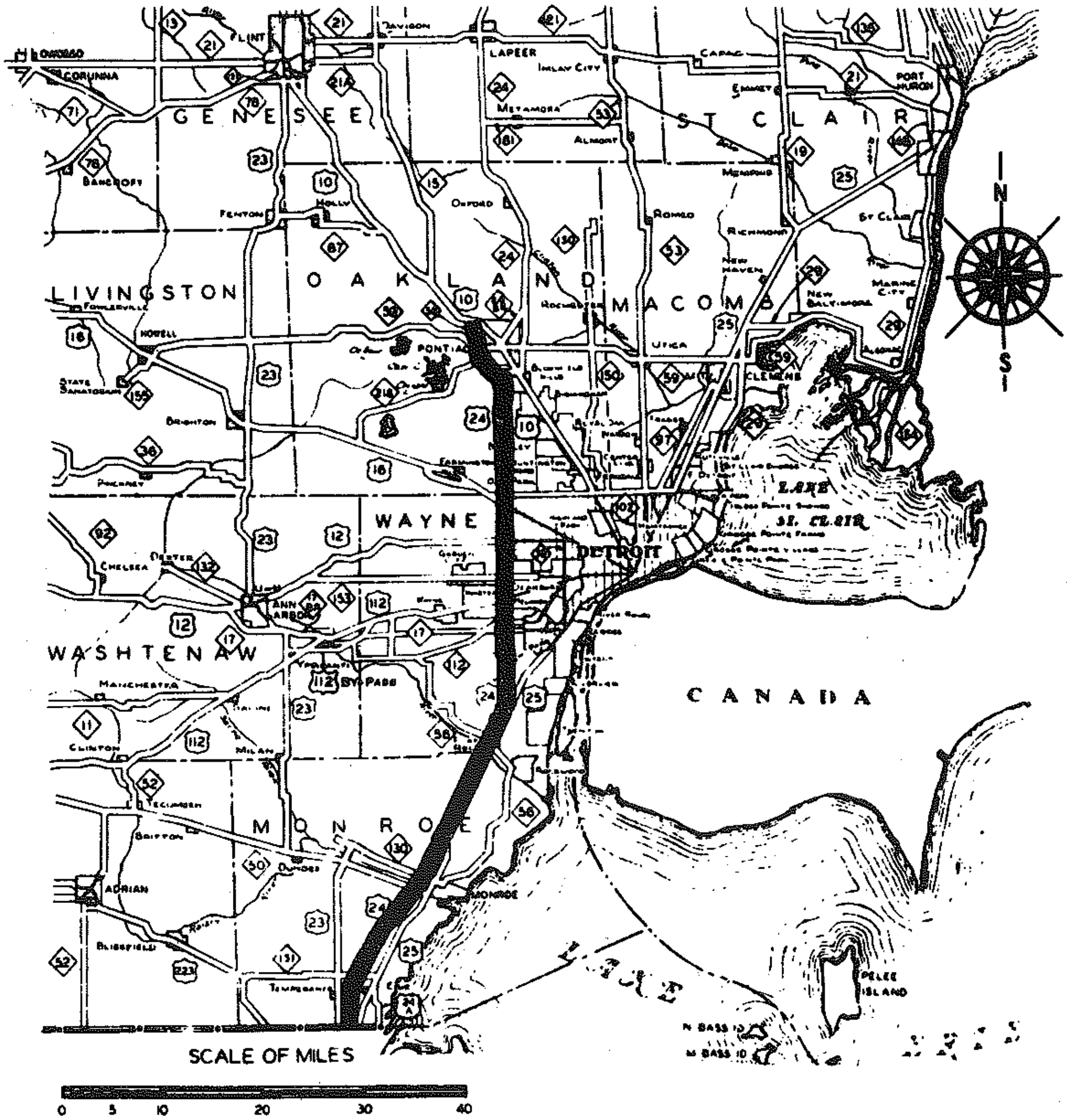

Figure 1

The study road is a section of an interstate highway between Toledo and industrial Michigan and as such carries a heavy traffic load with a high percentage of large commercial vehicles. Telegraph Road was originally built as a by-pass route around the Detroit metropolitan area, but suburban developments immediately along its roadside have seriously impaired its usefulness for through traffic.

The sections used for analytical purpose were not the 1000-foot sections established for recording the data. For the initial phase of the study, 3000-foot sections were used. Entirely different types of sections were established for the later operations of the study. These are fully explained in another part of this report.

The statistical analysis proceeded by two methods: The first method was to tabulate frequency distributions of accidents according to the distance of their place of occurrence from each specified type of feature. From these distributions, accumulative percentages within various distances were computed and rate curves were drawn. If the accidents showed a marked tendency to cluster about a certain type of feature, it could be presumed that that kind of design or roadside feature is hazardous to traffic.

The second method was to calculate correlation coefficients between the number of accidents and the number of various design and roadside features as these occurred in the several sections of the test road. If accidents and certain features were found to have a highly similar distribution among the road sections, it could be assumed that those features make some contribution to the occurrence of the accidents.

1949 PROGRESS REPORT

Less than a month after the IBM cards had been punched and when only the first computations had been made, a report of initial findings was prepared for presentation before the 35th Annual Meeting of the American Association of State Highway Officials. These preliminary results were interesting since they provided a new view of the vital relationships of accident causation. Certain of these findings stood out clearly and can be summarized briefly.

By the cumulative percentage criterion, intersections were indicated to be the most hazardous locations on or along the study road. Of the total number of accidents studied, 48 percent occurred at intersections. For this study road, accidents occurred in the area within 50 feet of intersections at the rate of 10.64 per hundred feet.

Measured by density of accident occurrence, Gas Stations with a rate of 14.5 per hundred feet at the feature, were found to be very closely associated with hazards to traffic. However, the fact that so many of these stations are located at intersections, may and probably does inflate their rate.

Transitions of Pavement Width and Crests of Hills both had accident rates of more than eight per hundred feet for the initial 50-foot distance. At greater distances from all types of features, the rates decreased sharply and at 250 feet became low and fairly uniform.

It was found that 32 percent of the total number of accidents occurred in ten of the 3000-foot sections into which the study road initially was divided. These ten sections, which represented only eight percent of the whole length of the study road, contained 20 percent of all the intersections.

The first correlation analysis indicated that, while it was difficult to single out the contributions of individual features to accident occurrence, it was possible to distinguish between the contributions of groups of features. It was found that there was a greater association between accidents and the total of selected roadside features, than between accidents and the selected design features. Both roadside and design features were found to be much more closely identified with accident occurrence than were

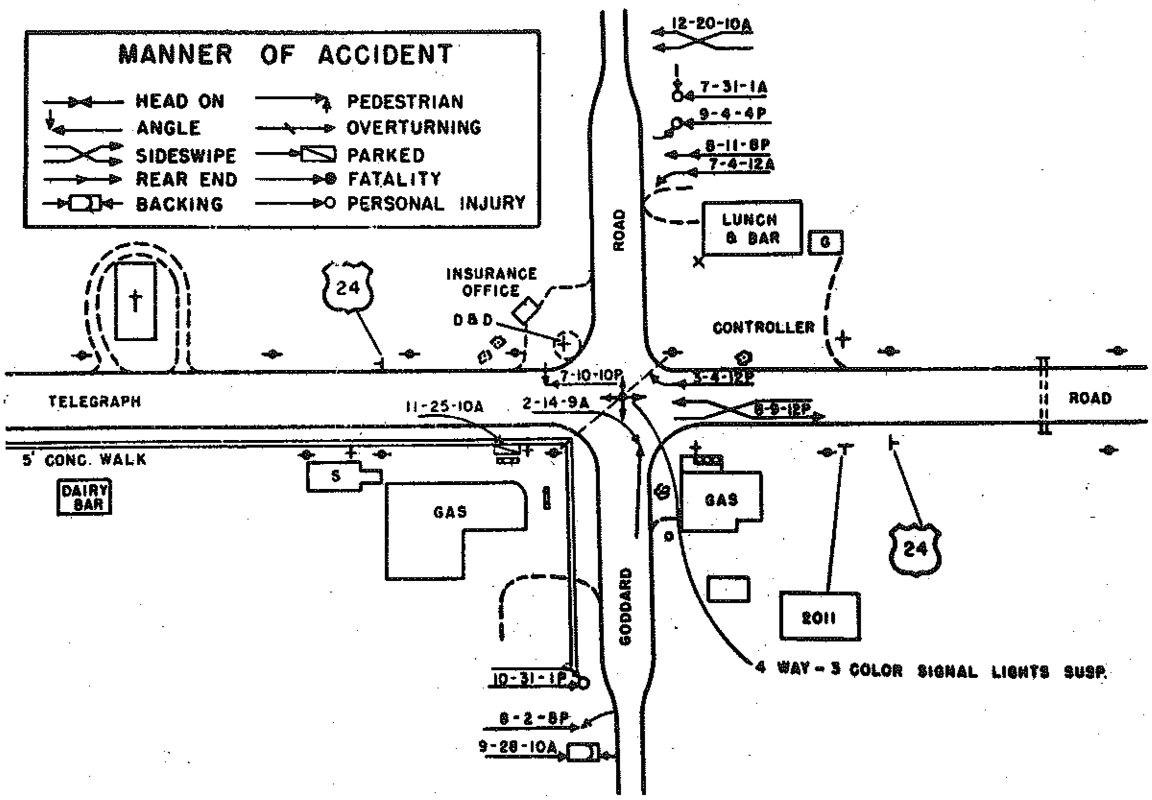

Figure 2

A section of the strip map which was drawn as an initial step in preparing accident data for analysis in relation to highway and roadside features. The features were inscribed on the map at the proper locations according to the preliminary inventory of conditions. The data for each accident were then located on the map exactly in accordance with information contained in the police reports. Later all these data were punched into IBM cards for machine computations and analyses.

advertising signs. Of the signs, only those which were illuminated, including neon and flashing neon signs, showed any appreciable association with accident locations. These types of signs are usually attached to roadside commercial places and their rate may be affected by this association.

These group relationships as revealed in this initial analysis of the data, are shown by the coefficients which resulted when the correlation of each of the three groups of features with accidents was computed. These correlation coefficients were:

Roadside Features	.79
Design Features	.61
Advertising Signs	.41

REVISION OF ANALYTICAL METHODS

Following the first analysis of the 1947-48 accidents on the study road and the release of the 1949 report, it was felt by many that the basic methods of approach could be improved. For instance, because roadside establishments of various kinds are so frequently concentrated at intersection locations, it was found to be impossible to satisfactorily analyze the relationship of individual features. For that reason it was decided that means should be found to more clearly segregate the influence of intersection traffic operation and roadside features in intersection locations.

Therefore, starting with the basic data as represented by the accident reports, a re-analysis was made. In an effort to improve the methods certain changes were made which are briefly described as follows:

1. Certain urban sections in or near the incorporated areas of Monroe, Flatrock, Dearborn, and Pontiac totalling about six miles of highway, were not included in the re-analysis. The object of this deletion was to confine the study to accidents occurring in areas more consistently rural in character.

2. Those parts of the route used were divided into two kinds of sections as follows:

   a. Intersection Sections
   b. Non-intersection Sections

   The intersection sections each included one or more major intersections; two of these sections which each included several major intersections, were slightly more than a mile in length. The non-intersection sections included no major intersections and altogether only two minor intersections. The average intersection section was about 830 feet long and the average non-intersection section was about 1,680 feet long. This division into two types of section answered the major criticism of the first analysis and at the same time made possible a more objective analysis of the data.

3. The traffic volume counts were spaced sufficiently close along the route to measure significant changes in traffic volume. These counts were used to establish a 1948 annual traffic volume for each section included in the study. This made possible the computation of number of accidents per million vehicle miles for any section or group of sections.

4. Several minor changes were made in the manner of recording the accidents in the tabulating cards. These changes were based on the experience gained in the first analysis.

The design features, roadside features, classifications of advertising signs and the numbers of each used in the second analysis were as follows:

Design Features 1/	Number in Each Kind of Section	
	Non-Intersection	Intersection
Intersection	2	232
Crest of Hill	18	6
Transition in Width or Arrangement of Lanes	10	36
Handrails at Bridges, Culverts, or Grade Separations	27	9
Culvert Posts	37	16
Guardrails	51	13
Roadside Features		
Private Drives (to dwellings and farms)	525	170
Parks - Including Roadside and Trailer	33	5
Taverns	13	28
Gasoline Stations and Commercial Garages	25	96
Stores	46	67
Restaurants	26	46
Other Establishments 2/	112	93
Advertising Signs		
Large and Prominent	119	62
Medium Size	191	162
Small Size	250	261
Signs were also classified as follows:		
Illuminated	58	108
Neon and Flashing Neon	68	98
Reflectorized	46	18
Miscellaneous	388	261

1/ Data relating to two other features, Points of Curvature and Grade Separations, Abutments and Piers, were recorded in the tabulating cards but were not used in the analysis because of their small number.

2/ In the second analysis "Other Establishments" includes used car lots, churches, hospitals, schools, lumber and coal yards, manufacturing plants, dry cleaners, and gravel pits. It does not include the features listed individually.

The tabulating cards of both forms were punched to include section identification--either intersection or non-intersection. The accident cards contained data for accidents occurring in 1947, 1948 and 1949, while the section cards contained data only for 1947 and 1948. Consequently, part of the analysis and the results presented were based on three years' accidents and part on two years' accidents.

FINAL REPORT OF STUDY

The second analysis proceeded in many respects like the first, except that in the second the data were analyzed separately for the most part for intersection and non-intersection sections. There was one change of viewpoint and objective which developed in the course of the second analysis.

The study was undertaken with the objective of learning to what degree features and accidents are associated, and not for the purpose of pinning the blame on any particular feature. It was considered that increasing the knowledge of the general conditions surrounding accident occurrence was a sufficiently worthwhile aim. The present analysis advanced beyond this aim to the point where some progress was made toward establishing definite relationships between accidents and specific roadside features.

The results of the study are presented in the following tables and figures which are accompanied by explanatory and interpretative comment:

Table I

Comparison of
Number of Accidents, Length, Vehicle Miles and Accident Rate in
Intersection and Non-Intersection Sections

Type of Section	1947-48 Accidents		Total Length		1948 Annual Average Daily Vehicle Miles		Accidents per Year Per Million Vehicle Miles
	Number	Percent	100 Ft.	Percent	Number	Percent	
Intersection	1,384	70	991	29	213,596	30	8.88
Non-Intersection	584	30	2,412	71	500,821	70	1.60
Total	1,968	100	3,403	100	714,416	100	3.77

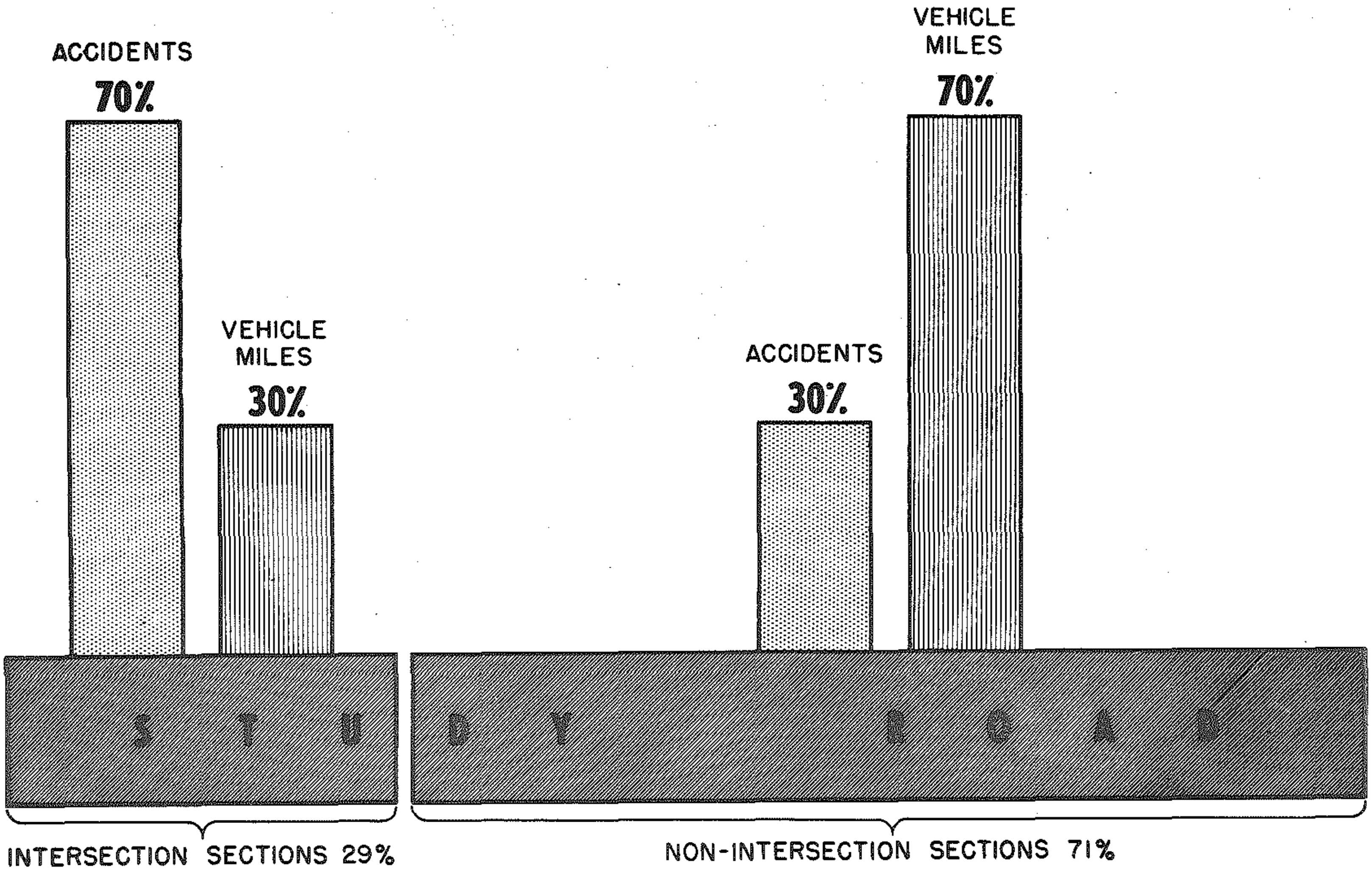

Figure 3

A graphic presentation of the percentages of study road mileage, traffic, and accidents accounted for, respectively, by the intersection and non-intersection sections into which the study road was divided for analytical purposes. It indicates that the per mile traffic density in the two types of sections was practically identical, but that accident occurrence was very much higher in the intersection sections.

Table I

The first analysis pointed clearly to the seriousness of the intersection situation along this route. The second analysis emphasizes it still more. The few figures in Table I will show at a glance that intersection sections have a much worse accident experience than non-intersection sections. The former occupy only 29 percent of the distance under study and generate only 30 percent of the vehicle miles, yet 70 percent of the accidents occurred here. The accident rate on these intersection sections is extremely high - 8.88 accidents per year per million vehicle miles. The accident rate on the non-intersection sections is 1.60; this figure compares favorably with that found for all Michigan rural state trunklines with high type surfaces of all widths in 1936-41. The latter rate was 1.68.

These relationships on the two kinds of sections are shown graphically in Figure 3.

Tables II and III

This analysis attacked the problem first from the angle of proximity of accidents to design and roadside features including large and prominent advertising signs. Frequency distributions of the distance (in increments of 100 feet) of accidents from each of the various features were tabulated. The numbers of accidents in each such distribution were divided by the appropriate total number of features to obtain the number of accidents occurring in three years (1947-48-49) per feature in each 100-foot increment of distance from the feature. This was done for the intersection and non-intersection sections separately. The results are shown in Tables II and III. These results are not comparable to those in the first analysis because they are for 3 years instead of 2 and for two kinds of sections separately. The features have been divided into 3 groups in each of Tables II and III according to maximum rates attained.

These two tables clearly demonstrate the vast difference between intersection and non-intersection sections. The intersection sections have rates of occurrence that are consistently much higher than those of the non-intersection sections. Attention is called to the rapidity with which the rates for some of the features in Group I of intersection sections fall off as compared to that for the same features in the non-intersection sections. The variation of the rates among increments of distance is much less for the same feature in the non-intersection than in the intersection sections. Tables II and III show the effect of the concentration of features about intersections. Undoubtedly Hill Crests and Intersections are bad combinations.

In the intersection sections, this and subsequent analyses pointed to the importance of one road feature and two roadside features. These are the Intersections themselves, and Gas and Service Stations, and Taverns. On Figure 4 Large Signs are also shown, not because they appear to be important but because they were the group of signs showing the greatest association with accidents.

In the non-intersection sections (Figure 5), the graphs of these same features show no important peaks of accident density; accidents are distributed through these sections rather evenly and without much reference to roadside features or signs.

These distributions underscore the importance of Intersections among the various features associated with accident occurrences. They also raise the question as to the extent to which the apparent association of some features with accidents is dependent on the location of these features relative to the Intersections.

Table II

Rate of Occurrence of Accidents per Feature per 100 Feet
Intersection Sections

Group I - Maximum Rates Exceeding 8.00

Distance (Feet)	Crests of Hill	Inter-Sections	Gasoline Stations & Commercial Garages	Taverns	Restaurants	Parks	Hand-rails
0-99	29.50	14.97	12.38	11.96	10.31	2.80	2.00
100-199	5.33	1.95	1.69	14.61	7.15	4.60	2.67
200-299	4.33	0.68	0.67	2.64	3.41	7.60	5.33
300-399	8.83	0.20	0.49	1.18	1.87	14.20	7.67
400-500	8.00	0.03	0.42	1.07	1.22	6.80	9.00

Group II - Maximum Rate Between 4.01 and 8.00

Distance (Feet)	Gurad-rails	Stores	Other Establish-ments	Transition in Width
0-99	7.92	6.51	5.30	4.64
100-199	5.85	3.69	4.49	5.28
200-299	6.26	1.70	2.32	1.25
300-399	3.77	2.19	1.89	0.94
400-500	2.92	0.88	0.84	0.92

Group III - Maximum Rate Never Exceeding 4.00

Distance (Feet)	Large and Prominent Signs	Culvert Posts	Private Drives
0-99	4.00	3.06	1.70
100-199	2.42	1.69	2.18
200-299	1.13	1.63	1.75
300-399	0.77	0.94	0.86
400-500	1.48	1.69	0.79

Table III

Rate of Occurrence of Accidents per Feature per 100 Feet
Non-Intersection Sections

Group I - Maximum Rate Between 2.01 and 3.00

Distance (Feet)	Taverns	Gasoline Stations & Commercial Garages	Restaurants
0-99	2.77	2.08	2.04
100-199	1.62	1.12	1.65
200-299	1.54	1.96	1.77
300-399	2.15	1.84	1.15
400-500	1.31	2.36	0.96

Group II - Maximum Rate Between 1.01 and 2.00

Distance (Feet)	Other Establish-ments	Guard-rails	Stores	Transition in Width	Crests of Hills	Handrails
0-99	1.68	1.67	1.54	1.20	1.17	1.07
100-199	0.72	0.39	0.74	1.50	0.78	0.81
200-299	0.46	0.37	0.89	1.30	0.56	0.81
300-399	0.37	0.16	1.00	1.40	0.50	0.85
400-500	0.31	0.45	0.96	1.80	1.00	0.56

Group III - Maximum Rate Never Exceeding 1.00

Distance (Feet)	Culvert Posts	Parks	Private Drives	Large and Prominent Signs
0-99	0.92	0.82	0.69	0.47
100-199	0.41	0.64	0.31	0.44
200-299	0.78	0.67	0.15	0.45
300-399	0.73	0.73	0.12	0.46
400-500	0.62	0.58	0.09	0.29

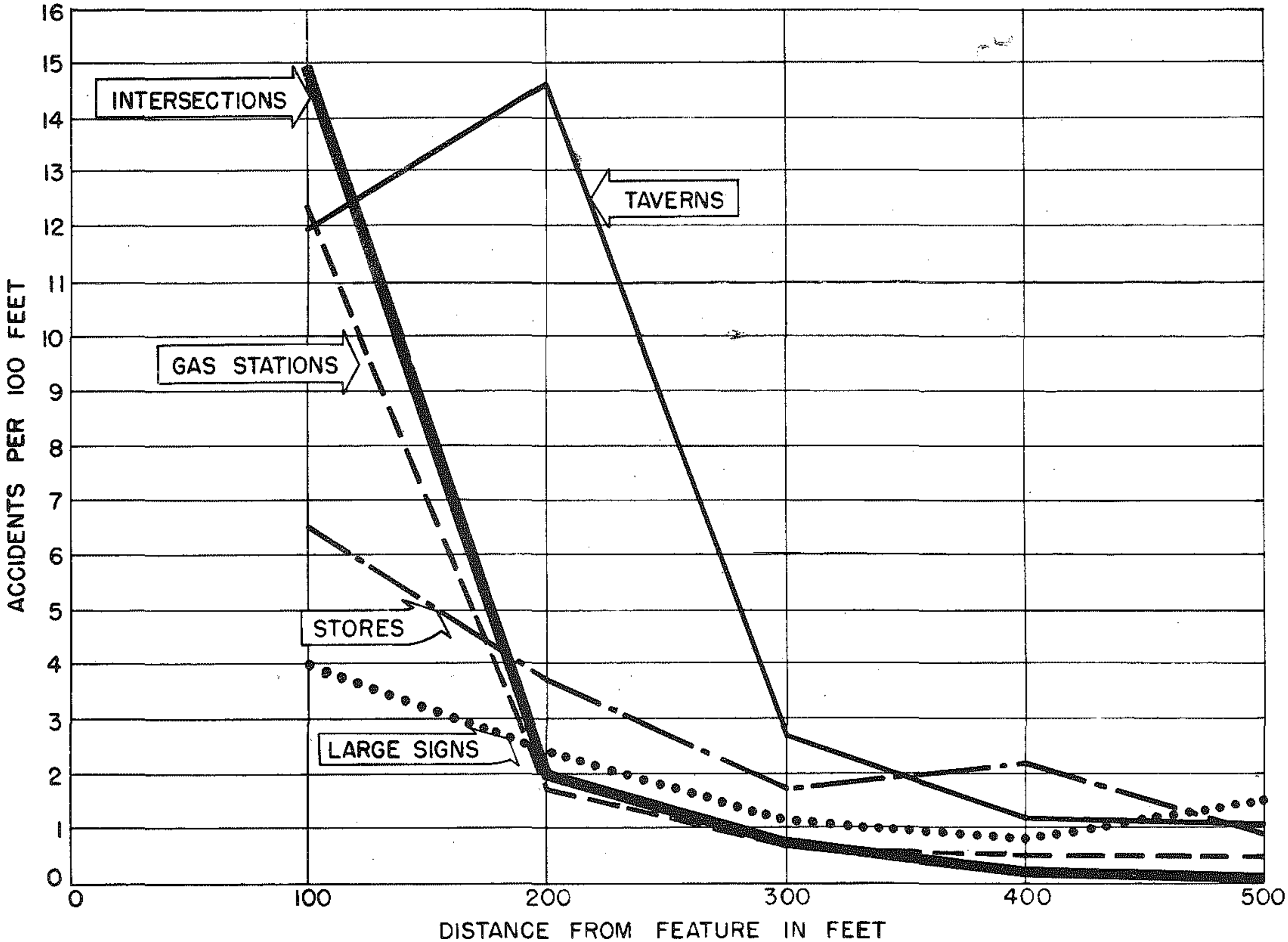

Figure 4

This graph of the number of accidents in intersection sections at various distances from several significant features, demonstrates the importance of intersections in the accident picture. The fact that the graph line for intersections seems to set the pattern for the other lines, raises the question as to the extent to which the shapes of these other lines reflect the location with respect to intersections of the features they represent.

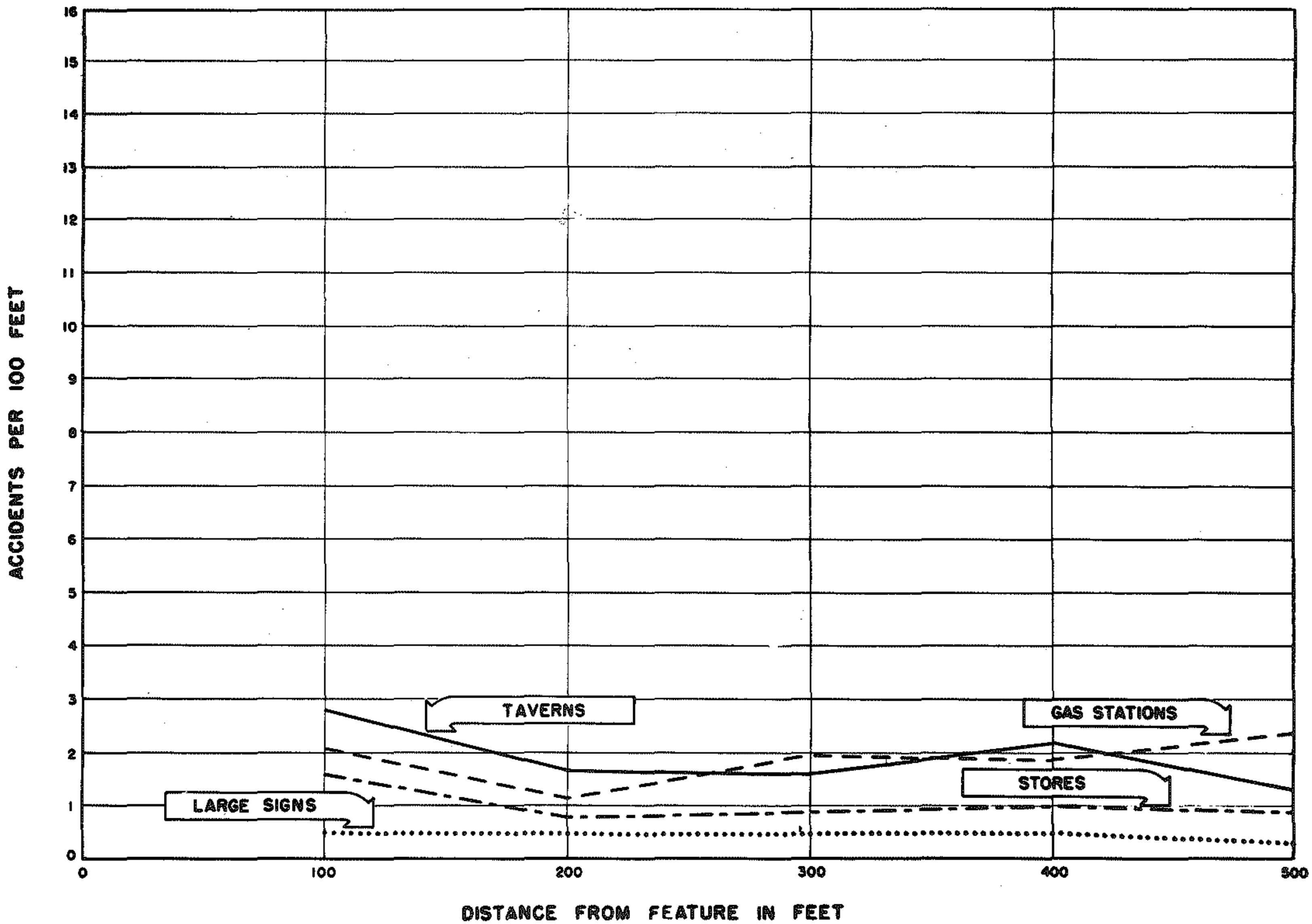

Figure 5

This graph shows the number of accidents in non-intersection sections at various distances from significant features. The same features are shown as in Figure 4 except that there are no intersections. The two facts of the absence of intersections and the less density of roadside features in these non-intersection sections, undoubtedly account for the flatness of the graph lines as compared with those in Figure 4.

Correlation Coefficients

The problem was next attacked by way of the correlation coefficient. This coefficient is a relative measure of the amount of association between one variable and one or more other variables. The amount of association is measured on a scale ranging from -1 to +1. It is an abstract number free of any unit of measure. If two variables are perfectly associated; i.e.; if one varies directly as the other, their correlation will be exactly one. Or if one varies inversely as the other, their correlation will be exactly -1. If one varies with perfect randomness with respect to the other, their correlation will be zero.

Graphically this means that if one variable is plotted against the other, and all points lie on a straight line the correlation between the two will be +1 or -1, depending upon whether the line has a positive or negative slope. The correlation coefficient provides a more objective method of approach than that of the proximity of features method.

Table IV

The correlation coefficients were computed from the data recorded in the section cards of which, as explained above, there was one for each intersection section and one for each non-intersection section. They are based on the accidents for the two years, 1947-1948. There were 119 intersection and 144 non-intersection sections. All correlation coefficients were computed for each kind of section separately. The correlation between accidents and the several design features, roadside features and advertising signs are shown in Table IV.

Most of these coefficients are higher for intersection than for non-intersection sections. Notable exceptions are Culvert Posts, Large and Prominent Signs and Reflectorized Signs. Considering each kind of feature or advertising sign individually, the difference between the correlation coefficients for intersection and non-intersection sections is hardly significant in most cases. But using the method of weighted average correlation coefficients, it was found that the association of accidents with these features and advertising signs combined is very significantly greater in intersection than in non-intersection sections. By the same procedure design features and advertising signs show no significant difference between the two types of sections while roadside features show a highly significant difference. From this we can safely conclude that:

1. Accidents are associated with design features to about the same extent in both intersection and non-intersection sections.
2. Accidents are associated with roadside features significantly more in intersection sections than in non-intersection sections.
3. Accidents are associated with advertising signs to about the same extent in both intersection and non-intersection sections.

Nearly all the correlation coefficients for design features are too small to be given serious consideration. Many are insignificantly small. The importance of Crests of Hills indicated by the proximity study does not appear in the correlation coefficient because of the very small number of this feature. Nevertheless, they do show greater association in intersection sections than any other design feature and are not to be ignored. Generally speaking, the association of accidents with design features is significantly less in both kinds of section than the association of accidents with roadside features or with advertising signs.

Table IV

Correlation Coefficients of Accidents with Features and Advertising Signs for Non-Intersection Sections and for Intersection Sections

Features Correlated with Accidents	Correlation Coefficient Non-Intersection	Correlation Coefficient Intersection
Design Features:		
Crest of Hill	-.002*	.374
Transition in Width or Arrangement of Lanes	-.016*	.206*
Handrails at Bridge, Culvert or Grade Separation	.164*	.197*
Culvert Posts	.353	-.137*
Guard Rails	.131*	.217*
Weighted Average	.129	.228
Roadside Features:		
Private Drives	.513	.264
Parks	.455	.162*
Taverns	.313	.698
Gas Stations and Commercial Garages	.442	.666
Stores	.321	.526
Restaurants	.438	.651
Other Establishments	.443	.720
Weighted Average (excluding Private Drives and Parks)	.393	.657
Advertising Signs:		
Large and Prominent	.418	.367
Medium Size	.597	.578
Small Size	.482	.695
Illuminated	.561	.588
Neon and Flashing Neon	.428	.660
Reflectorized	.304	.130*
Miscellaneous	.484	.559
Weighted Average	.472	.530
1948 Annual Average Daily Vehicle Miles	.680	.720
Section Length	.719	.687
Multiple Correlations:		
Design Features	.393	.480
Roadside Feature Less Private Drives and Parks	.640	.859
Large, Medium and Small Advertising Signs	.606	.710
Illuminated, Neon and Flashing Neon, Reflectorized and Miscellaneous Advertising Signs	.635	.758

*Insignificantly Small

The difference between the association of accidents with roadside features (not including private drives and parks) and of accidents with advertising signs is hardly significant in the non-intersection sections. This difference is highly significant in the intersection sections where accidents are associated with roadside features (not including private drives and parks) very much more closely than with advertising signs.

In computing the correlation coefficients, as well as in this discussion of them, Private Drives and Parks are not included in the general term "roadside features". Although it is true that these two features are roadside features in one sense and are included under roadside features in Table IV, it was desired to treat commercial establishments as a separate group. The term "roadside features" has generally been used for commercial establishments as a group.

It is worthwhile to note that accidents are significantly more closely associated with Private Drives and Parks in non-intersection than in intersection sections. In fact, these two are more closely associated with accidents than are any of the other roadside features in the non-intersection sections.

To show the specific influence of design and roadside features and of advertising signs, accidents were correlated with 1948 annual average daily vehicle miles and with section length. These coefficients are shown in Table IV. That there is little difference between the association of accidents with Vehicle Miles and with Section Length is not surprising since one is a function of the other. While it is true that Vehicle Miles and Section Length are much more closely associated with accidents than are Roadside Features and Advertising Signs (according to the weighted average coefficients of the latter), it is also true that Section Length is as closely or more closely associated with Roadside Features and Advertising Signs than are accidents. The following table shows the correlation among accidents, Section Length, Vehicle Miles, Roadside Features and Advertising Signs:

	Total Roadside Features 1/	Total Advertising Signs	Vehicle Miles	Section Length
Non-Intersection Sections -				
Accidents	.393	.472	.680	.719
Section Length	.353	.565	- - -	- - -
Intersection Sections -				
Accidents	.657	.530	.720	.687
Section Length	.734	.759	- - -	- - -

This means that, in the non-intersection sections, accidents tend to be somewhat evenly distributed spatially along the study route without much regard for Roadside Features and Advertising Signs. Roadside Features and Advertising Signs are not so evenly distributed spatially along the study route, but tend to be grouped. At the same time, accidents are occurring more closely associated with Section Length, and hence Vehicle Miles, than with roadside features and advertising signs.

In the intersection sections, accidents again tend to be somewhat evenly distributed with respect to Section Length. But here the Roadside Features and Advertising Signs

1/ Less Private Drives and Parks.

are much more evenly distributed with respect to Section Length; the association is significantly higher than in non-intersection sections. At the same time the association of accidents with Roadside Features has risen significantly over that found in non-intersection sections. The association of accidents with Advertising Signs has also risen appreciably, although not by a statistically significant amount.

All this is not to belittle the importance to accident occurrence of vehicle miles generated, but to point out that accidents, Roadside Features, Advertising Signs and Vehicle Miles appear to be interlocked. To completely isolate these various cross-influences is a very difficult problem. It has been one of the primary aims of the analysis to bring about this isolation.

In order to exhaust the possibilities of the correlation coefficient more completely, multiple correlations were computed. Multiple correlation permits measuring the association of one variable with two or more other variables simultaneously. It permits the independent variables to exert their influence jointly upon the amount of association existing. Multiple correlation coefficients for accidents with Design Features, Roadside Features less Private Drives and Parks, Advertising Signs classified by size and by type of lighting were computed for each kind of section. These are shown at the bottom of Table IV. These coefficients are much higher than the corresponding single coefficients because they reflect the additive effect of features and signs. Accident occurrence is much more closely associated with all Roadside Features or all Advertising Signs than with any one kind of feature or sign individually. The same is also true for Design Features. These multiple coefficients substantiate very well the findings from the simple coefficients.

The very high multiple correlation of 0.859 between accidents and Roadside Features in intersection sections is the most significant point in the correlation phase of this analysis. The coefficients of 0.710 and 0.758 for accidents with Advertising Signs rank second in this respect.

The difference between the coefficients for Advertising Signs classified by size and by type of lighting is not significant in either kind of section

Table V

While the use of correlation coefficients makes possible a somewhat more precise analysis and one whose results can be tested for significant differences, the results are more difficult to interpret properly and explain in writing. Therefore the problem was again attacked by the method of accident density. In each section card the total number of accidents occurring in the two years, 1947 and 1948, was divided by the section length in hundreds of feet. Thus accident density is the number of accidents per hundred feet of section length. The several items pertaining to accidents, section length, features, signs and vehicle miles were tabulated by accident density. From these tabulations percent of Section Length, percent of accidents, density of Roadside Features, and density of Advertising Signs were computed for each of five accident density groups. This was done for each kind of section separately. The results are shown in Table V.

In this table, attention is called first of all to the almost perfect consistency with which Roadside Feature density and Advertising Sign density increases as the accident density increases. Although it indicates only a general trend rather than specific relationships, it does lend considerable support to the correlation coefficients of Table IV; one might say that it explains in a way the coefficients of Table IV. It is worthwhile to note the difference in the various types of features and signs between the two kinds of section at the same accident density level. Table V explains the relatively low correla-

Table V

Percent of Section Length and Accidents and Number of Roadside Features and Advertising Signs Per 100 Feet For Each of Five Groups of Accident Density

		Accident Density (Number of Accidents per 100 Ft.)					
		None	0.01-0.49	0.50-0.99	1.00-3.99	4.00 & Up	Total
Intersection Sections							
Section Length	(percent)	4.4	18.5	28.5	44.8	3.8	100.0
Accidents	(percent)	0.0	4.0	14.8	61.1	20.1	100.0
				(number per 100 feet)			
Private Drives		.114	.208	.262	.115	.053	
Taverns		-o-	-o-	.014	.041	.158	
Gas Stations & Commercial Garages		-o-	.011	.092	.115	.448	
Stores		.023	.016	.060	.088	.184	
Restaurants		-o-	-o-	.046	.065	.105	
Other Establishments		.023	.027	.082	.128	.184	
Total Roadside Features		.045	.054	.294	.437	1.079	
Large & Prominent Signs		-o-	.055	.060	.077	.026	
Medium Sized Signs		.068	.087	.160	.185	.421	
Small Signs		.045	.082	.308	.290	.737	
Signs Illuminated or Reflectorized		.023	.033	.216	.275	.895	
Signs Not Illuminated or Reflectorized		.091	.191	.312	.277	.289	
Total Signs		.114	.224	.528	.552	1.184	
Non-Intersection Sections							
Section Length	(percent)	10.4	81.2	7.8	0.6	-o-	100.0
Accidents	(percent)	-o-	74.7	20.2	5.1	-o-	100.0
				(number per 100 feet)			
Private Drives		.171	.220	.261	.143	-o-	
Taverns		-o-	.004	.021	.071	-o-	
Gas Stations & Commercial Garages		.008	.009	.027	.071	-o-	
Stores		.008	.015	.064	.143	-o-	
Restaurants		-o-	.010	.016	.214	-o-	
Other Establishments		.024	.039	.117	.572	-o-	
Total Roadside Features		.040	.077	.245	1.071	-o-	
Large & Prominent Signs		.040	.051	.048	.071	-o-	
Medium Sized Signs		.056	.079	.096	.286	-o-	
Small Signs		.068	.101	.149	.500	-o-	
Signs Illuminated or Reflectorized		.028	.068	.122	.571	-o-	
Signs Not Illuminated or Reflectorized		.135	.162	.170	.286	-o-	
Total Signs		.163	.231	.293	.857	-o-	

tion of accidents with Private Drives and Large and Prominent Signs in intersection sections.

The percentages of Section Length and accidents by accident density groups indicate clearly the seriousness of the accident situation in intersection sections as compared to that in non-intersection sections. For example: In the intersection sections 81.2 percent of the accidents occurred at accident densities of 1.00 or more; while in the non-intersection sections only 5.1 percent of the accidents occurred at accident densities of 1.00 or more.

Table VI

Table VI is presented to show the nature of the relationship between accidents and Traffic Volumes. Accident rates and accident densities are shown by 1000-vehicle increments of 1948 annual average daily traffic volume. These data fail to show any evidence that accident rates or accident densities increase significantly as Traffic Volumes increase on the study route. The correlation coefficients of Traffic Volumes with accident rates and with accident densities are shown at the bottom of Table VI. Only one of these four correlations is significantly large. This is the one for accident rates with Traffic Volumes in the non-intersection sections, and since it is negative it indicates a tendency for the accident rates to decrease as Traffic Volumes increase.

Table VI is not offered to start or end a controversy. It is intended only to show the conditions relative to accidents and Traffic Volumes existing on the route under study.

Figure 6

Figure 6 gives an over-all view of the various factors in the accident experience analyzed in this study. The strip map shows the entire route, except those sections omitted in Monroe, Flatrock, Dearborn, and Pontiac. It includes the Accident Rate, the Roadside Features per 100 feet, 1948 average daily traffic, Pavement Widths, and the principal Intersecting Highways. The figure is drawn to scale along the route.

This composite view of the various factors analyzed suggests the variety of influences which may affect accident experience. Particularly pertinent is the coincidence on several sections of peak quantities of Roadside Features and peak Accident Rates. At another point a little north of Monroe, it is possible that frequent transitions of Pavement Width and a major Road Junction account for an isolated high Accident Rate. Also, it is fair to suppose that a section of overloaded 2-lane Pavement on the northern part of the study road is the reason for the otherwise unexplained coincidence of low Traffic Volumes and a high Accident Rate on that section.

There appears to be little relationship between the Number of Lanes and Accident Rate; for any apparent trend in this respect there can be found an exception. There is much more relationship between Number of Lanes and Traffic Volume. Generally speaking, the 4-lane portions carry higher traffic volumes than the 3-lane portions which in turn carry higher volumes than the 2-lane portion.

Figure 6 shows why the correlation coefficients between Accident Rates and Traffic Volumes (shown in Table VI) were negative. The portion of Telegraph Road lying between the two junctions with US-25 has the highest traffic volumes to be found along the route, reaching a peak of over 19,000 vehicles per day. Yet this same portion of the route has the lowest accident rate to be found on the study road except for a short section between M-151 and Dewar Road. The portion of the route lying north of Eight-Mile Road (M-102) has the lowest traffic volume and yet has a relatively high accident rate.

Table VI

Accidents per Year per Million Vehicle Miles and Accidents per Hundred Feet 1/ in each Kind of Section by 1948 Annual Average Daily Traffic Volumes

1948 Annual Average Daily Traffic Volumes	Accident Rates: Intersection Sections	Accident Rates: Non-Intersection Sections	Accident Densities: Intersection Sections	Accident Densities: Non-Intersection Sections
5,000 - 5,999	15.65	1.61	1.23	0.13
6,000 - 6,999	10.18	2.73	0.90	0.25
7,000 - 7,999	9.49	2.86	0.98	0.29
8,000 - 8,999	8.02	1.95	0.92	0.22
9,000 - 9,999	8.05	1.64	1.07	0.21
10,000 - 10,999	6.73	1.77	0.98	0.26
11,000 - 11,999	9.22	1.74	1.48	0.28
12,000 - 12,999	2.39	0.95	0.43	0.17
13,000 - 13,999	9.79	1.61	1.87	0.31
14,000 - 14,999	7.95	1.18	1.61	0.24
15,000 - 15,999	9.56	1.15	2.05	0.25
16,000 - 16,999	18.38	2.34	4.23	0.54
17,000 - 17,999	2/	2/	2/	2/
18,000 - 18,999	2.67	0.85	0.69	0.22
19,000 - 19,999	4.88	1.11	1.32	0.30
Correlation with 1948 Annual Average Daily Traffic Volumes	-0.302	-0.609	0.365	0.419

1/ In two years

2/ No traffic volumes in this range on the study route.

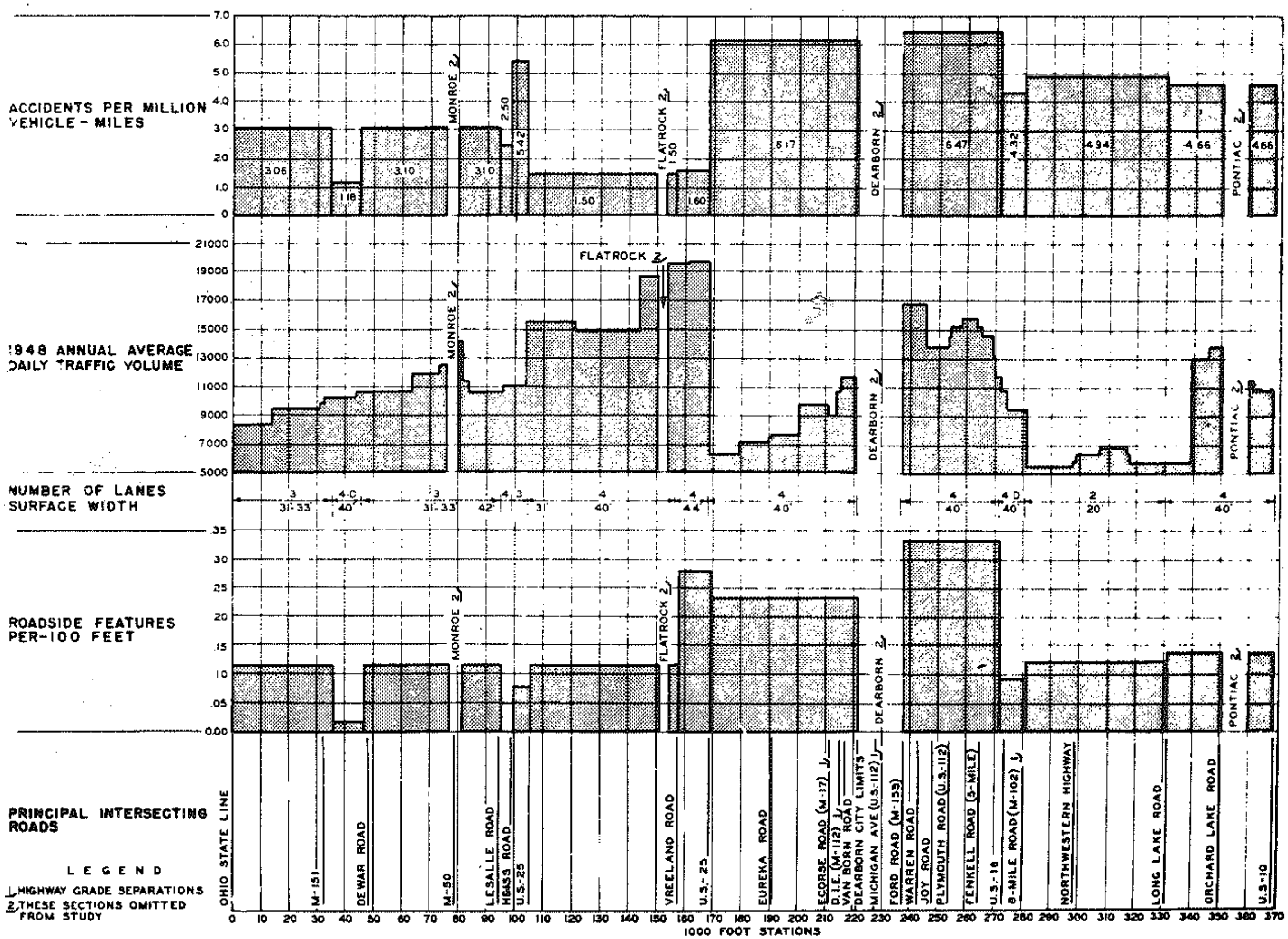

Figure 6

This graphic strip map shows how accident rates, traffic volumes, number of lanes, pavement widths, roadside features, and principal intersecting roads are distributed and related to one another on the study road. Quantities and rates are for the years 1947-48.

An analysis of accidents occurring in 1936-41 on Michigan rural state trunklines with high type surfaces revealed that when a 2-lane road was loaded beyond about 4,000 vehicles per day the accident rate increased sharply. This fact is very well substantiated by the 2-lane portion of Telegraph Road lying between 8 Mile Road and Long Lake Road. This portion has traffic volumes which are very low compared to the remainder of Telegraph Road, but they are far beyond the critical 4,000 vehicles per day, and the accident rate of 4.94 is among the highest along the route.

Tables VII and VIII

The question has come up repeatedly as to whether intersections are hazardous simply because they are intersections or whether they are hazardous because roadside features are built up around them. To answer this question the intersection sections were divided into three groups of roadside feature density (number of roadside features per 100 feet). For each group there was tabulated the number of sections, accidents, roadside features and advertising signs, section length and 1948 annual average daily vehicle miles. These are shown in Table VII. Then for each roadside feature density group there was computed percentage of accidents, roadside features, advertising signs, section length and 1948 annual average daily vehicle miles, accidents per 100 feet and accidents per year per million vehicle miles. These are shown in Table VIII. Both these Tables are based only on intersection sections.

In the first roadside feature density group containing no roadside features of any kind, 28.0 percent of the section length and 23.8 percent of the vehicle miles, there occurred only 10.0 percent of the accidents. This group contained at least 46 intersections. On the other hand, the last roadside feature density group which accounts for only 22.2 percent of the section length and 24.5 percent of the vehicle miles of travel, contained 45.8 percent of the roadside features and 37.2 percent of the accidents.

The last two columns of Table VIII show the rapid increase in accident density and accident rate as roadside feature density is increased. These two columns furnish the answer to our question. (Figure 7) Intersections are hazardous in themselves as indicated by the accident rate of 3.74 in 46 intersection sections containing no roadside features. Considering the manner in which accident density and accident rate increase as roadside feature density increases, it is evident that intersections are not only hazardous in themselves but that they become much worse as roadside features are built up around them.

Table IX

Another approach was made to the problem of accidents and roadside features by the way of frequency distributions. Accidents for the three years 1946, 1947 and 1948 and all roadside features except private drives, were used. The data for both kinds of sections were combined. Frequency distributions of number of accidents and of number of 200-foot units of distances by number of roadside features (less Private Drives) were constructed. Two other similar pairs of frequency distributions were constructed--one for 400-foot units of distance and one for 600-foot units of distance. The 400-foot units overlapped 200 feet and the 600-foot units overlapped 400 feet. The purpose of this overlapping was to obtain the same number of units of distance in all three pairs of distributions.

Then for each of the three pairs of distributions the number of accidents was divided by the number of units of distance at each number of roadside features. The results are shown in Table IX.

Table VII

Number of Sections, Accidents, Roadside Features, Advertising Signs; Section Length,
1948 Annual Average Daily Vehicle Miles
For Each of 3 Groups of Roadside Feature Density

Intersection Sections

Roadside Feature Density (Number of Roadside Features per 100 Feet)	NUMBER OF				Section Length (100's of Feet)	1948 Annual Average Daily Vehicle Miles
	Sections	Accidents	Roadside Features	Advertising Signs		
-0-	46	139	-0-	41	277	50,899
0.001 - 0.399	50	730	179	252	494	110,373
0.400 - and up	23	515	151	192	220	52,324
Total	119	1,384	330	485	991	213,596

Table VIII

Percent of Accidents, Roadside Features, Advertising Signs, Section Length, 1948 Annual Average Daily Vehicle Miles; Accidents per 100 Feet and Accidents per Year per Million Vehicle Miles for each of 3 groups of Roadside Feature Density

Intersection Sections

Roadside Feature Density (Number of Roadside Features per 100 Feet)	PERCENTAGE OF Accidents	Roadside Features	Advertising Signs	Section Length (100's of Feet)	1948 Annual Average Daily Vehicle Miles	Accidents per 100 Feet	Accidents per Year per Million Vehicle Miles
-0-	10.0	-0-	8.4	28.0	23.8	0.50	3.74
0.001 - 0.399	52.7	54.2	52.0	49.8	51.7	1.48	9.06
0.400 - and up	37.2	45.8	39.6	22.2	24.5	2.34	13.48
Total	100.0	100.0	100.0	100.0	100.0	1.40	8.88

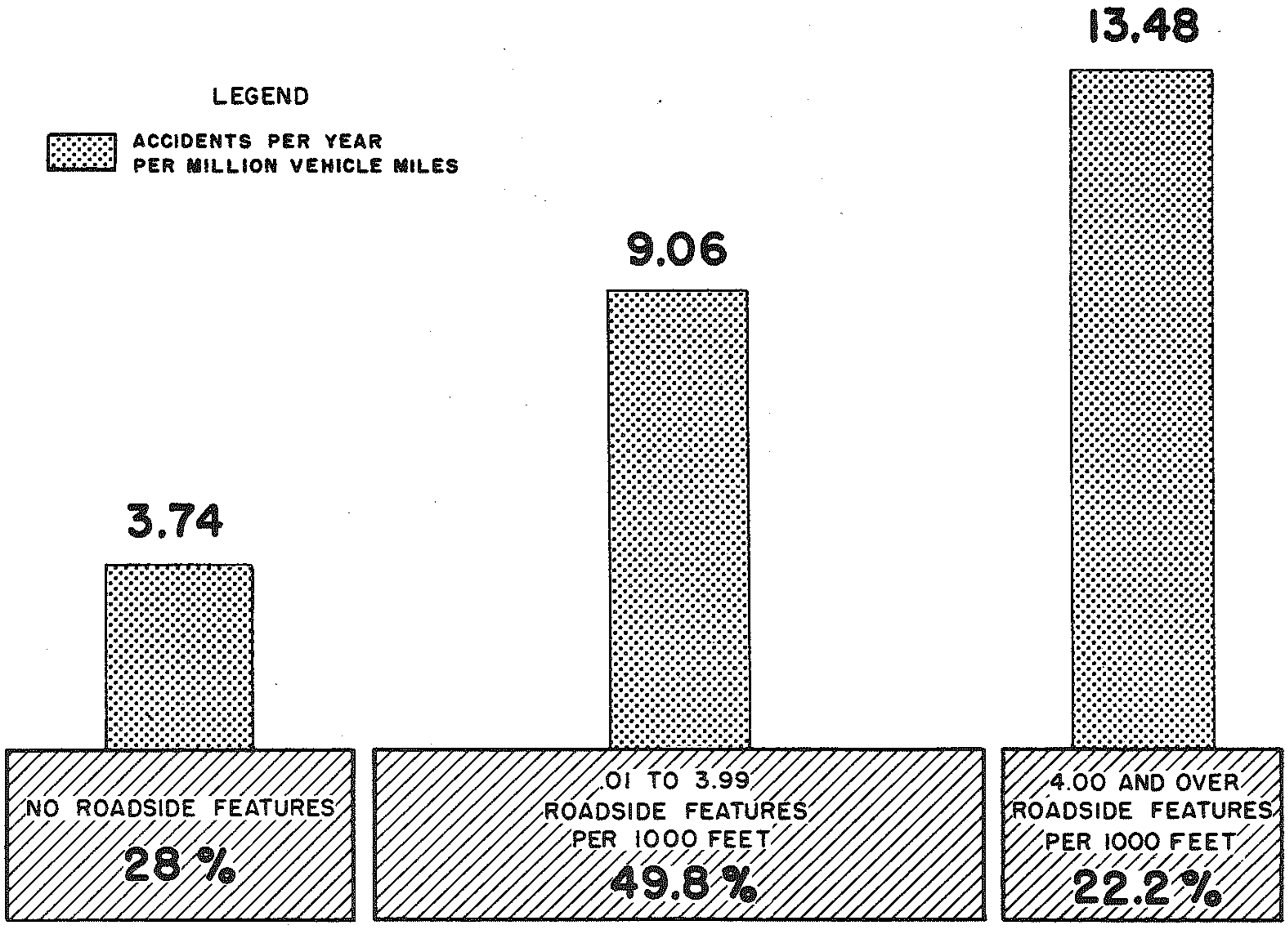

Figure 7

Comparison of accident rates per million vehicle miles in three groups of intersection sections in which the density of roadside features ranges from zero to more than 4 per 1000 feet. The heavy figures are the percentages of total intersection mileage in each group.

Table IX

Accidents per Unit of Distance by Number of Roadside Features 1/

Number of Roadside Features	Accidents per Unit of Distance		
	200-Foot Units	400-Foot Units	600-Foot Units
0	0.813	0.730	0.722
1	2.31	1.59	1.27
2	6.51	2.69	1.98
3	6.56	3.66	2.70
4	40.38	9.54	4.39
4 or more	51.11	14.33	8.78
5	111.00	14.94	10.31
6		24.30	13.24
6 or more		29.08	14.10
7		14.00	10.36
8 or more			20.67

1/ Less private drives.

Attention is called to the perfect consistency with which the number of accidents decreases as the unit of distance increases from 200 feet through 600 feet for a fixed number of roadside features. The implication of this is that the smaller the concentration of roadside features, the smaller will be the number of accidents.

Tables X and XI

Heretofore use has been made only of "total" correlations, whether single, multiple, or weighted average. A phase of correlation is now presented which is not too frequently used. It is called "partial" correlation.

It was recognized that in many of the foregoing analyses, the indicated degree of association of a feature with accidents might, in reality, include a reflection of the degree of association among the features themselves. In other words, certain of these correlation coefficients may well represent not only the association of an individual feature with accidents, but an accumulation of the association with accidents of other nearby features. For this reason it was desirable and necessary to segregate the association of each individual feature from the influence of other features.

Partial correlation was used for this purpose. It is a process by which the correlation of two variables is computed with the effect of other associated variables eliminated or held constant. To put it in another way, partial correlation measures the effect of one variable in its own right upon a second variable independently of the effect of third, fourth, or other variables which may be present in the field of study.

Partial correlations were computed for intersection and non-intersection sections between accidents and features in two ways. They were first computed for the individual roadside features and for private drives, design features, advertising signs, and vehicle miles. They were next computed for roadside features as a group and for the other factors and groups of features analyzed in the first partial correlation. It is believed that the partial correlation coefficients presented in these two tables constitute the best and most unbiased relative measure of the association between accidents and features obtainable from the data collected for this study.

There are slight variations in the partial correlation coefficients in the two tables, but in no case do these differences significantly affect the indications of the figures. These figures show that the greatest contribution to accidents, especially in the intersection sections, comes from Taverns. Other substantial contributions to accidents are made by Gas Stations and Commercial Garages in intersection sections, and by Other Establishments and Vehicle Miles in non-intersection sections.

Taverns have the highest partial correlation coefficient of any features in both kinds of sections. It is significant that Gas Stations and Commercial Garages make a much greater contribution to the occurrence of accidents in the sections where are concentrated most of the intersections; these stations are normally located at these points. The high partial correlation of accidents with Vehicle Miles in the non-intersection sections indicates the pure effect of exposure to high traffic volumes such as are encountered on the study road. (Figure 8)

It is clear that Stores and Restaurants make very little or no contribution to the occurrence of accidents, and that Advertising Signs have practically no effect whatever on the accident experience of this road. It is indicated that in intersection sections, Private Drives not only are not causes of accidents, but may actually contribute to preventing them; perhaps the presence of a number of private drives induces drivers to exercise a little added caution.

Table X

Partial and Total Correlation Coefficients of Accidents with Each of Five Types of Roadside Features, Private Drives, Design Features, Advertising Signs and Vehicle Miles for Non-Intersection and Intersection Sections

Features Correlated with Accidents	Non-Intersection Sections		Intersection Sections	
	Total	Partial	Total	Partial
Taverns	.313	.332	.698	.460
Gas Stations and Commercial Garages	.442	.144	.666	.365
Stores	.321	-.047	.526	.166
Restaurants	.438	.212	.651	-.026
Other Establishments	.443	.302	.720	.131
Private Drives	.513	.265	.264	-.132
Design Features 1/	.303	.226	.285	.122
Advertising Signs	.557	-.066	.712	.002
Vehicle Miles	.680	.444	.720	.256

1/ Except grade separations, piers and abutments.

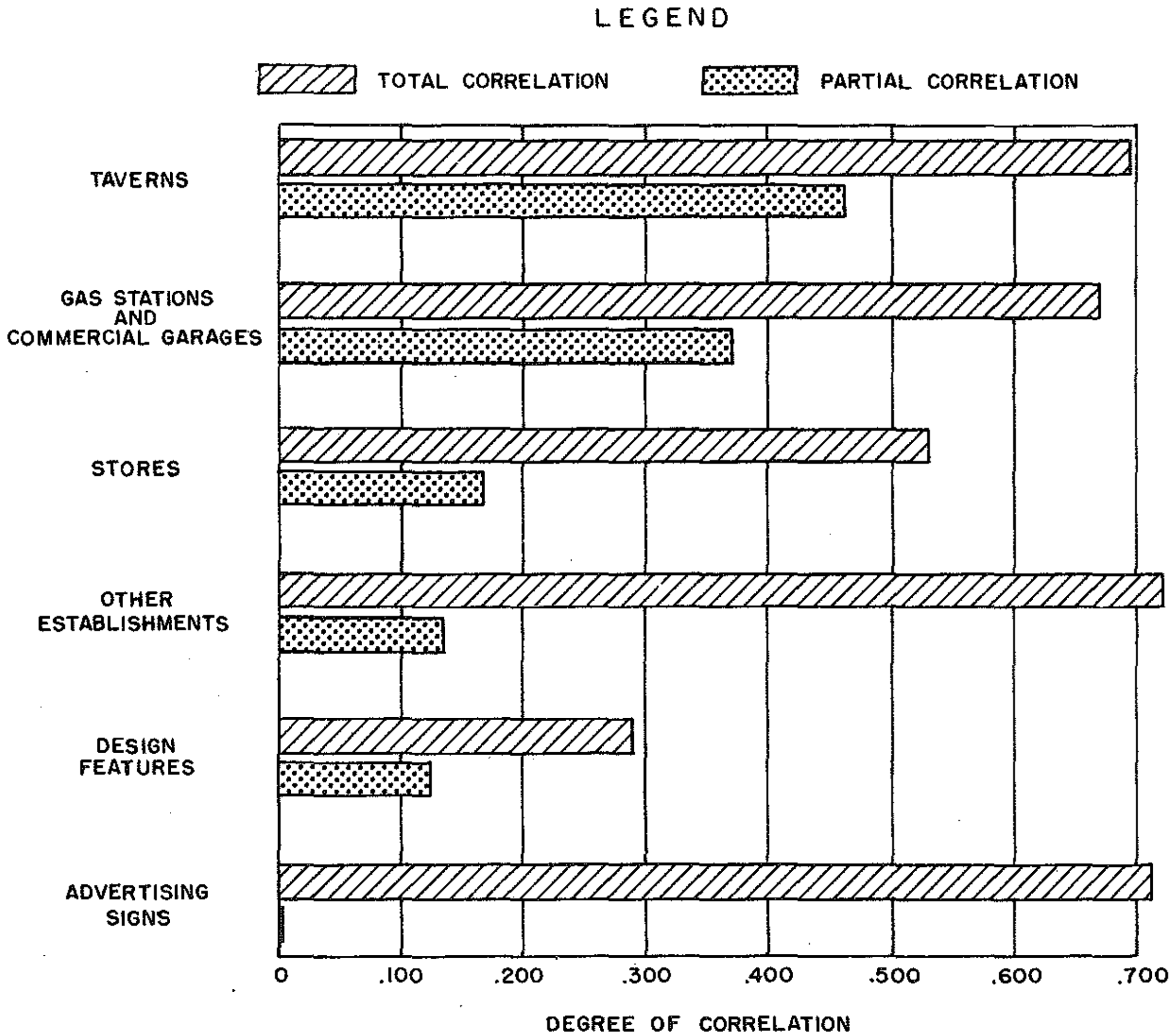

Figure 8

Graphic comparison of coefficients of total and partial correlation of various features with accidents.

The magnitude of the differences between the total coefficients and the corresponding partial coefficients in both these tables has only one meaning. It is an indication of the extent to which the association of accidents with a particular feature is inflated by the association of the accidents with the other features and by their association with each other.

Table XII

There is another viewpoint from which the association between accidents and features may be considered. That is the amount of variation, or variance, in the number of accidents in the various sections. These numbers range from zero to approximately 100. Obviously the distribution of accidents among sections depends to some extent upon the relative length of the sections, but it also depends on other factors such as have been considered in the partial correlation.

By means of an analysis of the variances, it was possible to compute the percentage contributions of various types of features to the total variance of the numbers of accidents in the several sections. This was done for five types of features and the derived percentage contributions are shown in Table XII.

Two points in this table require explanation. The first is the negative contribution of Private Drives in the intersection sections. This arises from the fact that accidents and Private Drives are negatively correlated while all the other types of features are positively correlated. The second point is the contribution assigned to Other Features Not Studied. These include such factors as weather, surface conditions, surface type, surface width, speeds of vehicles, composition of traffic, light conditions (daylight or darkness), driver ability, driver personality, etc.

This table indicates that the features analyzed in this study account for 63 percent of the variation in the number of accidents among non-intersection sections, and for 71 percent of the variation among intersection sections. The relatively large contribution indicated for Vehicle Miles is explained by the fact that this factor is representative not only of traffic volumes but approximately of section length.

Accidents and Intersections

It is interesting and instructive to examine the accidents which were the basic data for this study. During the three year period, 1947-49, a total of 3,025 usable accident reports were recorded on the study road. About 3 percent were fatal accidents, 30 percent were personal injury, and 67 percent were property damage accidents. This is not far from normal distribution as to severity, but the over-all accident rate of 3.8 is high; in fact, it is something more than double the rate for the Michigan rural trunkline system as a whole.

The 378 accidents which definitely involved ingress to or egress from roadside features, are specially pertinent to this study. These represent 12.5 percent of all accidents on the road. Two-thirds of them involved in-and-out movements at commercial establishments. It appears that turning off the highway to a roadside feature is about twice as hazardous as coming on. Nearly half the entering accidents were rear-end collisions.

These facts give some little indication of the disorganizing effect of a considerable density of business activity on the margin of a heavily traveled trunkline artery. Some measure of separation between these activities and the arterial movement is clearly indicated as a logical remedy.

Table XII

Percentage Contributions of Features To
Total Variance of Numbers of Accidents Among Sections

Type of Feature	Percentage Contributions Non-Intersection Sections %	Intersection Sections %
Total Roadside Features	21	45
Private Drives	9	- 3
Design Features	5	2
Advertising Signs	2	8
Vehicle Miles	26	19
Other Features Not Studied	37	29
Total	100	100

Possibly the most significant fact revealed by this analysis of the accident data, is that 37 percent of the accidents occurred at intersections and almost 60 percent within 100 feet of intersections.

This marked concentration of traffic conflicts at these points, may be due in large degree to the location of a long section of the study road across the western edge of the Detroit metropolitan area. This location makes it necessary for its own heavy traffic to pass squarely across the paths of the large traffic movements to and from the metropolis' western suburbs and on the several major trunklines from the city westward to outstate and interstate points.

Of course, other and probably equal influences are the clusters of commercial establishments which commonly develop about each of these important crossroads points. Unquestionably this coincidence of so many features, such heavy streams of intersecting traffic, and so many accidents at these intersection locations has a strong biasing effect on the operation of this or any statistical method for determining what features are associated with accident occurrence.

It needs to be pointed out that these findings are significant only in respect to the association of these various features with accidents. Except insofar as accident occurrence may be considered an index of traffic confusion, they give only the slightest statistical indication of the effect of these roadside developments in disorganizing and delaying the movement on the roadway itself.

CONCLUSION

As was emphasized earlier in this report, the results of a study of this kind are bound to be of a general nature. The continuing analysis of data has provided further evidence of the seriousness of the accident hazards at intersections as compared with other portions of the highways. It indicates that these locations are approximately five times as hazardous as the sections between, and it gives further proof of the danger created by concentrations of roadside features around intersections.

In working toward the principal objective of the later phase of the study -- the segregation of intersections from the roadside features at intersections -- definite progress was made. It is now clear that the development of roadside establishments at these points intensifies the hazardous conditions.

These are findings which have importance in basic problems of highway planning and traffic operation. They point to the fact that every effort should be made to provide highway facilities in suburban areas which will protect the main streams of trunkline traffic from interference by the movements which are generated along the roadside. They indicate that intersections in particular require this sort of protection.

The study points with some precision to the relative importance of various kinds of features as factors in creating conditions in which accidents occur with greater than what we believe is normal frequency.

The use of the methods of partial correlation and variance analysis are interesting developments of the latter part of the study. The resulting indications regarding the particularly close association of specific types of features with accident occurrence are steps toward setting up definite cause-and-effect relationships in the accident field.

As has been pointed out, most of the findings substantiate conclusions which had been reached but which hitherto lacked clear statistical support. The validity of these conclusions now is soundly established by this study.

Due to the importance of the matters dealt with by these analyses, it at one time was planned to double the length of the study road and to expand the scope of the investigation. However, because of the nature of the study and of the methods employed, it has been concluded that a continuation of its operation would merely add supporting data to conclusions which already have been adequately substantiated. It has been decided, therefore, that this accident project, having served its purpose and attained its objectives, should be terminated. This, then, is the final report of this analysis of accident experience in relation to road and roadside features.