CORRELATION OF ACCIDENT
RATES AND ROADWAY FACTORS

JULY, 1957

NO. 27

by

JOHN C.H. WOO

Joint
Highway
Research
Project

PURDUE UNIVERSITY
LAFAYETTE INDIANA

Final Report

CORRELATION OF ACCIDENT RATES AND ROADWAY FACTORS

TO: K. B. Woods, Director
Joint Highway Research Project

July 24, 1957

FROM: H. L. Michael, Assistant Director

File: 8-5-3
Project No. C-36-59C

Attached is a final report entitled, "Correlation of Accident Rates and Roadway Factors," by John C. H. Woo, Graduate Assistant on our staff. This report has also been used by Mr. Woo as his thesis in partial fulfillment of the requirements for the degree of Master of Science. The study was approved by the Board on January 24, 1957, and was performed under the direction of Professor H. L. Michael.

The results of the statistical analysis of the correlation of accidents with certain roadway factors on the State Rural Primary System in Indiana indicate that there is a correlation of traffic volume, congestion index, number of entrances per mile and lane width with number of accidents per mile.

As another product of this study, a listing of the high accident locations on the State Primary System is being prepared and will also be submitted to the Board as information.

This report is presented for the record.

Respectfully submitted,

Harold L. Michael, Assistant Director
Joint Highway Research Project

HLM:hgb

Attachment

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by

John C. H. Woo
Graduate Assistant

Joint Highway Research Project
Project No. C-36-59C
File 8-5-3

Purdue University
Lafayette, Indiana

July 24, 1957

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Lastly, the author would like to acknowledge the assistance obtained from the personnel of the Joint Highway Research Project in collecting the data.

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ABSTRACT

The primary purpose of this study was to investigate the correlation between motor vehicle accidents and roadway factors in the State of Indiana. The roadway factors evaluated were annual average daily traffic volume, capacity, congestion index, number of lanes, lane width, shoulder width, horizontal alignment, and number of entrances per mile. The factor of number of lanes, however, was eliminated early in the study because of the predominant mileage of two-lane highways.

The accident rates used in the study were number of fatalities per mile, number of non-fatal accidents per mile, total number of accidents per mile and total number of accidents per one million vehicle miles on the State Rural Primary System for the two-year period, 1954 and 1955. Only non-intersectional accidents were used.

A total of 3,136 miles of the State Rural Primary System was divided into 987 subsections on the basis of homogeneity in the roadway factors. The number of accidents for non-intersectional fatal and non-intersectional non-fatal was obtained from accident spot maps of the Indiana State Police, and the roadway data were obtained from a Highway Needs Study inventory of each subsection.

The results of the analysis revealed that there were positive and linear relationships between annual average daily traffic volume, congestion index, lane width, and total number of entrances per mile with

total number of accidents per roadway mile for the two-year period, 1954 and 1955.

A regression equation was also developed in an attempt to predict the number of accidents per mile by the use of the four significant roadway factors.

CORRELATION OF ACCIDENT RATES AND ROADWAY FACTORS

INTRODUCTION

The tremendous toll of traffic accidents not only causes much suffering and misery, but it is also a waste of national resources. An average annual toll of 1,111 deaths, 34,386 injuries, and economic losses of \$129,653,000 in Indiana for the years 1954-1955 (20)* emphasizes a problem that requires an immediate solution.

There are three basic elements in an accident - the driver, the vehicle, and the highway; and there are three major accident preventative measures - education, enforcement, and engineering. While the driver element involves primarily the enforcement of traffic regulations and education and training, the highway and vehicle elements primarily involve engineering.

Obviously engineering cannot make roads accident proof, but emphasis should be placed on highway engineering that will increase safety for the average driver. A study of the relationship between roadway factors and accidents is a positive engineering step toward reducing highway accidents.

This study was of all highways in the Indiana State Rural Primary System, and it utilized highway inventory data and accident records of 1954 and 1955. By the punch-card technique all pertinent information such as highway identification, location, roadway factors and accident rates were tabulated for the analysis.

*Numbers in parentheses refer to the Bibliography

The following factors were analyzed in this study:

1. Annual average daily traffic volume: It is commonly believed that the number of accidents on a section of highway has a direct connection with traffic volume on that road and that this factor is often the most important one.
2. Capacity: Safe highways are considered by many to be adequate highways, and capacity is a major element in adequacy.
3. Congestion index: This is the ratio of the annual average daily traffic (ADT) volume to capacity of the road section.
4. Width of traffic lanes: Ten feet had been the standard width in many states prior to 1941, but the trend in recent years is to twelve feet or more.
5. Number of traffic lanes: On highways having multiple lanes the traffic can be separated by direction of movement. This may virtually eliminate one of the worst types of accident, the head-on collision.
6. Width of shoulders: Sufficient width could provide areas for use in unusual traffic situation or in the event of vehicle disability.
7. Horizontal alignment: This factor is important in an evaluation of passing and safe-stopping sight distances, and in recent years has been utilized in highway design for the relief of monotony in driving.
8. Number of entrance points: An increasing number of access points confronts the driver with an increasing number of interruptions and conflicts.

Through the cooperation of the Statistical Laboratory of Purdue University, simple correlation coefficients and a multiple correlation coefficient were calculated in order to determine the relationship between

the above roadway factors and the number of accidents, the inter-relationship between some of the roadway factors themselves, and the multiple relationship of these roadway factors to accidents.

PURPOSE

The purpose of this study was to investigate the correlation between motor vehicle accidents and certain roadway factors. An understanding of any relationship would provide information for the planning and design of safer highways.

PREVIOUS INVESTIGATIONS

This study is an outgrowth of the country-wide interest in the engineering aspects of highway accidents. This study is also a continuation of safety research by the Joint Highway Research Project. In previous research, Mr. John Joseph O'Hara in his thesis (16) for the degree of Master of Science in June, 1946, suggested methods of performing research in traffic safety. His suggestion to investigate "the variation of accidents with traffic volume" was incorporated in this study.

The Bureau of Public Roads (21) made an Interstate Highway Accident Study of five thousand miles of Interstate roads from information submitted by fifteen states covering one year's accident experience. The basic approach was similar to this study. That Interstate Highway Accident Study found that traffic volume had a strong effect on accident rate, but did not find any consistent effect with other roadway factors. Furthermore, the year of 1941, on which the study was based, presented entirely different driving conditions from what we have now.

Many states also have been active in trying to find some definite

relationship between roadway factors and accidents. A study by D.M. Belmont (5, 25) that investigated tangents and paved shoulders on two lane rural highways found that the accident rate tended to be higher on roads with shoulders wider than six feet if the traffic volumes were similar.

Paul K. Eckhardt and John C. Flanagan (9) also studied the effect of roadway elements in Pennsylvania Turnpike accidents, and concluded that roadway design was ahead of the driver and vehicle part of the system.

In 1949, the Michigan State Highway Department (13) reported the results of an accident analysis for 1948 and 1949. Although the study emphasized the importance of intersections and accidents, it was found to be difficult to analyze any relationship between individual features at intersections and accidents.

Adolph May (15) discussed the permanence of the operative characteristics of controlled and uncontrolled access highways and also found that access control had resulted in low accident rates on existing controlled access roads.

Ray E. Jorgensen (14) of the Connecticut State Highway Department reported that a comparison of accident rates on substandard highways in different traffic volume groupings showed that a great reduction in accidents would be made possible by the reconstruction of the State Highway System to adequate standards.

In recent years, Earl Allgair and Sam Yaksich of the American Automobile Association (1) investigated some of the factors related to traffic death rates by use of the statistical technique. The study attempted to determine the characteristics of the various states which were related

to the traffic death rates for 1952. The basic technique involved in predicting death rates for a future year was essentially the same as used in this research.

As has been noted, the previous research in this area has been limited in scope and has produced inconclusive results.

PROCEDURE

The National Safety Council (2) reported that three-fourths of the motor vehicle deaths in 1954 occurred on rural highways. Consequently, a study of main rural highways would account for a large number of accidents in the state.

In this study the analyses were based on the philosophy that the precise causes of an accident could not be positively determined. However, by an analysis of roadway factors on the entire Primary System, one might find a realistic picture of the extent of relationship between accident occurrences and the roadway factors. The roadway factors, however, are by no means the only causes of accidents.

In order to group the data according to those factors whose effects might be of significance, the whole Primary System was divided into representative subsections on the basis of homogeneity in the selected roadway factors. The detailed procedures and criteria used are shown in the following pages.

The number of accidents per million vehicle miles has been widely used as the representative accident rate. This rate and the number of accidents per mile were calculated for each subsection. By the use of the above two rates, it was hoped to find the better correlated accident rate.

Collection of Data

The data for the various roadway factors were obtained from the

highway inventory that was conducted for the study of State Highway Needs in Indiana by the Joint Highway Research Project.

Figure 1 is an example of the forms S-1 and S-2-R, the Rural State Highway Inventory Data Sheets, which were developed by the Joint Highway Research Project for the inventory. The data recorded were from a comprehensive survey of highway conditions, land use, and other data for the year 1955. This information was also placed on IBM punch cards by code numbers (see Figure 2).

In this study only the 3,136 miles of the rural State Primary System were used. This mileage was divided into 967 subsections, units of highway which were as nearly as possible homogeneous with respect to roadway factors. Subsection length varied from 0.5 miles to 14 miles with an average of 3.2 miles. The following were the main criteria and procedures used for developing the subsections:

1. The termini of a maintenance section should also be a termini for a subsection.
2. All subsections were numbered in a northerly or in an easterly direction within each maintenance section.
3. A subsection should terminate at each change from rural to urban section or vice versa.
4. Each subsection should be not less than 0.5 miles in length.
5. A subsection should terminate at each change from divided to undivided highway and vice versa.
6. A subsection should terminate at each change of 10% or more in traffic volume.
7. A subsection should terminate at points of change in pavement

FORM 5-1

[illegible]

FIGURE 2 IBM CARDS USED FOR TABULATING PURPOSES

width.

8. A subsection should terminate at a change in the number of traffic lanes.

To obtain the number of accidents for each subsection, Indiana State police provided large size Traffic Accident Maps of Indiana for 1954 and 1955. All accidents were shown as fatal or non-fatal and as intersectional or non-intersectional at their respective location. The non-fatal accidents included injury accidents and property damage accidents of \$50.01 or more.

By use of large district maps, each subsection was located on the accident map accurately, and the non-intersection accidents were counted by number and type. As a double check technique, all subsection lengths located on the accident map were checked against the mileage shown for that particular maintenance section on the district maps. All sections of highway that passed through towns were eliminated from consideration in this study because of the complex roadway features involved.

The number of non-fatal, fatal and total accidents for 1954 and 1955 were tabulated for each subsection of highway. A portion of this tabulation is shown in Figure 3. The accident information was then placed on IBM cards and the accident rates desired were calculated by machine. Although four accident rates were calculated, the accident rate finally used in this study was total accidents per mile for 1954 and 1955. This is the accident rate referred to in the following pages unless specifically stated otherwise.

For tabulating and analysis purposes, all subsections were grouped

into accident rate groups. They are as follows:

<u>Accident Rate Group</u>	<u>Total Accident Rate for 1954 and 1955</u>
1	0 - 1.9
2	2 - 2.9
3	3 - 3.9
4	4 - 4.9
5	5 - 5.9
6	6 - 7.9
7	8 - 9.9
8	10 - 13.9
9	14 and above

The subsections were also grouped into nine groups by annual average daily traffic volume. These groups are as follows:

<u>ADT Group</u>	<u>Annual Average Daily Traffic Volume</u>
1	0 - 999
2	1,000 - 1,999
3	2,000 - 2,999
4	3,000 - 3,999
5	4,000 - 4,999
6	5,000 - 5,999
7	6,000 - 6,999
8	7,000 - 7,999
9	8,000 and above

A series of multiple IBM card tabulating sheets was then prepared for each highway subsection from the various IBM cards with information as to identification, roadway factors, accident numbers and accident rates. A sample for each type of multiple IBM tabulating sheet for the number of accident occurrences by subsection with all pertinent information grouped by annual average daily traffic volume, all pertinent information grouped by accident rate and all pertinent information by the sequence of rural primary highways is shown in Figures 4, 5, and 6 respectively.

As an aid to a better understanding of the procedure, the information listed by column in Figure 6 is further detailed as follows:

A. Identification

1. Route designation and highway number (State Rural Primary System only).
2. Maintenance section designation by alphabetical symbols as given on the Road Section Maps of the Indiana State Highway Department.
3. Subsection designations by number which were determined by evaluation of the homogeneity of roadway factors.
4. State Highway District Numbers: There are six district numbers as follows:

Crawfordsville	1
Fort Wayne	2
Greenfield	3
LaForte	4
Seymour	5
Vincennes	6

Route	Maintr. Lftr	Maintr. Number	County	Section Length	ADT	Capacity	Congestion Index	# of Lanes	Lane Width	Shoulder Width	Horiz. Align.	Total Entrances	Entrances Per Mile	Rate 1 Non Fatal	Rate 1 Fatal	Rate 1 Total	Rate 2	ADT Group
2026	A	1	86	27	560	4600	12	2	9	3		10	37	15		15	37	
2026	A	2	86	52	560	4600	12	2	9	3		20	38	12		12	29	
2028	C	1	79	45	620	5200	12	2	10	6		39	87	4		4	10	
2028	C	2	79	63	620	5200	12	2	10	10	2	55	87	13		13	29	
2028	N2	1	18	29	720	4100	18	2	9	7	2	35	121	7		7	13	
1036	M2	1	48	10	870	4800	18	2	9	3		11	110	30		30	48	
1036	M2	2	48	31	870	4300	18	2	9	3		47	152	16		16	26	
2037	A	4	62	10	800	1700	47	2	9	6	1	12	120	10		10	18	
2037	B	1	62	116	750	3000	25	2	10	6	3	86	74	17	3	20	37	
2054	E1	1	28	110	690	3700	19	2	9	8	3	128	116	27	2	29	59	
2054	E2	2	28	32	770	3400	23	2	9	8	2	19	59					
2054	F	1	47	34	590	3400	17	2	9	8	2	15	44	3		3	7	
2062	G	1	39	71	700	4500	16	2	11	11		81	114	21		21	42	
2063	G	2	83	53	930	4800	19	2	9	3	2	56	106	23		23	34	
2063	G	3	83	11	930	4800	19	2	10	3	2	4	36					
2063	J	2	86	60	370	5200	7	2	10	10		16	27	7	2	8	32	
2101	U	1	24	80	810	5000	16	2	10	9	2	45	56	11		11	19	
2101	E1	1	81	54	810	5000	16	2	10	9	2	36	67	2		2	3	
2131	A	1	10	13	610	2200	26	2	10	5		28	215	38		38	89	
2154	A	1	77	57	680	5200	13	2	9	6	3	43	75	2		2	4	
2154	B	1	77	82	620	4800	13	2	11	8	2	84	102	10	1	11	25	
																		N=21

FIGURE 4 MULTIPLE IBM CARD TABULATING SHEET WITH ALL PERTINENT INFORMATION, GROUPED BY ADT

ROUTE	MAINT. LETTER	MAINT. NUMBER	COUNTY	SECTION LENGTH	ADT	CAPACITY	CONGESTION INDEX	# OF LANES	LANE WIDTH	SHOULDER WIDTH	HORIZ. ALIGN.	TOTAL ENTRANCES	ENTRANCES PER MILE	RATE 1 NO-FATAL	RATE 1 FATAL	RATE 1 TOTAL	RATE 2	ACCIDENT RATE GROUP
1002	C	1	54	9.1	11450	4000	287	2	10	6	2	97	10.7	13	1	14	2	1
1003	E	1	40	1.2	12400	3200	390	2	9	3	2	16	13.3	17		17	2	
1003	I	1	35		4300	7300	55	2	14	4		7	35.0					
1009	E	1	45	3	4100	3500	63	2	12	11		6	20.0					
1007	I	1	3	1.3	2000	5200	50	2	10	7	2	14	14.0					
101	E	2	27	30	2000	4500	49	2	10	9	2	20	6.7	7	3	10	6	
1010	L	1			1000	3000	33	2	10	9		20	46.7	17		17	12	
1011	I	1	32	1.3	1000	5000	33	2	10	4		30	10.7	14		14	11	
101	I	3	32	3.0	1000	4000	31	2	10	10	1	49	7.0	10		10	9	
101	I	3	32	3.0	1000	4000	40	2	10	10	2	21	10.5	5		5	4	
101	I	4	29	1.1	1000	3500	36	2	10	10	1	14	12.7	9		9	8	
101	I	3	31	3.4	1000	3100	43	2	10	3	1	28	5.2	15		15	15	
101	I	5	27	1.4	1000	5000	22	2	11	11	2	55	9.2	18		18	16	
101	I	1	27	2	1700	5900	23	2	11			47	78.3	17		17	14	
101	I	7	27	1.3	1700	4500	34	2	10	3		26	20.0	8		8	6	
1024	I	2	56	4	3100	5500	48	2	12	6		1	25					
1024	I	3	56	9	3300	6500	51	2	12	6		16	17.8	11		11	5	
1024	I	4	37	1.1	3000	5500	60	2	12	6		6	5.5	18		18	6	
1025	I	9	5	1.7	2000	4800	46	2	9	8	2	5	2.9	6		6	4	
1025	F	3	9	1.4	2000	4800	60	2	9	8	2	21	11.1	16		16	8	
1025	I	5	25	50	4000	5400	91	2	12	6	2	42	8.4	8		8	2	
1025	A	1	56	2.7	3600	4600	12	2	9	3		10	3.7	15		15	3.7	
1025	A	2	56	5.2	5600	4600	12	2	9	3		20	3.8	12		12	2.9	
1027	U	5	89	3.3	2200	4400	50	2	9	5	2	19	5.8	12	3	15	10	
1027	K	5	1	5	3000	5600	70	2	11	11		4	8.0					
1028	A	1	86	7.5	1300	4800	27	2	10	10	2	43	5.7	11	1	12	13	
1029	91	2	23	3.1	2200	5200	42	2	10	10	2	11	3.5	6		6	4	

FIGURE 6 MULTIPLE IBM CARD TABULATING SHEET WITH ALL PERTINENT INFORMATION, GROUPED BY TOTAL ACCIDENT RATE

Rd	MAINT. Sec.	# MAINT.	DISTRICT	LENGTH IN Miles.	COUNTY	ADT 1955	CAPACITY	CONGESTION INDEX	# OF LANE	AVERAGE LANE WIDTH	SHOULDER WIDTH	HORIZ. ALT.	TOTAL ENTRANCES	RATE 1 Non-Fat.	RATE 1 FATAL	RATE 1 TOTAL	RATE 2 TOTAL
2001	0	1	2	.9	90	5200	5900	.88	3	10	9		65	8.9		8.9	2.4
2001	0	2	2	5.4	90	3700	6800	.54	3	10	9		64	4.6	.2	4.8	1.8
2001	0	3	2	2.8	90	3800	7500	.51	3	10	9		41	2.5		2.5	.9
2001	0	5	2	2.4	90	3600	6800	.56	3	10	9		54	3.8		3.8	1.4
2001	P1	1	2	3.7	2	4000	7500	.53	3	10	11		34	2.4		2.4	.8
2001	P2	1	2	2.7	2	4700	7500	.63	3	10	11	2	32	5.6	.4	5.9	1.8
2001	P2	3	2	1.7	2	13600	5900	2.31	3	10	11	2	73	26.5	.6	27.1	2.8
2002	C	1	4	9.1	64	11490	4000	2.87	2	10	6	2	97	1.3	.1	1.4	.2
2002	C	2	4	4.4	64	12240	4000	3.06	2	10	6	2	87	3.0	2	3.2	4
2002	D	1	4	4	64	3100	2700	1.15	2	10	5	2	17	5.0		5.0	2.3
2002	D	2	4	1.8	64	12860	1500	8.57	2	10	3	3	53	3.3		3.3	4
2002	U	3	4	6.0	64	12490	1500	8.33	2	10	3	3	102	3.7		3.7	4
2002	E	1	4	1.2	46	12490	3200	3.90	2	9	3	2	16	1.7		1.7	2
2002	E	2	4	9	46	13240	4800	2.76	2	10	4	2	12	4.4		4.4	5
2002	E	3	4	2.2	46	13240	3500	3.78	2	10	11	2	42	5.9		5.9	6
2002	E	4	4	3.1	46	13600	3500	3.89	2	10	11	1	31	6.5	3	6.8	7
2002	E	5	4	4.0	46	14650	4000	3.66	2	10	11	2	55	4.8		4.8	4
2002	F1	1	4	3.3	46	16700	3900	4.28	2	10	11	2	81	10.0		10.0	8
2002	F1	2	4	1.2	46	15700	3100	5.06	2	10	11	2	27	5.0		5.0	4
2002	F1	3	4	1.4	46	5700	2400	2.38	2	10	11		24	10.7		10.7	26
2002	F1	4	4	3	46	14850	5600	2.65	2	11	11	3	1	23.3		23.3	22
2003	G	1	5	7.4	16	4200	4800	.88	2	10	9	2	117	3.9		3.9	13
2003	H	1	3	3.0	70	2900	4500	.64	2	10	11	2	12	7.0		7.0	3.4
2003	H	2	3	2.2	70	2900	3500	.83	2	10	11	2	14	4.5		4.5	2.2
2003	H	3	3	4.2	70	3300	4800	.69	2	10	11	2	37	6.7	2	6.9	2.9
2003	H	4	3	1.7	70	4200	4000	1.05	2	10	11	2	23	2.9		2.9	1.0
2003	J	1	3	1.1	70	3600	3500	1.03	2	10	6		9	14.5		14.5	5.7
2003	J	2	3	7.1	70	3100	5200	.60	2	10	9		46	5.5	1	5.6	2.5

FIGURE 6 MULTIPLE IBM CARD TABULATING SHEET WITH ALL PERTINENT INFORMATION BY SEQUENCE OF RURAL HIGHWAYS

5. Length of subsection to the nearest one-tenth of a mile.
6. Ninety two counties in Indiana have been coded alphabetically from 01 to 92.

B. Roadway Factors

1. ADT (annual average daily traffic volume) was taken from State Highway Department Traffic Flow Maps for 1955.
2. Capacity was computed following the concepts of the Highway Capacity Manual, U. S. Department of Commerce, 1950.
3. Congestion Index was computed by dividing ADT by capacity.
4. Number of travel lanes.
5. Average lane width was found by dividing the surface width by number of lanes.
6. Width of shoulder on right side to nearest foot.
7. Horizontal alignment was coded as follows: (a non-critical was one that did not necessitate a reduction in normal speed).

<u>Frequency of Curves</u>	<u>Code</u>
None	0
One curve, non-critical	1
Two to continuous curves, non-critical	2
Continuous curves less than one-half critical	3
Continuous curves, more than one-half critical	4

8. Total number of entrances on left and right divided by the subsection length.

C. Accident Rates

1. Accident rate 1: the number of non-fatal accidents per mile for 1954 and 1955.
2. Accident rate 1: the number of fatal accidents per mile for 1954 and 1955.
3. Accident rate 1: the number of total accidents per mile for 1954 and 1955.
4. Accident rate 2: the number of accidents per one million vehicle miles for 1954 and 1955.

Formula used:

$$\frac{(\text{Total number of accidents for 1954 and 1955}) \times (1,000,000)}{(\text{Subsection length}) \times (\text{ADT}) \times (365 \times 2)}$$

From the tabulation of highways by their sequence number, an accident rate map, Figure 7, was developed showing 1954 and 1955 non-intersectional traffic accidents per mile on the rural Primary System of Indiana.

Examples of some of the subsections with the high and low accident rates per mile are shown in the photographs of Figures 8, 9, 10 and 11.

FIGURE 7

Figure 8. An example of a Highway from the Highway Building, Lake Group (11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100).

Figure 9. A Second Example of a Highway from the Highest Accident Rate Group (14 and above). Accident rate of 22.0; note numerous roadway entrances and curve.,
(SR 25, Subsection C2)

Figure 10. A Third Example of a Highway from the Highest Accident Rate Group (14 and above). Accident rate of 35.0; note combination of steep curve and roadside interferences from the shopping center.
(SR 43, Subsection K3)

Figure 11. An Example of a Highway from the Lowest Accident Rate Group (below 2). Accident rate of 0.3; note wide road with excellent visibility and absence of entrances. (SR 28, Subsection C1)

ANALYSIS OF THE DATA

Preliminary analysis pointed out clearly the magnitude of data involved and the similarity between 1954 accident occurrence and 1955 accident occurrence (see Table 1). It is very interesting to note the same number of fatal accidents for 1954 and 1955 on the subsections of this study. The percent of difference in total accident occurrence from 1954 to 1955 was only 1.7 percent.

The average non-intersection accident occurrence per year was 2.47 non-fatal per mile, 0.06 fatal per mile, and 2.52 total accidents per mile on the Rural State Primary System.

The extent of the close relationship between 1954 and 1955 accident occurrence can be expressed by a simple correlation coefficient as positive 0.86 as shown in Table 2. This similarity is further visualized by the accident occurrences on typical sections of highways shown on Figure 12.

When tabulated by accident group (see Table 3), accident rate groups 1 and 2 had the greatest mileage, 1,042 miles or 33% of the total mileage. On the contrary, the highest accident rate group, group 9, consisted of 254 miles or only 8% of the total length.

It was observed that the mean of ADT, capacity, congestion index, lane width, and total entrances per mile increased as the accident rate increased.

There appeared to be some systematic trend between accident rate

Table 1
Number of Accident Occurrences

<u>Number of Subsections</u>	<u>Total Length</u>	<u>Non-fatal Accidents</u>	<u>Fatal Accidents</u>	<u>Total Accidents</u>
987	3,136 Miles	7661 (1954) <u>7794 (1955)</u>	183 (1954) <u>183 (1955)</u>	7844 (1954) <u>7977 (1955)</u>
		15455 (Total)	366 (Total)	15821 (Total)

Ratio of non-fatal to fatal accidents: 42 to 1.

Table 2

Simple Correlation Coefficient Between
1954 and 1955 Accident Occurrence

	<u>1954</u>	<u>1955</u>
Total Accidents	7844	7977
Mean of Accidents per Subsection	7.95	8.08
Standard Deviation	8.71	8.53

Simple Correlation Coefficient = 0.862

Standard Error of Estimate = 4.6

SUBSECTIONS OF SR 30 & 31 (50.7 MILES)
 TYPICAL RELATIONSHIP BETWEEN ACCIDENT OCCURRENCE
 OF 1954 AND 1955 AT THE SAME SUBSECTIONS

FIGURE 12

Table 3

Mean Value of Roadway Factors by Accident Rate Groups

Accident Rate Group	Group Range	Number of Subsections	Mileage	Percent Total	ADT	Mean Value					Entrances Per Mile
						Capacity	Congestion Index	Lane Width	Horizontal Alignment	Shoulder Width	
1	0-1.9	166	519.9	16.58	2600	4600	0.62	10.5	7.5	1.2	13.0
2	2-2.9	142	521.7	16.64	3200	4700	0.73	10.7	8.4	1.2	10.9
3	3-3.9	119	412.6	13.16	3400	4600	0.90	10.6	7.8	1.3	13.1
4	4-4.9	109	409.7	13.07	3800	4900	0.85	10.7	7.9	1.4	14.8
5	5-5.9	96	332.7	10.61	4000	4900	0.89	10.8	8.0	1.3	13.7
6	6-7.9	148	469.8	14.98	4200	4800	0.97	10.9	8.2	1.3	15.0
7	8-9.9	74	237.1	7.56	4800	5000	1.13	10.8	8.2	1.5	19.0
8	10-13.9	75	168.4	5.81	5500	5100	1.38	10.9	8.2	1.5	21.0
9	14 and above	58	62.8	2.29	7700	6300	1.72	11.7	8.7	1.2	29.0
Total		987	3135.7	100.0							

groups and increase of ADT. A study of the variation of ADT within accident rate groups revealed that the lowest rate group consisted primarily of roads with an ADT 560 to 4900 with a few higher volumes. The highest accident group had a range of ADT 1400 to many with a volume of 10,000 or more.

When tabulated by ADT groups (see Table 4), the data showed that the means of accident rate, capacity, congestion index, lane width, and total number of entrances per mile increased as the ADT increased. Particularly, accident rate increased by an increment of 1.3 accidents per mile as the ADT increased by 1000 between groups 1 through 7. Generally, congestion and capacity showed some direct relationship with ADT. The total number of entrances per mile also indicated a fairly good relationship with ADT but no such systematic trend appeared as for the accident rate.

The mean of lane width increased irregularly as ADT increased. There were no definite trends for shoulder width and horizontal alignment. It was noted that the traffic volume of 2000 to 5000 comprised more than one-half of all accident rates and total mileage.

Investigation of the variation of accidents within each ADT group revealed that the lowest ADT group had a range of 0 to 3.8 accident rate, whereas the highest ADT group had a range of 1.7 to 46.3 and an exceptional rate of 165.0.

Table 4

Mean Value of Roadway Factors by ADT Groups

ADT Group Group Range	Number of Subsections	Percent of Total Mileage	Number of Total Accidents	Percent of Total Accidents	Acci- dent Rate City Index	Mean Value			Total Entrances per Mile		
						Conges- tion Index	Shoul- der Width	Horiz- ontal Alignment			
1 0-999	21	104.6	144	0.91	1.3	4500	0.16	9.4	6.4	1.3	8.6
2 1,000-1,999	93	348.4	866	5.47	2.6	4200	0.39	10.2	7.1	1.3	12.3
3 2,000-2,999	242	797.9	2656	16.79	3.7	4500	0.63	10.6	7.3	1.3	12.9
4 3,000-3,999	250	844.3	4094	25.68	5.2	4800	0.78	10.7	8.0	1.4	13.5
5 4,000-4,999	179	501.9	3285	20.78	6.5	5000	1.0	11.0	8.6	1.3	15.0
6 5,000-5,999	72	213.8	1639	10.36	8.5	5900	1.2	11.1	8.2	1.5	18.5
7 6,000-6,999	43	122.4	1074	6.79	10.0	5700	1.5	10.6	10.0	1.3	18.6
8 7,000-7,999	37	92.7	866	5.47	8.7	5000	1.7	11.1	9.4	1.1	26.1
9 8,000 and above	51	111.3	1194	7.55	16.6	6200	2.8	11.8	8.6	1.3	31.1
Total	987	3135.7	15821	100.00							

Study of Simple Correlation Coefficients

This part of the study was made to determine the relationship between individual roadway factors and the accident rate.

Table 5 shows the simple correlation coefficients between eight roadway factors and four types of accident rates. The correlation coefficients measure how closely the points plot along a line. Because of a large amount of data the statistical laboratory obtained summation figures such as the sum of squares and the sum of cross products between roadway factors and accident rates by mechanical methods. The detailed mathematical technique is described in Appendix A.

In the investigation of the correlation with fatal accidents, ADT showed the strongest relative strength in the positive trend. The horizontal alignment showed the highest numerical strength in the negative trend, indicating there were less fatal accidents as the curvature increased. It should be noted, however, that the evaluation of horizontal alignment was difficult and on the basis of quantity of curves. The rest of the factors showed very little effect on the fatal accidents.

As for the non-fatal accidents, the relationship of the roadway factors to accident rates were all in a positive direction. ADT and congestion index showed the strongest relationship. On the contrary capacity, shoulder width and horizontal alignment showed very little relationship compared to other factors: their effects were approximately one twentieth of the ADT and one fifth of the effect of lane width and total entrances per mile.

Table 5
Simple Correlation Coefficients Between Roadway Factors
and Accident Rates - Ungrouped Data

<u>Roadway Factors</u>	<u>Non-fatal</u>	<u>Fatal</u>	<u>Total Accidents</u>	<u>Total Accidents Per Million Vehicle Miles</u>
ADT	0.466	0.192	0.471	-0.053
Capacity	0.081	0.066	0.083	-0.076
Congestion Index	0.429	0.067	0.431	0.048
Number of Lanes	0.171	0.065	0.173	0.025
Lane Width	0.139	0.051	0.201	0.014
Shoulder Width	0.027	0.090	0.024	-0.058
Horizontal Alignment	0.025	-0.34	0.024	0.053
Total Number of Entrances Per Mile	0.166	0.016	0.239	-0.023

The relationship between total accident rate and roadway factors was about the same as for non-fatal accidents; however, lane width and total entrances per mile improved in their relationship. From the results shown in Table 5, the accident rate per million vehicle miles was eliminated from further analysis because of too little correlation with roadway factors. Because of very few fatal accidents compared to non-fatal accidents, it was also decided to use only total accident rate per mile for further analysis.

At this stage, ADT, congestion index, lane width, and total entrances per mile were chosen to be significant factors with total accident rate.

To test the hypothesis of linearity of regression, an analysis of variance technique was used to test whether or not the mean for each group was located on a straight line. The detailed technique is described in Appendix B, Figure 1B.

Figure 13 shows the scatter diagram for ADT versus total accidents per mile and its regression line. Figure 14 shows the scatter diagram for congestion index versus total accidents per mile and its regression line.

The result of F-tests revealed that the hypothesis of linearity was reasonable for the significant factors. The detailed techniques used in this analysis are described in Appendix B. Thus, the correlation coefficients for ADT, congestion index, lane width and total entrances per mile shown in Table 5 for total accident rate were verified and found to be acceptable.

Because the majority of State Rural Primary highway consist of two

FIGURE 13 SCATTER DIAGRAM AND REGRESSION LINE BETWEEN ADT AND ACCIDENT NUMBER PER MILE

FIGURE 14 SCATTER DIAGRAM AND REGRESSION LINE BETWEEN CONGESTION INDEX AND ACCIDENT NUMBER PER MILE

lane (97% of highways in this study were classified as two lane), further analysis excluded any other than two lane highways. It was believed that the multiple lane highways presented entirely different facilities.

Table 6 shows re-calculated simple correlation coefficients for two lane highways only between roadway factors and total accidents per mile. There was no appreciable change from the correlation coefficients shown in Table 5. It was noted that capacity improved in relationship while other factors showed a slight decrease. However, overall trends were not changed in any way. Also, tests for the linearity were made as described in Appendix B and it was found that the selected significant roadway factors were linear with the total accident rate.

Study of Data Grouped by ADT

The simple correlation coefficients between the significant roadway factors and accident rate were calculated for the various ADT ranges in order to refine those relationships which were found in the ungrouped data.

Table 7 shows the results of correlation coefficients for the 9 ADT ranges. The study of these correlation coefficients revealed that ADT and entrances per mile showed not only positive correlation with total accident rate in all ADT ranges but also they showed the same trend in the variability of their strength. This analysis indicates that the accident occurrences were most related to the ADT and total number of entrances per mile when the traffic volume was the lowest. Quite good correlation was also noted for ADT Groups 8 and 9 for total entrances

Table 6

Simple Correlation Coefficients Between Roadway Factors and
Total Accident Rate for Two Lane Highways

<u>Roadway Factors</u>	<u>Simple Correlation Coefficient</u>
ADT	0.426
Capacity	0.100
Congestion Index	0.425
Lane Width	0.188
Shoulder Width	0.012
Horizontal Alignment	0.027
Entrances Per Mile	0.194

Table 7

Simple Correlation Coefficients Between Roadway Factors
and Total Accident Rate by ADT Groups

<u>ADT Group</u>	<u>ADT Range</u>	<u>ADT</u>	<u>Congestion Index</u>	<u>Lane Width</u>	<u>Entrances Per Mile</u>
1	0 - 999	0.54	0.20	0.02	0.67
2	1,000 - 1,999	0.11	0.29	0.44	0.06
3	2,000 - 2,999	0.19	0.18	-0.03	0.15
4	3,000 - 3,999	0.08	0.03	-0.03	0.20
5	4,000 - 4,999	0.08	0.08	-0.04	0.01
6	5,000 - 5,999	0.04	0.07	0.05	0.05
7	6,000 - 6,999	0.30	-0.03	-0.19	0.12
8	7,000 - 7,999	0.15	-0.04	-0.05	0.78
9	8,000 and above	0.23	0.28	0.33	0.20

per mile and ADT with accident rate.

Lane width shows some important relationship in ADT group 2 and 9, but the relationship became negative for the traffic volume range of 2,000 to 8,000, indicating that less accidents could be expected on roadways with wide lanes for these volumes. However, when the traffic volume exceeded 8,000 or was below 2,000, the accident occurrences increased with wide lanes.

Congestion index also manifested some positive relationship when the ADT was low or high, and there was some negative relationship when the volumes were between 6,000 and 8,000.

Multiple Correlation Coefficient

In order to measure the association of accident rate with the four significant roadway factors simultaneously; the multiple correlation coefficient was calculated from the simple correlation coefficients between roadway factors and accident rate that are shown in Table 7, and inter-correlation coefficients between the roadway factors that are shown in Table 8.

These inter-correlation coefficients show that the relationship between ADT and congestion index was very strong. The lane width and total entrances per mile show the strongest relationship indicating that as the lane width was increased the total number of entrances also increased proportionally. Most other relationships demonstrated some significance although congestion index shows very little relationship with lane width.

By the method of Doolittle Solution, the multiple correlation

Table 8

Inter-correlation Coefficients Between Roadway Factors

ADT vs Congestion Index	0.74
ADT vs Lane Width	0.24
ADT vs Entrances Per Mile	0.28
Congestion Index vs Lane Width	0.06
Congestion Index vs Entrances Per Mile	0.28
Lane Width vs Entrances Per Mile	0.75

coefficient squared, multiple correlation coefficient, Beta coefficients and multiple regression equation were developed. The detailed technique is described in Appendix C.

The multiple correlation coefficient (0.4734) indicates the proportion of the sum of squares of the accident rate which was explained by the multiple regression equation. The calculation shows that about 22% ($R^2 = 0.22413$) of variance in the total accident rate on two lane highways of this study was attributed to the four significant roadway factors.

Table 9 shows the Beta coefficients in the multiple regression equation. These coefficients measure the relative importance of the roadway factors in the multiple regression equation. It was noted that the congestion index played a major role in predicting the number of accidents in this particular equation.

Percent of Error in Prediction

In order to check the accuracy of the regression equation in predicting the number of accidents, the accident occurrences for 1953 and 1956 were deployed against the predicted values. While the lane width and total entrances per mile were the same number as for 1954 and 1955, the factor of increase from 1953 to 1954 and 1955 to 1956 in traffic volume was studied. It was assumed that there was a constant increase of traffic volume from 1953 to 1956. This is generally correct for Indiana. It was therefore assumed that the total ADT and congestion index of 1954 and 1955 would be the same for the years 1953 and 1956.

Table 9
Beta Coefficients for the Significant Roadway Factors
in the Multiple Regression Equation

<u>Roadway Factors</u>	<u>Beta Coefficient</u>
ADT	0.179
Congestion Index	0.302
Lane Width	0.180
Total Entrances Per Mile	-0.073

The Regression Equation developed is as follows:

Accident number per mile for two year period =

0.00056 (ADT) + 2.86238 (Congestion Index) + 1.24009 (Lane Width)

-0.04189 (Total Entrances Per Mile) - 11.78211

Table 10 shows the comparisons between actual accident occurrences for 1953 and 195⁶~~4~~ and the predicted accidents for these years for random subsections. These comparisons were made within ADT groups and accident rate groups so that the effect of prediction could be analyzed.

The few exceptionally high percents of error, above 150%, were excluded in the group average percent of error calculation. All of these high percents of error were negative, indicating the predicted values were higher than the actual values.

In ADT groups, the percent of error varied from 0% to -1140% for an individual prediction. The average for each ADT group shows that the percent of error varied from + 49% to + 3% and -17% to -5%. The average percent of error for all ADT groups was + 6%.

It was noted that for lower traffic volumes up to 4000, positive percent of error was obtained but became negative from traffic volumes between 4000 and 8000.

In accident rate groups, the percent of error varied from + 2% to + 84% or - 83%. As for each accident rate group, the percent of error varied from + 1% to + 45%. The average percent of error for all accident rate groups was - 2.5%.

The negative percents of error were obtained for lower rates (from 0 to 8), and the positive percents of error systematically increased as the accident rates were increased.

In general, the percent of error increased as the traffic volume decreased, and the percent of error decreased for the higher traffic volume.

The accident rate group shows a rather irregular trend; however, it

was observed that the accident rate range of 5 to 10 showed relatively smaller percent of error compared to other rate ranges.

1953 and 1956	6.3	6.9	6.1	12.1	15.1	
Predicted Values	8.9	10.2	10.3	8.1	7.6	
Percent of Error	-41	-48	-69	+33	+51	- 15

Group 6 (8,000 and above)

1953 and 1956	1.5	2.5	36.7	15.2	8.8	
Predicted Values	14.8	30.9	17.9	17.1	11.4	
Percent of Error	(-877)	(-1140)	+51	-12	-30	+ 3

Average + 6%B. Accident Rate Grouping

Group 1 (0-1.9)

1953 and 1956	1.5	6.8	2.6	0.4	1.9	
Predicted Values	14.8	1.8	2.9	0.9	5.4	
Percent of Error	(-887)	+74	-11	-125	(-184)	- 21

Group 2 (2-2.9)

1953 and 1956	1.3	6.4	8.0	3.5	2.7	
Predicted Values	4.7	8.6	5.2	5.5	1.1	
Percent of Error	(-261)	-34	+35	-57	+59	+ 1.

Group 3 (3-3.9)

1953 and 1956	2.8	3.1	3.5	4.2	1.4	
Predicted Values	4.0	5.0	5.1	0.5	4.9	
Percent of Error	-43	-61	-46	-19	(-250)	- 42

Group 4 (4-4.9)

1953 and 1956	10.0	2.0	5.8	4.7	2.2	
Predicted Values	8.2	0.4	7.2	4.8	5.1	
Percent of Error	-18	+80	-24	-2	-132	- 12

Group 5 (5-5.9)

1953 and 1956	5.6	4.3	2.5	5.3	4.3	
Predicted Values	4.4	5.0	3.7	5.7	1.2	
Percent of Error	+21	-16	-48	-7	+72	- 4

Group 6 (6-7.9)

1953 and 1957	3.7	7.6	6.7	2.8	5.7	
Predicted Values	3.9	5.1	5.6	3.2	10.3	
Percent of Error	-5	+33	+16	-14	-81	- 8

Group 7 (8-9.9)

1953 and 1956	2.5	2.5	9.6	11.2	8.4	
Predicted Values	6.8	4.4	5.8	1.3	8.9	
Percent of Error	(-172)	-95	+40	+88	-6	+ 7

Group 8 (10-13.9)

1953 and 1956	6.4	5.6	9.9	3.1	9.1	
Predicted Values	21.2	6.9	5.7	4.4	3.5	
Percent of Error	(-231)	-23	+42	-42	+62	+ 10

Group 9 (14 and above)

1953 and 1956	38.3	8.5	17.5	20.0	13.1	
Predicted Values	6.0	3.7	12.3	11.0	11.1	
Percent of Error	+84	+56	+30	+45	+15	+ 46

Average = 2.5%

SUMMARY OF RESULTS AND CONCLUSIONS

All of the following results and conclusions are for non-intersectional accidents on the two-lane Indiana Rural State Primary System of Highways:

Summary of Results

1. There was a very strong positive relationship between the number of accidents for 1954 and 1955 on the same subsection, thus confirming the theory of exposure (12).
2. The average number of accidents per mile was 5.1 for 1954 and 1955. The highways with accident rates below this average comprised 70% of the total system. The ratio of non-fatal to fatal accidents was 42 to 1.
3. The mean of the number of traffic accidents for each traffic volume group increased quite systematically as the traffic volume increased by an increment of 1000 vehicles per day.
4. The range of traffic volumes from 2000 to 5000 included more than one half of the total accidents and one half of the total mileage.
5. The accident rate per million vehicle miles showed very little relationship with roadway factors. The accident rate per mile showed a reasonable relationship and this rate was used in the detailed analysis of this study.
6. Four roadway factors were found to possess quite good linearity with accident rate; they were annual average daily traffic (ADT), con-

gestion index, lane width and total entrances per mile.

7. Three roadway factors were found to possess little correlation with accident rate in this study; they were capacity, shoulder width, and horizontal alignment.

8. ADT and total number of entrances per mile showed a positive correlation with accident rate in all ADT groups, and they followed a similar trend in variability in that correlation.

9. ADT and total number of entrances per mile were very highly correlated with accident rate in roads with traffic volumes of 2000 or less, and exhibited very good correlation on roads with ADT volumes above 8000.

10. Among the four significant roadway factors, there was a strong relationship between ADT and congestion index, and between width of lane and total number of entrances per mile.

11. A regression equation that used the four significant factors to predict accident rate per mile was developed and was found to be:

Accident rate per mile for two years = 0.00056 (ADT) + 2.86238 (Congestion Index) + 1.24009 (Lane Width) - 0.04189 (Total Entrances per Mile) - 11.78211

12. The relative strength of the four roadway factors in the regression equation was, in order of strength; congestion index, lane width, ADT and total number of entrances per mile. Congestion index exhibited a major role in the above regression equation.

13. When the accident rates for 1953 and 1956 were predicted from the regression equation, average predicted rates for total accidents for the system as well as for ADT groups showed only a small percent of error

but accident rates for individual subsections of roads showed a high variability.

14. The multiple correlation coefficient of the four roadway factors was 0.4734. This gives a multiple correlation coefficient squared, 0.22413; or 22% of the variance in total accident rate was explained by the regression equation.

Conclusions

1. The number of traffic accidents on rural highways is quite strongly related linearly to traffic volume and congested conditions. Total number of entrances per mile and lane width also have some significant linear relationship.

2. The number of accidents per mile was not significantly correlated with capacity, shoulder width or horizontal alignment as they were evaluated in this study.

3. The number of accidents per roadway mile has more correlation with roadway factors than the number of accidents per vehicle mile.

4. Approximately 22% of the variance in total accident rate was explained by the joint effect of the four significant roadway factors, and 78% of the variance in total accident rate was attributed to the other causes.

5. The dominant effect of traffic volume and the close relationship between 1954 and 1955 accident occurrences on the same highways confirm the theory of exposure in accident occurrence. Thus the amount of hazard exposed on the two lane rural highways which do not involve

intersections and urban crossings could be represented by traffic volume and mileage of the highways.

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APPENDIX

APPENDIX A

CALCULATION OF SIMPLE CORRELATION

Formulas used for the simple correlation coefficients between roadway factors and accident rates:

Standard deviation for roadway factors:

$$S_x = \sqrt{\frac{N \sum X^2 - (\sum X)^2}{N(N-1)}}$$

Standard deviation for accident rates:

$$S_y = \sqrt{\frac{N \sum Y^2 - (\sum Y)^2}{N(N-1)}}$$

Coefficient of linear equation:

$$b = \frac{N \sum XY - \sum X \sum Y}{N \sum X^2 - (\sum X)^2}$$

Simple correlation coefficient:

$$r = \frac{b S_x}{S_y}$$

Standard error of estimate:

$$s_{y.x} = \sqrt{\frac{N-1}{N-2} (s_y^2 - b^2 s_x^2)}$$

Linear regression equation for total accident rate:

$$\hat{Y}_{T3} = \bar{Y}_{T3} + b_3 (X_1 - \bar{X})$$

Formula used for the simple inter-correlation coefficients between roadway factors.

$$r = \frac{N \sum X_1 Y_3 - \sum X_1 \sum Y_3}{\sqrt{\left[N \sum X_1^2 - (\sum X_1)^2 \right] \left[N \sum Y_3^2 - (\sum Y_3)^2 \right]}}$$

The results of correlation coefficient were shown on the Table

5, 6, 7, and 8.

N = Total number of subsections

X_1 = Roadway factors:

X_1 = ADF

X_2 = Capacity

X_3 = Congestion Index

X_4 = Number of lanes

X_5 = Lane width

X_6 = Shoulder width

X_7 = Horizontal alignment

X_9 = Total number of entrances per mile

Y_k = Accident rates:

Y_1 = Number of fatal accidents per mile

Y_2 = Number of non-fatal accidents per mile

Y_3 = Total number of accidents per mile

Y_4 = Total number of accidents per one million vehicle miles

X_1 = Sum of roadway element measurements

X_1^2 = Sum of the square of roadway element measurements

$\sum_{i,k} X_i Y_k$ = Sum of the cross products

$\sum_k Y_k$ = Sum of accident rates

$\sum_k Y_k^2$ = Sum of the square of accident rates

APPENDIX B

TEST FOR LINEARITY OF REGRESSION

Table 1B

Summation Table for Test of Linearity

Items	Grouped Roadway Factors			Total Summation
N	=====	=====	=====	N
$\sum y_{i.}^T$	=====	=====	=====	$\sum y_{i.}^T$
$\sum y_{i.}$	=====	=====	=====	$\sum y_{i.}$
$\sum y_{ij}^2$	=====	=====	=====	$\sum y_{ij}^2$
$\frac{\sum y_{i.}^T}{N_i}$	=====	=====	=====	$\frac{\sum y_{i.}^T}{N_i}$
$\sum x_{i.}^T$	=====	=====	=====	$\sum x_{i.}^T$
$\sum y_{i.}^T x_{i.}^T$	=====	=====	=====	$\sum y_{i.}^T x_{i.}^T$
$\sum N_i x_{i.}^2$	=====	=====	=====	$\sum N_i x_{i.}^2$

Table 2B

Analysis of Variance Table for Test of Linearity

$$\text{Model: } Y_{ij} = \bar{Y}_{..} + (\hat{Y}_x - \bar{Y}_{..}) + (\bar{Y}_1 - \hat{Y}_x) + (Y_{ij} - \bar{Y}_1)$$

<u>SOURCES OF VARIATION</u>	<u>DEGREE OF FREEDOM</u>	<u>SUM OF SQUARES</u>	<u>MEAN SQUARES</u>
Among Group:	K	$\frac{\sum T_i^2}{N_1} - \frac{y^2}{N}$	$\frac{S.S.}{d.f.}$
Due to linear regression:	1	$\frac{[\sum (xy)]^2}{\sum (x)}$	
Departure from linear regression:	K - 1	Difference	
Error within groups:	N - 1 - K	Difference	
Total	N - 1	$\sum \sum Y_{ij}^2 - \frac{T_{..}^2}{N}$	

$$b_1 = \frac{sp(xy)}{ss(x)} = \frac{\sum y_i x_i - \frac{T_{..} y T_{.y}}{N}}{\sum N_i x_i^2 - \frac{y T_{..}^2}{N}}$$

Test of Linearity as follows:

H: Departure = 0

Alternate H: Departure $\neq 0$

$$F \text{ Test} = \frac{\text{M. S. of Departure from Regression}}{\text{M. S. of Error Within Groups}}$$

$$\eta^2 \text{ (Eta-squared)} = \frac{\text{S.S. Among Group}}{\text{S. S. Total}} : \text{shows percent of variation}$$

due to regression of curve went through all column means.

$$r^2 \text{ (Correlation coefficient squared)} = \frac{\text{S.S. due to linear regression}}{\text{S. S. Total}}$$

shows percent of variation due to given regression equation.

Table 3B shows the summary of F test and eta-squared, and correlation coefficient squared.

Table 3B

The Results of Test of Linearity

<u>All Rural Primary System</u>					<u>Rural two-lane Primary System</u>				
	F Test (5% Level)	Conclusion	η^2	r^2		F Test (5% Level)	Conclusion	η^2	r^2
AFT	$\frac{60}{48.1}$	- 1.16 < 2.01	Yes	0.1909	0.163	$\frac{56.1}{43.1}$	- 1.3 < 2.01	Yes	0.1650 0.1597
Congestion Index	$\frac{8}{48.1}$	< 1	Yes	0.1150	0.115	$\frac{23.2}{45.2}$	- 0.74 < 1	Yes	0.1191 0.1170
Lane Width	$\frac{112}{55.5}$	- 2.09 < 3	Yes	0.0148	0.011	$\frac{107.5}{50.5}$	- 2.13 < 3	Yes	0.0142 0.0097
Total Entrance Per Mile	$\frac{57}{526}$	< 1	Yes	0.0311	0.030	$\frac{113}{48.1}$	- 2.34 < 2.61	Yes	0.0628 0.0559

*Yes = the hypothesis of linearity is acceptable.

APPENDIX C

CALCULATION OF MULTIPLE CORRELATION COEFFICIENT

Table 1C

Doolittle Solution for Multiple Correlation

$r_{01} = 0.42587$	$r_{03} = 0.42544$	$r_{09} = 0.19456$	$r_{05} = 0.18834$
$r_{13} = 0.74075$	$r_{19} = 0.27691$	$r_{15} = 0.24421$	$r_{35} = 0.06400$
$r_{39} = 0.27503$	$r_{59} = 0.74941$		

	X_1	X_3	X_9	X_5	X_0	Check Sum	Check Sum
x_1	1.00000	0.74075	0.27691	0.24421	0.42587	2.68774	
x_3		1.00000	0.27503	0.06400	0.42544	2.50522	
x_9			1.00000	0.74941	0.19456	2.49591	
x_5				1.00000	0.18834	2.24596	

A_1	1.00000	0.74075	0.27691	0.24421	0.42587	2.68774	
B_1	1.00000	0.74075	0.27691	0.24421	0.42587	2.68774	

A_2		0.45129	0.06991	-0.11690	0.10998	0.51428	0.51428
B_2		1.00000	0.15491	-0.25804	0.24370	1.13957	1.13957

A_3			0.91249	0.69990	0.05960	1.67199	1.67199
B_3			1.00000	0.76702	0.06512	1.83234	1.83234

A_4				0.37324	0.06711	0.44036	0.44036
B_4				1.00000	0.17960	1.17960	1.17960

$B_5 = 0.17980$							
-----------------	--	--	--	--	--	--	--

$$B_9 = 0.06532 - 0.76702 (0.17980) = -0.07259$$

$$B_3 = 0.24370 - 0.15491 (-0.07259) - (-0.25904) (0.17980) = 0.30152$$

$$B_1 = 0.42587 - 0.74075 (0.30152) - (0.27691) (-0.07259) - 0.24421 (0.17980) = 0.17671$$

$$1(0.17671) + 0.74075 (0.30152) + 0.27691 (-0.07259) + 0.24421 (0.17980) = 0.42587$$

$$0.74075 (0.17671) + 1 (0.30152) + 0.27503 (-0.07259) + 0.06400 (0.17980) = 0.42544$$

$$0.27691 (0.17671) + 0.27503 (0.30152) + 1 (-0.07259) + 0.74941 (0.17980) = 0.19456$$

$$0.24421 (0.17671) + 0.06400 (0.30152) + 0.74941 (-0.07259) + 1 (0.17980) = 0.18334$$

$$R_{0.1395}^2 = \sum B_1 r_{01} = 0.22413$$

$$R_{0.1395} = 0.4734$$

$$b_1 = B_1 \frac{\sqrt{n \sum X_0^2 - (\sum X_0)^2}}{\sqrt{n \sum X_1^2 - (\sum X_1)^2}} = 0.17671 \left(\frac{6,821.6623}{21,725.1968 \div 100} \right) = 0.00056$$

$$b_3 = 0.30152 \left(\frac{6,821.6623}{18,359.84} \right) = 2.86238$$

$$b_9 = -0.07259 \left(\frac{6,821.6623}{11,822.0264} \right) = -0.04189$$

$$b_5 = 0.17980 \left(\frac{6,821.6623}{589.067237} \right) = 1.24009$$

$$b_0 = \bar{X}_0 - b_1 \bar{X}_1 - b_3 \bar{X}_3 - b_9 \bar{X}_9 - b_5 \bar{X}_5 = -11.78211$$

$$X_0 = 0.00056X_1 + 2.86238X_2 = 0.04189X_3 + 1.24009X_4 - 11.78211$$

Test R^2 for significant of difference from 0:

$$F = \frac{\frac{R^2}{K}}{\frac{1-R^2}{N-K-1}} = \frac{0.22413 (950)}{4(0.77587)} = 68.61$$

$$68.61 > 2.38 \quad (4:950)$$

Thus, R^2 is highly significant and successful in accounting for 22 percent of the variance in accident occurrences.