CORRELATION OF DESIGN
CHARACTERISTICS AND OPERATIONAL
CONTROLS WITH ACCIDENT RATES ON
URBAN ARTERIALS

SEPTEMBER 1966

NO. 14

Joint
Highway
Research
Project

by
T. E. MULINAZZI

PURDUE UNIVERSITY
LAFAYETTE INDIANA

Final Report

CORRELATION OF DESIGN CHARACTERISTICS AND OPERATIONAL CONTROLS WITH ACCIDENT RATES ON URBAN ARTERIALS

To: G. A. Leonards, Director
Joint Highway Research Project

September 22, 1966

From: H. L. Michael, Associate Director
Joint Highway Research Project

File: 8-5-8
Project: C-36-59H

Attached is a final report, "Correlation of Design Characteristics and Operational Controls with Accident Rates on Urban Arterials," by Mr. Thomas E. Mulinazzi, Graduate Assistant on our staff. The research was approved by the Board on March 25, 1965, and has been directed by Professor Harold L. Michael. Mr. Mulinazzi also used the report as his thesis for the MSCE degree.

The results given in the attached report can be used to evaluate the design characteristics and operational controls which affect the traffic accident rate on an urban arterial street where full control of access is not practical.

The report is presented to the Board for the record and for acceptance as fulfillment of the research plan.

Respectfully submitted,

Harold L. Michael

Harold L. Michael, Secretary

HLM:jgs

Attachment

Copy:

F. L. Ashbaucher
J. R. Cooper
J. W. Delleur
W. L. Dolch
W. H. Goetz
W. L. Grecco
G. H. Hallock
F. S. Hill
J. F. McLaughlin

F. B. Mendenhall
R. D. Miles
J. C. Oppenlander
W. P. Privette
M. B. Scott
F. W. Stubbs
K. B. Woods
E. J. Yoder

Digitized by the Internet Archive
in 2011 with funding from

LYRASIS members and Sloan Foundation; Indiana Department of Transportation

Final Report

**CORRELATION OF DESIGN CHARACTERISTICS AND OPERATIONAL
CONTROLS WITH ACCIDENT RATES ON URBAN ARTERIALS**

by

**Thomas E. Milinazzi
Graduate Assistant**

Joint Highway Research Project

File No.: 8-5-8

Project No.: C-36-59H

**Purdue University
Lafayette, Indiana**

September 22, 1966

Page 100

 

UNIVERSITY OF CHICAGO

ACKNOWLEDGMENTS

The author wishes to express his sincerest appreciation to Professor Harold L. Michael, Professor of Highway Engineering and Associate Director, Joint Highway Research Project, for his assistance and recommendations throughout this study and his critical review of the manuscript; and to Professor W.H. Goetz, Professor of Highway Engineering, and Professor Irving W. Burr, Professor of Mathematics and Statistics, for their review of the manuscript.

Acknowledgments are also given to the Indiana State Police, Accident Records Division; the State Highway Commission, Division of Planning; the accident divisions for the city police departments of Frankfort, Kokomo, Lafayette, Logansport, and West Lafayette, Indiana; and to the Bureau of Traffic Engineering, Indianapolis, Indiana.

The author is grateful to the Joint Highway Research Project for the use of its facilities and equipment, and to the State Highway Commission for their financial Assistance.

Thanks are also extended to William J. Fehribach and Larry Wright for their assistance in the data collection.

The author is especially grateful to his wife for her confidence and patience throughout this study.

TABLE OF CONTENTS

	Page
LIST OF TABLES	v
LIST OF FIGURES	vii
ABSTRACT	viii
INTRODUCTION	1
PURPOSE	7
THE STUDY LOCATIONS	8
REVIEW OF LITERATURE	20
Roadway Development	21
Access Control	24
Other Factors	25
Traffic Engineering Improvements	27
DATA COLLECTION	30
Accident Data	31
Volume Data	37
ANALYSIS OF DATA	43
Accident Rates	43
Multiple Linear Regression	46
Five Phases of the Regression Analysis	48
Phase I - The One-hundred Sections	49
Accidents per 100 Million Vehicle	
Miles (Y_2)	49
Accidents per Mile (Y_2)	57
Phase II - Thirty-five Low Volume Sections	59
Accidents per 100 Million Vehicle	
Miles (Y_1)	59
Accidents per Mile (Y_2)	67
Phase III - Thirty-two High Volume	
Sections	69
Accidents/100 Million Vehicle Miles	71

TABLE OF CONTENTS (continued)

	Page
Accidents per Mile (Y_2)	78
Phase IV - Two Lane Sections	80
Accidents per 100 Million Vehicle Miles	87
Accidents per Mile (Y_2)	89
Phase V - 32 Sections ² Four Lane or One-way Streets	90
Case Studies	91
CONCLUSIONS	108
BIBLIOGRAPHY	110
APPENDIX A	113
APPENDIX B	116

LIST OF TABLES

Table		Page
1	Urban Accidents in Indiana	4
2	Details of Study Sections	11
3	Independent Variables	32
4	Accident Rates for Study Sections	34
5	Factors to Expand 24 Hour Weekday (Mon., Tues., Wed., Thurs.) Volumes to A.D.T. - 1964	41
6	Variable Means and Standard Deviations for the One-Hundred Sections	50
7	Simple Correlation Coefficients Between Each Variable and All Other Variables For the One-Hundred Sections	51
8	Independent Variables Used in the Final Multiple Linear Regression Analysis for the One-Hundred Sections	54
9	Coefficients for Multiple Linear Regression Equations for the One-Hundred Sections	55
10	Variable Means and Standard Deviations for the Thirty-five Low Volume Sections	60
11	Simple Correlation Coefficients Between Each Variable and all Other Variables for the Thirty-five Low Volume Sections	62
12	Independent Variables Used in the Final Multiple Linear Regression Analysis for the Thirty-five Low Volume Sections.	64
13	Coefficients for Multiple Linear Regression Equations for the Thirty-Five Low Volume Sections	65

Table		Page
14	Variable Means and Standard Deviations for the Thirty-Two High Volume Sections in Indianapolis	70
15	Simple Correlation Coefficients Between Each Variable and All Other Variables for the Thirty-Two High Volume Sections in Indianapolis	72
16	Independent Variables Used in the Final Multiple Linear Regression Analysis for the Thirty-Two High Volume Sections in Indianapolis	75
17	Coefficients for Multiple Linear Regression Equations for the Thirty-Two High Volume Sections in Indianapolis	76
18	Variable Means and Standard Deviations for the Sixty-Eight Two Lane Sections	81
19	Simple Correlation Coefficients Between Each Variable and all Other Variables for the Sixty-Eight Two Lane Sections	82
20	Independent Variables Used in the Final Multiple Linear Regression Analysis for the Sixty-Eight Two Lane Sections	85
21	Coefficients for Multiple Linear Regression Equations for the Sixty-Eight Two Lane Sections	86
22	Variable Listed in Appendix B	116
23	Characteristics of the Sixty-Eight Two-Lane Sections	117
24	Characteristics of the Twenty-One Four-Lane Undivided Sections	124
25	Characteristics of the Four Four-Lane Divided Sections	126
26	Characteristics of the Seven One-Way Street Sections	127

LIST OF FIGURES

Figure		Page
1	Miles Driven in Indiana (Source: Indiana Traffic Crash Facts)	5
2	Vehicle Registration	6
3	Study Locations	9
4	Study Locations in Indianapolis	10
5	Effect of Control of Access on Accidents and Fatalities in Urban Areas . .	26
6	Investigating Officers Accident Report Form, Side One	38
7	Investigating Officers Accident Report Form, Side Two	39
8	Inventory Form - Page 1	113
9	Inventory Form - Page 2	114
10	Inventory Form - Page 3	115

ABSTRACT

Mulinazzi, Thomas Ernest. MSCE, Purdue University, August, 1966. Correlation of Design Characteristics and Operational Controls with Accident Rates on Urban Arterials. Major Professor: Harold L. Michael.

The purpose of this research was to evaluate the design characteristics and operational controls which affect the traffic accident rates on an urban arterial street where full control of access is not practical. To attain this objective, the design characteristics and operational controls on one-hundred segments of the arterial street system in the State of Indiana were analyzed in detail to determine their relationships to urban traffic accidents. Accident data on these one-hundred sections were collected for the period starting January 1, 1963, and ending December 31, 1965.

The data were analyzed by a simple correlation coefficient analysis, a multiple linear regression technique, and a case study approach. Two different types of accident rates, the number of accidents per 100 million vehicle miles and the number of accidents per mile, were computed and compared.

This study found that traffic accidents on an urban arterial decreased as the volume on the arterial decreased,

the number of traffic signal per mile decreased, the amount of parking decreased, and the number of heavily used driveways per mile decreased. These were the most important correlations found between individual variables and the dependent variables.

Although this study only included one-hundred segments of the urban arterial street system in Indiana, the findings should be of considerable value on similar facilities throughout the state and the nation.

INTRODUCTION

The first recorded traffic fatality occurred in New York City in September, 1899, when a man was hit by an automobile while helping a woman off a streetcar.(6) Since that event the number of traffic deaths each year has reached epidemic conditions. However, one should not concentrate entirely on the spectacular fatal accident because the factors which cause a fatal accident are similar to those for other accidents, especially in urban areas where speeds are slower. A traffic accident has been defined as "a failure of the road-car-driver system to perform one or more operations necessary for completing a trip without damage or injury... . It is also believed that the necessary and sufficient cause of an accident is a combination of simultaneous and sequential factors, each of which is necessary but none of which is by itself sufficient."(5)

In the past much of the research has been concentrated on rural accidents because a large percentage of the fatal accidents occur on rural highways where higher speeds increase the severity. However, a majority of all non-fatal injury collisions happen in urban areas where approximately 48 percent of the total vehicle miles were

driven in 1964.(13) It seems apparent that much accident research is needed in the urban areas, especially with the multitude and magnitude of urban areas being forecasted for the future.

Most of the work being presently performed in urban areas is focused on the development of freeways and expressways, with the role of the major urban street as an arterial highway being neglected.

By necessity the main function of an urban arterial is the movement of traffic; and as a result, speeds and volumes are usually higher on this type of facility than on the average urban street. On the other hand, many of these arterial streets also serve an access function for abutting property. The resulting intersectional and roadside conflicts reduce capacity and increase congestion. These conflicts have been found to be a catalyst for urban accidents and point to a proven method of accident prevention, the control of access.(1)(5)(19)(24)(27)

Control of access, however, is not practical on most urban arterials and improvements in highway safety must be sought in design characteristics and operational controls if the problem is to be reduced. Some of these improvements will have to come in the areas of signing, parking controls, traffic signal installations, street markings, and lighting.

Indiana had over 113,000 urban accidents in 1965 which included 26,966 non-fatal injury accidents and 386 fatal collisions.(12) Table 1 shows that the annual total

of urban accidents has been increasing each year since 1961. With the higher volumes and speeds on the urban arterial street, a majority of these urban accidents probably occur on this system and it appears that little is being done to effectively curtail this increasing trend.

One of the reasons for this increasing trend in urban accidents in Indiana is the ever growing number of vehicle registrations. More vehicles are being driven more miles which all leads to congestion and greater potentials for accidents, as shown in Figures 1 and 2.

Table 1 Urban Accidents in Indiana

	1961	1962	1963	1964	1965
Fatal Collisions	246	262	302	339	386
Non-Fatal Injury Collisions	18,153	21,138	23,094	26,635	26,966
Property Damage Collisions	70,239	72,834	80,447	83,694	85,739
Totals	88,638	93,234	103,843	110,668	113,091

(Source: Indiana Traffic Crash Facts)

FIGURE 1 - MILES DRIVEN IN INDIANA

(SOURCE : INDIANA TRAFFIC CRASH FACTS)

FIGURE 2 - VEHICLE REGISTRATION

PURPOSE

The purpose of this research was to evaluate the design characteristics and operational controls which minimize accident hazard on an urban arterial street where full control of access is not practical. By evaluating the reasons why some high volume arterials had far lower accident rates than other arterials carrying similar volumes, it was hoped that beneficial information could be obtained which would assist in reducing urban traffic accidents. In other words, this research was an attempt to determine the "safest" design characteristics and operational controls for urban arterials.

THE STUDY LOCATIONS

One-hundred sections, varying in length from 0.254 of a mile to 4.167 miles, were analyzed in this study. Sixty-eight of these sections were located within a fifty mile radius of Lafayette, Indiana, with the remaining thirty-two sections selected in Indianapolis, Indiana. The location of each city relative to Lafayette, each with one or more sites, is shown in Figure 3. Those sites established within the Indianapolis area are illustrated in Figure 4. Table 2 is a list of the cities in which sections were located, the length of each section, and the specific boundaries of each section. The listing is according to alphabetical order by counties.

FIGURE 3- STUDY LOCATIONS

FIGURE 4 - STUDY LOCATIONS IN INDIANAPOLIS

Table 2 Details of Study Sections

<u>CITY</u>	<u>COUNTY</u>	<u>SECTION NUMBER</u>	<u>LENGTH</u>	<u>ROUTE</u>	<u>LOCATION</u>
Thorntown	Boone	8	1.098	SR 47 Main St.	(W. City Limits- E. City Limits) (Cy.Lt.) ¹
Lebanon	Boone	25	0.971	SR 32 South St.	(W.Cy.Lt.-West St.)
		36	0.833	SR 32 South St.	(East St.-R.R. spur on Spencer)
		41	0.701	SR 39 S. Lebanon St.	(By-pass ramps N.- C.C.C. and St. L.R.R.)
		51	0.947	SR 39 N. Lebanon St.	(Sunnybrook Lane- North St.)
Delphi	Carroll	29	0.701	US 421 Washington St.	(Front St.-S.Cy.Lt.)
		40	0.492	US 421 Main St.	(N.W.Cy.Lt.-Market St.)
Flora	Carroll	20	0.919	SR 18 Columbia St.	(W.Cy.Lt.-E.Cy.Lt.)
Logansport	Cass	26	0.720	SR 29 Burlington	(Clinton St. ² -E. Main St. ²)
		39	0.398	US 35 E. Main St.	(Burlington ² -E.Cy.Lt.)

¹City Limits²Section ends 200 feet from given intersection and does not include intersection

Table 2 (Continued)

<u>CITY</u>	<u>COUNTY</u>	<u>SECTION NUMBER</u>	<u>LENGTH</u>	<u>ROUTE</u>	<u>LOCATION</u>
Logansport	Cass	44	0.994	SR 25 Michigan Ave.	(N.E.Cy.Lt.-N. Sixth St.)
		47	0.739	US 24 E. Market	(E.Cy.Lt.-24th St. ²)
		48	0.568	SR 17 Third St.	(S. Hillcrest- Tacoma St.)
		50	1.250	US 24 E. Market	(7th St.-24th St. ²)
		52	0.477	SR 25 Cicott St.	(Lafayette Rd.- ² W. Market St.)
		56	1.250	US 24 Broadway	(7th St.-24th St.)
Walton	Cass	61	0.729	US 24 W. Markett-Dewey	(Cicott St. ² -R.R. Butler Div. Penn.)
		3	0.606	SR 218	(W.Cy.Lt.-E.Cy.Lt.)
Galveston	Cass	23	0.777	US 35 Main St.	(S.Cy.Lt.-N.Cy.Lt.)
		2	0.701	SR 18	(W.Cy.Lt.-E.Cy.Lt.)
Kirklin	Clinton	11	1.025	US 421 Main St.	(N.Cy.Lt.-S.Cy.Lt.)
Mulberry	Clinton	6	0.820	SR 38 Jackson Highway	(W.Cy.Lt.-E.Cy.Lt.)

Table 2 (Continued)

<u>CITY</u>	<u>COUNTY</u>	<u>SECTION NUMBER</u>	<u>LENGTH</u>	<u>ROUTE</u>	<u>LOCATION</u>
Michigantown	Clinton	15	0.606	SR 29 Michigan St.	(N.Cy.Lt.-S.Cy.Lt.)
Rossville	Clinton	7	0.549	US 421 Cross St.	(N.Cy.Lt.-S.Cy.Lt.)
		10	1.042	SR 26 Main St.	(W.Cy.Lt.-E.Cy.Lt.)
Frankfort	Clinton	5	0.254	SR 75 Delphi Ave.	(Kyger Jct. US 421- N.Cy.Lt.)
		16	0.644	Washington Ave.	(Clay St.-Hoke Ave.)
		24	1.004	US 421 Jackson and Kyger	(Morrison-Rowe St.)
		49	1.068	SR 39 S. Jackson	(S.Cy.Lt.-Walnut St. ²)
		53	0.568	US 421 Walnut St.	(Clay St.-Hoke Ave.)
		57	0.909	SR 28 Walnut and McKinley	(Columbia ² -W.Cy.Lt.)
Attica	Fountain	14	0.682	SR 28 Jackson and Main	(S.E.Cy.Lt.- ² Council St.)
		42	0.758	US 41 Council St.	(Jackson Jct. 28 ² - S.Cy.Lt.)
Covington	Fountain	13	0.398	US 136 3rd and Pearl	(W.Cy.Lt.- Jefferson St.)

Table 2 (Continued)

<u>CITY</u>	<u>COUNTY</u>	<u>SECTION NUMBER</u>	<u>LENGTH</u>	<u>ROUTE</u>	<u>LOCATION</u>
Covington	Fountain	27	0.852	US 136 Liberty St.	(5th St.-S.E.Cy.Lt.)
Veedersburg	Fountain	33	0.814	US 41	(N.Cy.Lt.-200 feet south of Jct. 136 W.)
		34	0.616	US 136 2nd St.	(Mill St.-W.Cy.Lt.)
Kokomo	Howard	38	1.023	SR 22 Sycamore St.	(Webster St.-Berkeley Rd.)
		58	2.273	US 31 By-pass	(Jefferson St. ² -200 ft. N. of Smith Rd.)
		72	1.212	US 35 Markland	(Cooper St.- Washington St.)
		76	0.701	US 35 Markland	(Davis Rd.-Taylor St.)
		84	4.167	US 31 By-pass	(Jefferson St. ² - Alto Rd. ²)
Rensselaer	Jasper	4	0.701	SR 114 Cullen-Grace	(Rutsen St.-E.Cy.Lt.)
		9	0.833	SR 114 Cullen-Clark	(W.Cy.Lt.- Angelica St.)
		31	0.644	US 231 College Washington	(S.Cy.Lt.-Milroy Ave.)

Table 2 (Continued)

<u>CITY</u>	<u>COUNTY</u>	<u>SECTION NUMBER</u>	<u>LENGTH</u>	<u>ROUTE</u>	<u>LOCATION</u>
Rensselaer	Jasper	32	0.890	US 231 McKinley	(Washington- N.Cy.Lt.)
Remington	Jasper	17	0.634	US 24 Division St.	(W.Cy.Lt.-E.Cy.Lt.)
Waynetown	Montgomery	22	0.852	US 136 Washington St.	(W.Cy.Lt.-E.Cy.Lt.)
Linden	Montgomery	19	0.852	US 231 Main St.	(N.Cy.Lt.-S.Cy.Lt.)
Crawfordsville	Montgomery	30	0.644	SR 43 Lafayette Rd.	(Market ² -N.Cy.Lt.)
		35	0.663	US 136 Main-Oak Grace)	(Darlington Ave. ² - Grace)
		54	0.739	US 136 Market St.	(Barr St.-N. Grant St.)
Lafayette	Tippecanoe	55	0.833	SR 25 Teal Rd.	(9th St.-Summerfield)
		62	1.080	Main St.	(17th-Alabama-Earl Ave.)
		63	0.833	South St.	(18th St.-Earl Ave. ²)
		67	0.758	SR 43 4th St.	(Montefiore St.- Fountain)

Table 2 (Continued)

<u>CITY</u>	<u>COUNTY</u>	<u>SECTION NUMBER</u>	<u>LENGTH</u>	<u>ROUTE</u>	<u>LOCATION</u>
Lafayette	Tippecanoe	77	3.125	US 52 By-pass	(Monon St.-Jeager Rd.)
		88	2.811	US 52 By-pass	(SR 25 Schulyer-End of two lanes)
W. Lafayette	Tippecanoe	1	1.098	SR 126 Cherry Lane	(Northwestern Ave. ² - End of route)
		43	0.559	SR 43 N. River Rd.	(N.Cy.Lt.-Beginning of 4-way)
		60	1.089	SR 231 Northwestern Ave.	(Lindberg Rd.- Stadium Ave.)
		74	1.061	SR 26 State St.	(McCormick Rd.- Grant St.)
Brookston	White	21	0.909	SR 43 Praire St.	(S.Cy.Lt.-N.Cy.Lt.)
Monticello	White	37	0.701	US 421 Main St.	(S.Cy.Lt.- Harrison St.)
		45	0.550	US 42 Broadway St.	(6th St.-Monon R.R. Tracks)
Reynolds	White	12	0.795	SR 43 Kenton St.	(S.Cy.Lt.-N.Cy.Lt.)

Table 2 (Continued)

<u>CITY</u>	<u>COUNTY</u>	<u>SECTION NUMBER</u>	<u>LENGTH</u>	<u>ROUTE</u>	<u>LOCATION</u>
Reynolds	White	28	0.777	US 24 2nd St.	(W.Cy.Lt.-E.Cy.Lt.)
Monon	White	18	0.947	US 421 Market St.	(S.Cy.Lt.-N.Cy.Lt. excluding from Monon R.R. to the Library)
Indianapolis	Marion	46	0.795	S. East St.	(Parkway-Raymond)
		59	0.947	S. Meridian	(Adler-McCarthy)
		64	0.682	Arlington	(English-Washington ²)
		65	2.311	N. College	(42nd-65th)
		66	1.307	Arlington	(22nd-Massachusetts ²)
		68	2.008	N. College	(Fairfield-16th)
		69	1.326	30th	(Columbia-Capitol)
		70	0.871	Arlington	(Pleasant Run Pkwy. N. Dr.-16th)
		71	1.345	E. 16th	(Volney-Dearborn)
		73	0.909	Prospect	(Olive N.-Keystone Ave. ²)
		75	1.402	Capitol	(37th-Fall Creek Bridge)
		78	1.174	N. Meridian	(46th ² -Westfield Blvd.)

Table 2 (Continued)

<u>CITY</u>	<u>COUNTY</u>	<u>SECTION NUMBER</u>	<u>LENGTH</u>	<u>ROUTE</u>	<u>LOCATION</u>
Indianapolis	Marion	79	0.795	N. Meridian	(57th N. of Westfield-White River Bridge)
		80	0.966	N. 10th	(Oakland-Colorado)
		81	1.061	Northwestern	(32nd-Fall Creek Pky. N. Dr.)
		82	1.496	N. Central Ave.	(Fall Creek Pky. S. Dr. ² -11th)
		83	2.254	Massachusetts Ave.	(Sherman ² -Arlington ²)
		85	0.795	Capitol	(Fall Creek Pky. S. Dr. ² -16th)
		86	2.083	E. Michigan	(N. Kealing-Fulton)
		87	2.822	SR 67 Kentucky	(Olender Dr.- Raymond ²)
		89	1.402	SR 67 Kentucky	(Belmont ² -White River Pky. W. Dr.)
		90	2.178	New York	(Fulton-Sherman ²)
		91	1.231	N. Meridian	(27th-38th ²)
		92	1.572	E. Washington	(Ewing-Whittier Place)
		93	1.667	W. Washington	(Ingomar St.- McClure St.)
		94	2.860	38th St.	(Massachusetts ² - Sherman)

Table 2 (Continued)

<u>CITY</u>	<u>COUNTY</u>	<u>SECTION NUMBER</u>	<u>LENGTH</u>	<u>ROUTE</u>	<u>LOCATION</u>
Indianapolis	Marion	95	1.742	E. Washington	(Post Rd.-Jct. 100 ²)
		96	0.985	E. Washington	(N. Bolton St.- Jct. 100 ²)
		97	1.155	W. 16th St.	(Tremont- Livingston Ave.)
		98	1.269	38th St.	(Station St.-Orchard)
		99	1.439	W. Washington	(Rockville Rd.-Elder)
		100	1.686	38th St.	(Monon R.R., Sutherland- Capitol St.)

REVIEW OF LITERATURE

Since emphasis has been placed on the spectacular fatal accident which occurs principally in rural areas, most of the literature dealing with accidents is concerned with rural accidents. However, one source was found which summarized most of the research previously performed in the area of urban accidents. This publication prepared by the Automotive Safety Foundation in cooperation with the Bureau of Public Roads was a study of traffic controls and roadway elements and their relationship to highway safety.(4) Separate chapters were devoted to the effects of such factors as traffic volume, intersections, driveways, one-way streets, parking, and illumination on urban accident rates. Each chapter contained excellent summaries of the traffic research performed on the particular design characteristic or operational control. One final conclusion of this publication was that more research was needed to evaluate the contribution of each design characteristic or operational control. Excellent features of this work were the detailed author and subject indexes which included every aspect of accident research, including both published and unpublished material.

Roadway Development

Three articles which dealt with the relation of traffic accidents to roadside development on rural highways came to the same basic conclusions. Even though these studies were concerned with rural areas, the results may be useful in urban areas.

Schoppert used multiple correlation techniques to arrive at the following conclusions:(29)

- "1. Motor vehicle accidents are directly related to vehicle volumes and certain physical features of the highway.
2. Access to the highway through driveways or intersections is directly related to accidents at all ADT levels. The number of access points is a reasonably good predictive index of the number of potential accidents within an ADT group.
3. Accidents are essentially chance occurrences resulting from errors in judgment. The number of accidents increase with the number of situations presenting a change in conditions, and therefore requiring a decision on the part of the motor vehicle operator."

In 1957, Woo also used multiple regression analysis to correlate accident rates with roadway factors of rural Indiana highways.(35) The accident rate per mile, instead of the accident rate per million vehicle miles, was used in

his analysis because it presented a better relationship. Four roadway factors were found to be significantly related to accident rate; ADT, congestion index, lane width, and total number of entrances per mile.

In the final report of the Minnesota Roadside Study, Kipp concluded that traffic accidents can not be predicted on the basis of roadway elements and roadside features because of numerous immeasurable factors. However, it was evident that these factors, either alone or in combination with other, did contribute in varying ways to the chance of an accident. The general conclusion was that "the magnitude or frequency of these characteristics governed the extent to which accident potential was generated."(14)

Two other studies have been completed which relate traffic accidents to roadside features in suburban areas. Michigan conducted a research project in the late 1940's and arrived at very general results.(18) The most significant conclusion was that intersections were centers of traffic hazard and that hazard increased as the complexity of the intersection was increased by roadside development.

Peterson, while analyzing traffic accidents on a high volume suburban arterial, arrived at the conclusions that accidents increased at intersections when the ADT increased, the number of intersection approaches increased, or the total width of driveways within two hundred feet of the intersection increased; and that accidents increased on

non-intersection locations when the total number of establishments per mile increased, the ADT increased, of the total number of low volume intersections increased.(35)

The Oregon State Highway Department conducted research to develop equations which could be used to predict accidents on urban extensions of state highways from roadway elements such as ADT, commercial and residential driveways, signalized and non-signalized intersections, and lane width.(11)

The following conclusions were drawn:

- "1. Motor vehicle accident rates are related to certain physical features of urban extensions of the highway system. This relationship is strong enough in the higher ADT ranges to make it possible to predict accident rates with a reasonable degree of accuracy on the basis of known physical features..
2. Accident rates on low volume roads do not have a strong relationship with any roadway feature.
3. Motor vehicle accident rates increase when:
 - a. Number of commercial units adjacent to the section increases.
 - b. Number of traffic signals increase.
 - c. Number of intersections increase.
 - d. Indicated speed decreases.
 - e. Average daily traffic increases.
 - f. Pavement width increases."

Access Control

It was decided at the beginning of this research to limit the sections to non-access controlled locations. This decision was made on the basis that all of the literature dealing with access control stated that its use significantly reduced the number of accidents.

The Bureau of Public Roads has been analyzing data on this subject for several years. Its findings were summarized in "The Federal Role in Highway Safety" as follows:(9)

"Full control of access whereby entrance and exit movements to and from the through-traffic lanes are limited to designated points where these maneuvers can be performed safely has been the most important single factor in accident reduction ever developed. Accident and fatality rates on fully controlled access highways have been only one-third to one-half as great as those on highways with no control of access. This is not due wholly to the control of access feature but to grade separation of intersections, provisions of separate roadways for opposing directions of traffic, and the other design refinements customarily employed in conjunction with access control."

Figure 5 shows some significant results from the available data.

Other Factors

There have been other factors which have been correlated with the accident rate in previous research. Some of these factors or variables are parking, signalization, one-way street operation, illumination, and number of driveways. The research material available on the relationships of these characteristics to accident occurrence often resulted in only general conclusions.

One project, however, found that the removal of curb parking actually reduced urban accidents by more than 16 percent. Also, equivalent space in off street parking facilities was justified by the reduction in economic losses due to accidents and congestion.(9)

One-way street operation has been shown to be an effective measure in accident reduction if it was a part of a well-planned, integrated system; but, where it was inappropriate or inadequate, the number of accidents increased.(4)

Many people forget that the functional purpose of signalization is to bring order to the traffic flow and not safety. Most of the research in this area stated that often accidents increased after signalization with a definite change in the accident pattern.(17)(28)

It has been shown in previous studies that street lighting substantially reduced night accidents if it met some minimum level of illumination.(4) It was noted that

this was especially true for intersectional and pedestrian accidents in urban areas.

Both Head and Schoppert found the number of driveways to be an important factor in the prediction of accidents on urban and rural highways.(11)(29) Another study discovered that commercial driveways had a measurable effect on the accident rate, but residential driveways did not.(14)

To look at the multitude of additional factors which have been associated with accidents in previous research would add many additional pages to this review. It seems sufficient to refer the reader to the first publication mentioned in this review for a summary of the work already accomplished in these other areas of accident research.(4)

Traffic Engineering Improvements

A study was performed in 1959 by the Bureau of Public Roads with the cooperation of the District of Columbia Department of Highways and Traffic in order to estimate how great an increase in traffic capacity could be achieved within the existing right-of-way limits, if all known traffic-control techniques could be adopted.(8) This report presented measures to increase the traffic capacity of an urban arterial; but when the traffic flow is smooth, safety is usually enhanced. This is why this article is included in the review of literature. The possible improvements that could be made to increase the capacity of an urban arterial were classified into three groups;

1. Traffic control measures which require relatively minor expenditures and little or no construction
2. Measures requiring moderate expenses and/or construction
3. Measures requiring major expenditures and construction

Under each of the above groups, a number of methods for improvement were studied. Some of the possible areas for improvement mentioned under group one were:

1. Parking restrictions
2. Turning movement control
3. One-way street operation
4. Improved street system
5. Through street system
6. Signs and markings
7. Street lighting
8. Pedestrian control
9. Enforcement of operations

Some of the improvements which fell under group two were in the following areas:

1. Correction of specific bottlenecks
2. Upgrading of major intersections
3. Upgrading of signalization
4. Resurfacing of existing street
5. Effective night lighting

Improvements in the last category came in the following divisions:

1. At-grade reconstruction of intersections
2. Construction of grade separations
3. Widening or reconstruction of major structures or
even entire streets
4. Creation of additional streets.

DATA COLLECTION

The method of investigation used in this study consisted of taking a large collection of accident data and analysing them relative to accident occurrence. It was believed that an informative pattern would result from the large number of sections chosen. This is basically the same procedure used in the Michigan Study of the late 1940's.(18)

At least three trips were made to each study location. The purpose of the trips were:

1. To obtain maps of each city and initial survey
2. To establish definite section boundaries and collection of pertinent information such as section length, number of intersections, number of driveways, parking conditions, width of street, etc. Appendix A shows the forms that were used to collect the necessary data for each section.
3. To obtain relative volumes and to assign a light, medium, or heavy volume rating to each friction point. A friction point was defined as any point where conflict to the traffic flow might occur. For example, a four-leg intersection comprised two friction points to the arterial but a three-leg intersection had only one friction point.

A fourth trip was made to those sections which had a significant change in the number of accidents during the three study years in order to determine if there had been any definite cause or causes which might explain the variability in the yearly number of accidents.

The independent variables that were analyzed to find their effects on the accident rate are shown in Table 3.

Accident Data

A three year study period was chosen to ensure an adequate size sample of accident data. It was felt that the average number of accidents over a three year period would also eliminate some of the chance occurrence associated with an annual number of traffic accidents. The numbers of accidents occurring on each of the one-hundred test sections were collected for the period January 1, 1963, through December 31, 1965. From this information the number of accidents per mile and the number of accidents per 100 million vehicle miles were calculated and are shown in Table 4.

A majority of the accident data for study sections outside of Indianapolis was collected from the Accident Records Division of the Indiana State Police. Accident data were also obtained from the traffic accident files of the following Indiana cities; Attica, Covington, Frankfort, Kokomo, Lafayette, Logansport, and West Lafayette. Additional information for the Lafayette and Kokomo by-passes was collected from the files of the Indiana State Police Post

Table 3 Independent variables

Number	Variable Description
1	Volume (ADT) on the Arterial in Thousands of Vehicles
2	Intersection per mile
3	Heavy Volume Intersections per Mile (Intersections with Arterial Streets)
4	Medium Volume Intersections per mile (All Cross Streets Except Arterials and Low Volume Local)
5	Traffic Signals per Mile
6	Driveways per Mile
7	Commercial Driveways per Mile
8	Medium and Heavy Volume Commercial Driveways per Mile (Rated on Basis of Commercial Activity)
9	Light Volume Commercial and Residential Driveways per Mile
10	Friction Points per Mile
11	Street Width
12	Number of Moving Lanes
13	Posted Speed Lanes
14	Quality of Signing
15	Quality of Street Markings
16	Parking Allowed on One Side Only
17	Parking Allowed on Two Sides
18	Intersectional Street Lighting Only
19	Continuous Street Lighting
20	Quality of Street Lighting

Table 3 (Continued)

Number	Variable Description
21	Four-way Intersections per Mile
22	One-way Street Operation
23	Three-way Intersections per Mile
24	Urban Design of Pavement Cross-Section
25	Yellow Flashers per Mile
26	Ratio - Commercial Driveways per Mile to Total Number of Driveways per Mile

Table 4 Accident rates for study sections

Section Number	Accidents 100 million vehicle miles	Accidents Mile
1	00000	0
2	1675	9
3	969	5
4	782	4
5	599	4
6	318	2
7	713	5
8	624	5
9	685	6
10	493	6
11	708	9
12	466	6
13	725	10
14	721	15
15	791	12
16	1489	22
17	540	8
18	964	15
19	224	4
20	630	10
21	624	10
22	572	9
23	537	9
24	1225	22
25	1258	23
26	152	3
27	322	6
28	203	4
29	451	9
30	473	9
31	928	17
32	1319	27
33	177	4
34	234	5
35	712	15
36	932	20
37	1042	23
38	966	22
39	222	5
40	1591	37
41	855	20
42	566	13

Table 4 (Continued)

Section Number	Accidents 100 million vehicle miles	Accidents Mile
43	371	9
44	459	11
45	1067	27
46	1378	35
47	463	12
48	737	19
49	748	20
50	829	22
51	1332	27
52	862	25
53	784	23
54	1047	32
55	877	29
56	877	29
57	629	21
58	213	7
59	1461	52
60	770	28
61	564	21
62	945	35
63	798	30
64	268	10
65	604	24
66	227	8
67	793	33
68	1433	63
69	2301	103
70	826	34
71	439	21
72	2629	129
73	1005	50
74	999	50
75	893	46
76	2399	127
77	347	19
78	498	27
79	551	30
80	739	45
81	1408	85
82	963	61
83	115	8
84	501	35
85	862	63

Table 4 (Continued)

Section Number	Accidents 100 million vehicle miles	Accidents Mile
86	750	55
87	29	2
88	920	70
89	456	35
90	599	46
91	640	51
92	712	60
93	343	29
94	619	54
95	283	26
96	573	55
97	796	81
98	900	99
99	863	95
100	665	78

No. 3 in Lafayette and the Howard County Sheriff's Office in Kokomo. In all cases the accident information was taken from investigating officer's accident report forms. (Figures 6 & 7)

For the sections in the Indianapolis area, the accident data were acquired through the city's Bureau of Traffic Engineering which supplied accident data for every intersection on the thirty-two sections in Indianapolis.

Indiana state law requires that all accidents involving a personal injury, death, or property damage of \$50 or more be reported to the police. All of the sources for accident data had accident records based on this criteria except the West Lafayette Police Department, who keeps records of all reported accidents. This diversity was taken into consideration in the final analysis.

The analysis of accident data was limited to the development of spot maps for each section for the individual study years. With over then thousand accidents in the project, the author felt that such analysis was sufficient for the completion of his objectives.

Volume Data

The volume data for sections not in Indianapolis were obtained from the Indiana State Highway Commission, Division of Planning, who had volume counts on every urban extension of the state highway system. The latest counts in the ten

Mail Report To: INDIANA STATE POLICE, INDIANAPOLIS 4, INDIANA

DO NOT WRITE IN THIS SPACE	
(8) TYPE	(9) SOURCE
(10-11) ANALYSIS	(12) LOSS
(13-14-15) LOCATION	(16) ACCIDENT NO

TIME	(17-18) DATE OF ACCIDENT	(19-20) DAY OF WEEK	(21) TIME OF DAY	AM	PM	(22-24) (37) (38-39) (30-31)
------	--------------------------	---------------------	------------------	----	----	------------------------------

L O C A T I O N	PLACE WHERE ACCIDENT OCCURRED: If accident occurred outside of city limits, indicate distance from nearest city or town limits, using two directions, if necessary. Occurred within corporate limits. _____ MILES NORTH. _____ MILES SOUTH. _____ MILES EAST. _____ MILES WEST OF. _____ Occurred outside corporate limits. _____ LIMITS OF _____ City or Town _____ (35-36) (37-38-39-40)					
	ROAD ON WHICH ACCIDENT OCCURRED _____ AT ITS INTERSECTION WITH _____ Name of Street or Major Highway (US or STATE). If no No., use name. Name or Number of intersecting Street or Highway.					
	IF NOT AT INTERSECTION _____ FEET (_____ N _____ S _____ E _____ W) OF _____ Show nearest intersection, house number, or other identifying landmark.					

D O N O T M A R K I N B O X E S	VEHICLE NUMBER 1: (41) (42-43) (44) YEAR MAKE TYPE Sedan, Truck, Bus, etc. LICENSE PLATE Number State Year DRIVER (Print) Last Name First Middle ADDRESS (Print) Street or R.F.D. (45-46) (47) City and State BIRTH DATE AGE SEX DRIVER'S LICENSE Number State Type (49) OWNER Last Name First Middle ADDRESS Street or R.F.D. City State PARTS OF VEHICLE DAMAGED ESTIMATE OF REPAIR \$ VEHICLE REMOVED TO BY (33-34) (35) NAME (Print) Last Name First Middle AGE SEX ADDRESS (124) Street or R.F.D. City (37) State DRIVER PASSENGERS IN VEHICLE NUMBER PEDESTRIAN Other (EXPLAIN) NATURE AND EXTENT OF INJURIES Mark First One That Applies (101)	VEHICLE NUMBER 2: (41) (42-43) (44) YEAR MAKE TYPE Sedan, Truck, Bus, etc. LICENSE PLATE Number State Year DRIVER (Print) Last Name First Middle ADDRESS (Print) Street or R.F.D. (45-46) (47) City and State BIRTH DATE AGE SEX DRIVER'S LICENSE Number State Type (49) OWNER Last Name First Middle ADDRESS Street or R.F.D. City State PARTS OF VEHICLE DAMAGED ESTIMATE OF REPAIR \$ VEHICLE REMOVED TO BY (33-34) (35) NAME (Print) Last Name First Middle AGE SEX ADDRESS (124) Street or R.F.D. City (37) State DRIVER PASSENGERS IN VEHICLE NUMBER PEDESTRIAN Other (EXPLAIN) NATURE AND EXTENT OF INJURIES Mark First One That Applies (101)
--	---	---

DAMAGE TO OTHER PROPERTY	Name of Object (s)	Owner's Name and Address	Nature of Damage
ESTIMATE OF REPAIR \$			

This form is approved by the Superintendent, Indiana State Police, pursuant to Bureau Indiana Statutes 47-1910, Acts 1929, Ch. 46.

FIGURE 6 - INVESTIGATING OFFICERS ACCIDENT REPORT FORM, SIDE ONE.

<p>(9) CHEMICAL TEST Driver 1 2 (Check one) 0 No test offered 1 Test offered but refused 2 Breath test given 3 Blood test given 4 Urine test given</p> <p>(10) ARREST - (Check one) Driver 1 2 0 Not arrested 1 Arrested for D U I 2 Arrested for other violation</p> <p>(11) SPEED LIMIT _____ MPH</p> <p>(12) SPEED BEFORE ACCIDENT Veh 1 _____ MPH Veh 2 _____ MPH</p> <p>(13) CONTRIBUTING CIRCUMSTANCES INDICATED Driver 1 2 1 Speed too fast 2 Failed to yield right of way 3 Drove left of center 4 Improper overtaking 5 Passed stop sign 6 Disregarded traffic signal 7 Followed too closely 8 Made improper turn 9 Other improper driving 10 Inadequate brakes 11 Improper lights 12 Had been drinking</p> <p>(14) VEHICLE DEFECTS Driver 1 2 0 No defects 1 Brakes defective 2 Lights defective 3 Defective steering 4 Puncture or blowout 5 Other defects</p> <p>(15) VISION OBSCURED Driver 1 2 0 Not obscured 1 By building/s 2 By embankment 3 By signboard 4 Trees, crops, etc. 5 By hillcrest 6 _____ (Specify other)</p>	<p>INDICATE ON THIS DIAGRAM WHAT HAPPENED</p> <p style="text-align: right;">DRAW DIAGRAM TO SCALE</p> <p style="text-align: right;">Indicate North by arrow </p> <p>DESCRIBE WHAT HAPPENED: Refer to vehicle by number</p> <p>WHAT DRIVERS WERE GOING TO DO BEFORE ACCIDENT: (16) Driver No 1 was headed N S E W on _____ (Name or number of street or highway) Driver No 2 was headed N S E W on _____ (Name or number of street or highway) (Check applicable items for each driver) Driver 1 Driver 2 0 Passing 1 Backing 2 Start time parked position 1 Turn right 2 Slow or stop 3 Arriving veh. at intersection 3 Turn left 4 Going straight ahead 4 Stopped before applying brakes 5 Make U turn 6 Start in traffic lane 5 Stopped after applying brakes 7 _____ 8 _____ 6 Parked</p> <p>WHAT PEDESTRIAN WAS DOING BEFORE ACCIDENT (17) _____ along _____ Pedestrian was going N S E W across or into _____ Street or Highway From _____ to _____ (N S corner to S E corner or from West side to East side, etc.) (Check one) 0 Not in roadway 1 Walking in roadway with traffic 2 Walking in roadway against traffic 3 Pushing or working on vehicle 4 Getting on or off vehicle 5 Standing in roadway 6 Other working in roadway 7 Playing in roadway 8 Other (Specify actions) 9 Crossing or entering not at intersection 10 Crossing or entering at intersection</p>	<p>CONDITION OF DRIVERS AND PEDESTRIANS (Check one) Driver 1 2 Ped. 0 Had NOT been drinking 1 Obviously drunk 2 Ability impaired 3 Ability not impaired 4 Unknown if impaired (18) (19) 11 Apparently normal 12 Eyesight defective 13 Hearing defective 14 Other defects 15 Illness 16 Fatigued 17 Apparently sobriety 18 Attention diverted 19 Advanced sobriety 20 Other handicaps (Specify other handicaps)</p>					
<p>(20) ROAD DEFECTS 1 Foreign material on surface 2 Loose sand, gravel, etc. 3 Holes, ruts, dips, bumps, etc. 4 Defective shoulders 5 Obstruction not lighted or signaled 6 Standing water, landslide, etc. 7 Obstructed by previous car 8 All other defects</p>	<p>WITNESSES Name _____ Address _____ Location _____ Name _____ Address _____ Location _____</p> <p>POLICE ACTION ARRESTS: Name _____ Charge _____ Name _____ Charge _____</p> <p>INVESTIGATION: Time notified of accident _____ AM _____ PM Time of arrival at the scene _____ AM _____ PM Where else was investigation made? _____ Is investigation complete? Yes No Were photographs taken? Yes No Driver report form furnished to driver No. 1 driver No. 2 SIGNATURE _____ Department _____ Date of report _____</p>						

ARS-1 Investigator's Report Rev. 68

FIGURE 7 - INVESTIGATING OFFICERS ACCIDENT REPORT FORM, SIDE TWO.

counties, not counting Marion County, were made in different years. The years in which the last counts were made in each county are listed below:

Boone	1961	Howard	1964
Carroll	1964	Jasper	1964
Cass	1960	Montgomery	1961
Clinton	1963	Tippecanoe	1960
Fountain	1962	White	1958

Every count taken prior to 1964 was expanded to a 1964 volume. This was accomplished by applying the conversion factors used by the Division of Planning for the Indiana State Highway Commission. Three of the counties had counts taken in 1964 so these values were merely converted to ADT. The others, depending on the year in which the counts were taken, were multiplied by the following factors to get them into 1964 volumes:

Year	Correction from to	Year	Factors (% increase)
1958		1959	2.0
1959		1960	2.0
1960		1961	2.0
1961		1962	3.5
1962		1963	5.5
1963		1964	6.5

All such corrected counts were twenty-four hour weekday volumes taken during different months of the year. Table 5 shows the factors that were then used to convert these twenty-four hour volumes to average daily traffic (ADT) for 1964. The factors in group four, state roads in suburban areas, were used because it was felt these most closely represented the correction factors for urban areas.

Table 5 Factors to Expand 24 Hour Weekday (Mon., Tues., Wed., Thurs.) Volumes to A.D.T. - 1964

Group	<u>Months of the Year</u>											
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
<u>State Roads in Most Rural Areas</u>												
Group I	1.332	1.311	1.217	1.132	1.068	0.965	0.925	0.918	1.014	1.077	1.118	1.172
<u>State Roads in Rural Resort Areas</u>												
Group II	1.608	1.562	1.417	1.308	1.170	0.937	0.861	0.867	1.108	1.299	1.367	1.448
<u>State Roads in Mining Areas</u>												
Group III	1.159	1.167	1.111	0.997	0.965	0.967	0.912	0.872	0.970	0.989	1.054	1.029
<u>State Roads in Suburban Areas</u>												
Group IV	1.223	1.169	1.118	1.044	1.007	0.967	0.940	0.938	0.963	1.011	1.054	1.090
<u>Local Roads in Rural Areas</u>												
Group V	1.292	1.224	1.101	1.026	0.958	0.907	0.910	0.913	1.044	1.044	1.049	1.085

Several counting stations were located on each section. Every one of these counts were updated and converted to a 1964 ADT. To obtain an estimate of the volume on any particular section, the corrected volumes at all of the counting stations were analyzed and a representative value for the volume on the arterial was chosen. Each section was selected on the basis of having similar volumes and characteristics throughout its length. This determined the length of each section.

The volume data for the sections in the Indianapolis area, Marion County, were acquired through William Fehribach in the Bureau of Traffic Engineering for Indianapolis. The data received were the 1964 volume counts used by the Indianapolis Regional Transportation and Development Study. It consisted of computer print-out sheets of the ADT between major intersections on every urban arterial in Indianapolis. Thirty-two sections, with an ADT range from 7000 to 32,000 were selected to give a wide variety of volumes and characteristics.

ANALYSIS OF DATA

Accident Rates

Two forms of accident rates were used as dependent variables in this study to determine which one correlated better with the given independent variables and to see if the same independent variable were important for both forms. The dependent variables were expressed as the number of accidents per 100 million vehicle miles (Y_1) and the number of accidents per mile (Y_2). An expression of the accident rate as an exposure rate (Y_1) was chosen in hope that the volume factor would be minimized as much as possible so that the effect of other factors subject to possible corrective action would be maximized. The Traffic Engineering Handbook suggests that the accident involvement rate be expressed as accidents per 100 million vehicle miles so this form was selected to be one of the dependent variables.(5) The other dependent variable, the number of accidents per mile, (Y_2), was selected because it expresses accident rate in a manner that is easily understood.

Before it was possible to determine an accident rate for each section, it was necessary to find the average number of accidents per year over the three year study period. The average was found simply by dividing the three

year total of accidents on a particular section by three. It was then desired to test the hypothesis that the three yearly numbers of accidents came from the same population. This was achieved by the use of a chi-square test:(7)

$$\chi^2 = \sum_{i=1}^3 \frac{d_i^2}{\bar{x}}$$

Where

d_i = the difference between the number of accidents for the year i and the average number of accidents per year over the three study years

$\bar{x}$ = the average number of accidents per year over the study period.

As an example, suppose that the number of accidents reported for the three years of the study were 22, 31, and 19. The purpose of this procedure was to test the null hypothesis that the true number of accidents for given conditions was constant, in other words, $\bar{x} = n/3$. In this example $n = 72$ accidents; so the estimated expected number of accidents for each year was $\bar{x} = 72(1/3) = 24$, and the corresponding values of $d_i = x_i - \bar{x}$ for the three years were $22 - 24 = -2$, $31 - 24 = 7$, $19 - 24 = -5$. The test statistic, with degrees of freedom $k-1 = 2$, was

$$\chi^2 = \sum_{i=1}^3 \frac{d_i^2}{\bar{x}} = \frac{(-2)^2}{24} + \frac{(7)^2}{24} + \frac{(-5)^2}{24} = 3.25$$

For this test a significance level of $\epsilon = 0.10$ was used. The 0.90 value of χ^2 with 2 degrees of freedom is 4.61. Since $\chi^2 = 3.25$ was less than the table value of $\chi^2 = 4.61$, the test did not show any significant difference in the number of accidents for the three years. Therefore, it was assumed that the number of accidents for each year came from the same population and the average of these would be a good basis on which to calculate the section's accident rate.

When this test was applied to the one-hundred sections, twenty-one of them were out of control, that is they had significant variance in the number of yearly accidents. Of these twenty-one sections, eight were found after a more extensive inventory to have obvious reasons for the variation in their yearly accidents. These conditions were taken into consideration and representative values for the accident rates on these sections were established. A good example of this procedure was Markland Street in Kokomo, Indiana. The number of accidents for each of the study years, 1963 through 1965, were 200, 181, and 157. Upon further investigation, it was found that the only change in this section had been the removal of curb parking during 1964. Therefore, the number of accidents in 1965, 157, was used to calculate the accident rate because it best represented the conditions in 1965 when the field inventories had been made.

Concerning the other thirteen sections that were out of control, there were no obvious reasons for these conditions. However, since a significance level of 0.10 was established at the outset of this testing procedure, it is possible that a "Type I" error could account for the thirteen sections being out of control. A "Type I" error is committed when the hypothesis is really true but is rejected. It was then decided to run one complete analysis including all of the sections and another with the eighty-seven sections in control. Better prediction equations resulted with the inclusion of all sections so it was concluded that the effects of the sections out of control balanced each other sufficiently to be included in further analysis.

Multiple Linear Regression

The twenty-six independent variables used in this research were analyzed by multiple linear regression to develop equations which would predict both the number of accidents per 100 million vehicle miles and the number of accidents per mile for four combinations of the study sections.

The computer program employed for the multiple linear regression analysis was WRAP, or a "tear-down" regression process, which is a least squares technique. The program deck was acquired through the Purdue University Statistical Laboratory Library Program.

This program was used to develop separate equations

for the two dependent variables, accidents per 100 million vehicle miles and accidents per mile using the twenty-six independent variables shown in Table 3. From this technique two regression equations were computed for several groupings of the sections. The first step in the WRAP program was to have all of the independent variables included in a regression equation. After this was done, the program deleted the variable with the lowest F-ratio until a fixed F-ratio or a fixed probability level of 0.9999 was reached.

A test was then conducted on each regression equation to determine if the multiple coefficient of determination, R_k^2 , for k independent variables was significantly smaller than R_{k+1}^2 for (k+1) variables.(3)

The test used was an F-test which determined the first independent variable that did not result in a significant increase in R^2 when it was added to the regression equation. For example, the testing process was started by taking the first variable and checking to see if the value of R^2 significantly increased when two variables were considered. If this check showed a significant increase in R^2 , then the process was carried one step further and so on until the first non-significant increase in R^2 was encountered.

The purpose of this test was to develop simplified equations which could be used to adequately predict accident rates on urban arterials by using a minimum of easily measured variables. The F-test used to determine

this significant increase in R^2 is stated mathematically as follows:

$$F = \frac{\frac{R_j^2 - R_k^2}{j - k}}{\frac{1 - R_j^2}{N - j - 1}}$$

with $(j-k)$ and $(N-j-1)$
degrees of freedom and
where $j = k+1$

F = the calculated F value,

R_j^2 = the multiple coefficient of determination for
"j" independent variables,

R_k^2 = the multiple coefficient of determination for
"k" independent variables,

N = the number of observations,

j = the number of independent variables in the regression equation to be tested for a significant increase in R^2 , and

k = the number of independent variables in the regression equation used to base the significant increase in R^2 .

The significance level for this F -test was set at the .05 level.

Five Phases of the Regression Analysis

The data were separated into the following categories for analysis by multiple linear regression:

1. the one-hundred sections
2. the thirty-five lowest volume sections
3. the thirty-two high volume sections in Indianapolis
4. the sixty-eight two lane facilities
5. the thirty-two four lane or one-way street facilities.

Phase I - The One-hundred Sections

The variables listed in Table 3 represent the independent variables which were considered in the initial analysis for predicting the two accident rates for all of the sections. The means and standard deviations for each of the variables are shown in Table 6, and the simple correlation coefficients between each variable and all other variables are shown in Table 7.

A regression equation utilizing the twenty-six variables was then developed. On the basis of each variable's contribution to the regression equation and other considerations - such as ease of variable measurement, high correlation with another variable, insufficient accuracy in variable measurement, etc., - the independent variables used in the final analysis were determined. The independent variables to obtain separate prediction equation for the two accident rates, Y_1 and Y_2 , are listed in Table 8. The coefficients of the variables used in these multiple regression equations appear in Table 9.

Accidents per 100 Million Vehicle Miles (Y_2)

The prediction equation utilizing the independent variables used in the final analysis for the determination of Y_1 , the number of accidents per 100 million vehicle miles on the one-hundred sections, is as follows:

Table 6 Variable Means and Standard Deviations for the One-Hundred Sections

Variable	Mean	Standard Deviation
1	10.37	7.42
2	12.60	4.52
3	1.85	1.75
4	7.51	4.24
5	1.48	1.88
6	19.89	22.23
7	22.78	17.74
8	20.43	16.08
9	29.52	19.51
10	73.65	24.68
11	35.62	11.75
12	2.51	0.92
13	31.85	4.85
14	1.43	0.61
15	1.34	0.74
16	0.14	0.35
17	0.46	0.50
18	0.39	0.49
19	0.51	0.50
20	1.22	0.75
21	6.02	3.34
22	0.07	0.26
23	6.44	4.27
24	0.73	0.45
25	0.13	0.46
26	47.23	27.04
Y ₁	766.26	459.73
Y ₂	29.00	27.27

TABLE 7

**SIMPLE CORRELATION COEFFICIENTS BETWEEN
EACH VARIABLE AND ALL OTHER VARIABLES
FOR THE ONE-HUNDRED SECTIONS**

TABLE 7

Y(2)	X(1)	0.604415	X(2)	0.354639	X(3)	0.678218	X(4)	-0.045999	
	X(5)	0.796346	X(6)	0.145477	X(7)	0.488586	X(8)	0.456088	
	X(9)	-0.209884	X(10)	0.229632	X(11)	0.497390	X(12)	0.435301	
	X(13)	-0.054177	X(14)	0.088441	X(15)	0.187810	X(16)	-0.076473	
	X(17)	0.229233	X(18)	-0.365711	X(19)	0.485102	X(20)	0.267465	
	X(21)	0.311305	X(22)	0.171888	X(23)	0.103615	X(24)	0.354466	
	X(25)	-0.162026	X(26)	0.422179	X(27)				
CORRELATION MATRIX									
(1, 1)	0.100000E-01	(1, 2)	0.1342625E-00	(1, 3)	0.3867077E-00	(1, 4)	-0.317734E-00	(1, 5)	0.585172E-00
(1, 6)	0.1437674E-00	(1, 7)	0.4576813E-00	(1, 8)	0.4047067E-00	(1, 9)	0.7050163E-00	(1, 10)	0.8085911E-01
(1, 11)	0.6368639E-00	(1, 12)	0.2523419E-00	(1, 13)	0.3901509E-00	(1, 14)	0.4373400E-00	(1, 15)	0.6938520E-01
(1, 16)	0.1754180E-00	(1, 17)	-0.4507125E-00	(1, 18)	0.4368102E-00	(1, 19)	0.3611370E-01	(1, 20)	0.1803974E-00
(1, 21)	0.3956963E-01	(1, 22)	0.1927584E-00	(1, 23)	0.6211444E-00	(1, 24)	0.2630346E-00	(1, 25)	0.6320139E-01
(1, 26)	-0.2031515E-00	(1, 27)	0.2996737E-00	(1, 28)	-0.6981716E-01	(1, 29)	0.8716359E-01	(1, 30)	0.2873555E-00
(2, 2)	0.100000E-01	(2, 3)	0.3167706E-00	(2, 4)	0.1205601E-02	(2, 5)	0.3087349E-00	(2, 6)	0.2629607E-00
(2, 7)	0.1289473E-00	(2, 8)	0.6893777E-00	(2, 9)	0.3816991E-00	(2, 10)	0.7031431E-00	(2, 11)	0.3360970E-01
(2, 12)	0.9862711E-01	(2, 13)	-0.3858659E-01	(2, 14)	0.2601395E-00	(2, 15)	-0.1841718E-00	(2, 16)	0.1560123E-00
(2, 17)	0.2962422E-00	(2, 18)	0.2816868E-00	(2, 19)	-0.1871175E-00	(2, 20)	-0.1871175E-00	(2, 21)	0.1279306E-00
(2, 22)	0.4231446E-00	(2, 23)	0.9772258E-01	(2, 24)	0.2247491E-00	(2, 25)	0.3762138E-00	(2, 26)	0.1137519E-00
(2, 27)	0.3753646E-00	(2, 28)	0.1725642E-00	(2, 29)	-0.9777186E-01	(2, 30)	0.2630561E-00	(2, 31)	0.2740407E-01
(3, 3)	0.100000E-01	(3, 4)	-0.1295445E-00	(3, 5)	0.3552731E-01	(3, 6)	0.3204629E-00	(3, 7)	-0.542137E-01
(3, 8)	0.4706345E-01	(3, 9)	0.5128690E-00	(3, 10)	0.3993029E-00	(3, 11)	-0.9373122E-01	(3, 12)	-0.2257713E-00
(3, 13)	-0.5691744E-00	(3, 14)	0.2211445E-00	(3, 15)	0.3488460E-00	(3, 16)	0.1704744E-00	(3, 17)	-0.2847192E-01
(3, 18)	0.1423127E-00	(3, 19)	0.3488460E-00	(3, 20)	0.2255492E-01	(3, 21)	0.4092767E-00	(3, 22)	
(4, 4)	0.100000E-01	(4, 5)	0.1404134E-00	(4, 6)	-0.1095656E-00	(4, 7)	0.3537402E-00	(4, 8)	0.3016147E-00
(4, 9)	0.1694726E-00	(4, 10)	0.1768588E-00	(4, 11)	0.4955089E-00	(4, 12)	0.4132098E-00	(4, 13)	-0.1341450E-00
(5, 5)	0.100000E-01	(5, 6)	0.2968278E-01	(5, 7)	0.1423761E-00	(5, 8)	0.5287723E-00	(5, 9)	0.1828421E-00
(5, 10)	-0.1091928E-00	(5, 11)	0.2863171E-00	(5, 12)	0.2016776E-00	(5, 13)	0.1668764E-00	(5, 14)	0.3722450E-00
(5, 15)	-0.1199332E-00	(5, 16)	0.3239816E-00	(5, 17)		(5, 18)		(5, 19)	
(6, 6)	0.100000E-01	(6, 7)	0.5343885E-00	(6, 8)	0.5063288E-00	(6, 9)	0.7024072E-00	(6, 10)	0.5415976E-00
(6, 11)	0.8872779E-00	(6, 12)	0.1278034E-00	(6, 13)	0.2166810E-00	(6, 14)	-0.1403768E-00	(6, 15)	-0.1167868E-00
(6, 16)	-0.8475177E-01	(6, 17)	-0.1276108E-00	(6, 18)	0.8409219E-01	(6, 19)	-0.1083097E-01	(6, 20)	-0.1747427E-00
(6, 21)	0.5218015E-01	(6, 22)	0.1072700E-00	(6, 23)	0.1560917E-00	(6, 24)	-0.5662659E-01	(6, 25)	-0.4543661E-01
(6, 26)	-0.1545665E-00	(6, 27)	0.2938731E-00	(6, 28)	0.1242692E-00	(6, 29)	0.5036916E-01	(6, 30)	
(7, 7)	0.100000E-01	(7, 8)	0.9791362E-00	(7, 9)	-0.2017566E-00	(7, 10)	0.5415976E-00	(7, 11)	-0.1167868E-00
(7, 12)	0.3024201E-00	(7, 13)	-0.6620131E-01	(7, 14)	0.2060029E-01	(7, 15)	-0.1747427E-00	(7, 16)	-0.4543661E-01
(7, 17)	0.2643464E-00	(7, 18)	0.3477244E-01	(7, 19)	0.7210626E-01	(7, 20)	0.6678441E-00	(7, 21)	0.2667545E-00
(7, 22)	0.2589507E-00	(7, 23)	0.2177343E-01	(7, 24)	0.4156100E-01	(7, 25)	-0.7419663E-01	(7, 26)	0.2550563E-00
(8, 8)	0.100000E-01	(8, 9)	-0.2485316E-00	(8, 10)	0.5177094E-00	(8, 11)	-0.9460360E-01	(8, 12)	0.2550563E-00
(8, 13)	-0.6850350E-01	(8, 14)	-0.1100674E-01	(8, 15)	-0.1700759E-00	(8, 16)	-0.6859028E-01	(8, 17)	0.2235920E-00
(8, 18)	-0.6125775E-01	(8, 19)	0.685458E-01	(8, 20)	0.7093531E-01	(8, 21)	0.6654272E-00	(8, 22)	
(8, 23)	-0.2165885E-01	(8, 24)	0.5744649E-00	(8, 25)		(8, 26)		(8, 27)	
(9, 9)	0.100000E-01	(9, 10)	0.5744649E-00	(9, 11)	-0.8142317E-01	(9, 12)	0.1327459E-01	(9, 13)	

TABLE 7 (CONT'D)

(9,13)	-0.117428E-30	(9,14)	-0.2246852E-01	(9,15)	-0.6888194E-01	(9,16)	0.145093CE-00
(9,17)	0.1454997E-01	(9,18)	0.2351783E-00	(9,19)	-0.8089700E-01	(9,20)	0.1321463E-00
(9,21)	-0.1295566E-00	(9,22)	-0.1163506E-00	(9,23)	0.1906169E-00	(9,24)	0.1694197E-00
(9,25)	-0.4194943E-02	(9,26)	-0.6910799E-00	(10,1)	0.9378516E-01	(10,11)	-0.3220294E-00
(10,10)	0.1000000E-01	(10,11)	0.1155045E-00	(10,12)	0.1430304E-00	(10,13)	0.1613757E-00
(10,14)	-0.1185533E-00	(10,15)	-0.1981500E-00	(10,16)	0.2640599E-00	(10,21)	0.2338241E-00
(10,18)	0.7566735E-01	(10,19)	0.1741662E-00	(10,20)	0.2797617E-00	(10,25)	0.3576125E-01
(10,22)	-0.9661876E-01	(10,23)	0.3333746E-00	(11,1)	0.6566816E-00	(11,11)	0.2468003E-00
(10,26)	-0.1004733E-00	(11,12)	0.6566816E-00	(11,13)	0.1505889E-00	(11,14)	0.4404964E-00
(11,11)	0.1000000E-01	(11,16)	-0.1076772E-00	(11,17)	0.5328590E-00	(11,18)	-0.4404964E-00
(11,15)	0.2874134E-00	(11,20)	0.2537904E-00	(11,21)	0.2514266E-00	(11,22)	0.1632656E-00
(11,19)	0.435545E-00	(11,24)	0.4696108E-00	(11,25)	-0.2020823E-00	(11,26)	0.2360211E-00
(11,23)	-0.5358608E-01	(12,1)	0.3537547E-00	(12,11)	0.2737755E-00	(12,15)	0.3222453E-00
(12,12)	0.1000000E-01	(12,17)	0.796769E-01	(12,18)	-0.4251301E-00	(12,19)	0.3511175E-00
(12,16)	-0.1676061E-01	(12,21)	-0.3372871E-02	(12,22)	0.1475675E-00	(12,23)	-0.6311176E-01
(12,24)	0.1426657E-00	(12,25)	-0.1576554E-00	(12,26)	0.1858304E-00	(13,1)	-0.1247093E-00
(13,13)	0.1000000E-01	(13,14)	-0.3272373E-01	(13,15)	0.1992358E-01	(13,20)	-0.2529488E-00
(13,17)	-0.1874555E-00	(13,18)	-0.2213721E-00	(13,21)	-0.1008513E-00	(13,24)	-0.3760861E-00
(13,21)	-0.3547041E-00	(13,22)	-0.239382E-01	(13,23)	-0.1549536E-00	(14,1)	0.2397443E-00
(13,25)	-0.6301595E-01	(13,26)	0.9715252E-01	(14,16)	-0.1917274E-00	(14,21)	0.1253362E-00
(14,14)	0.1000000E-01	(14,15)	0.6365718E-00	(14,20)	0.1234302E-00	(14,25)	0.5055004E-01
(14,18)	-0.1737820E-01	(14,19)	0.2009554E-00	(14,24)	0.2091287E-00	(15,18)	-0.1183742E-00
(14,22)	0.1290793E-00	(14,23)	-0.1554350E-00	(15,17)	0.2001442E-00	(15,22)	0.1922910E-00
(14,26)	-0.8112961E-01	(15,16)	-0.1468641E-00	(15,21)	0.4346832E-01	(15,26)	0.7414186E-01
(15,15)	0.1000000E-01	(15,20)	-0.4525644E-01	(15,25)	-0.710508E-01	(16,19)	-0.6572105E-01
(15,19)	0.1263409E-00	(15,24)	0.1896427E-00	(16,18)	0.1500002E-00	(16,23)	0.1141808E-00
(16,16)	0.1000000E-01	(16,17)	-0.3723830E-00	(16,21)	-0.1111255E-01	(17,23)	0.3209434E-00
(16,20)	0.3569793E-01	(16,25)	-0.5119280E-01	(17,18)	-0.1620777E-00	(17,24)	0.3161156E-00
(16,24)	0.1804630E-00	(17,17)	0.1000000E-01	(17,22)	0.2972525E-00	(18,21)	-0.2334595E-01
(17,17)	0.1000000E-01	(17,21)	0.3943548E-00	(17,26)	0.2661475E-01	(18,25)	0.1301304E-00
(17,25)	-0.1729678E-00	(18,18)	0.1000000E-01	(18,19)	-0.8157450E-00	(19,22)	0.1121147E-00
(18,18)	0.1000000E-01	(18,22)	-0.5965937E-01	(18,23)	-0.3936018E-01	(19,26)	0.1660049E-00
(18,26)	-0.2460189E-00	(19,20)	0.5058231E-00	(19,24)	0.3501020E-00	(20,23)	-0.2154052E-02
(19,19)	0.1000000E-01	(20,21)	0.4119340E-00	(20,25)	-0.2508387E-01	(21,24)	0.3497182E-00
(19,23)	0.1485314E-00	(21,22)	-0.1628674E-01	(21,26)	-0.1628674E-01	(22,25)	-0.7726079E-01
(20,20)	0.1000000E-01	(22,23)	-0.1482722E-00	(23,24)	0.1106500E-00	(23,26)	0.8734763E-01
(20,24)	0.4272773E-00	(24,25)	-0.2390897E-01	(24,26)	-0.3622412E-01	(24,26)	0.8734763E-01
(21,21)	0.1000000E-01	(25,26)	-0.3622412E-01	(26,26)	0.1000000E-01	(26,26)	0.1000000E-01
(21,25)	-0.4085071E-01	(26,26)	0.1000000E-01				
(22,22)	0.1000000E-01						
(22,26)	0.7340531E-01						
(23,23)	0.1000000E-01						
(24,24)	0.1000000E-01						
(25,25)	0.1000000E-01						
(26,26)	0.1000000E-01						

XY CORRELATION COEFFICIENTS

Y(1)	X(1)	-0.000466	X(2)	0.365028	X(3)	0.531930	X(4)	0.262767
	X(5)	0.477927	X(6)	0.075545	X(7)	0.233713	X(8)	0.239164
	X(9)	-0.109321	X(10)	0.271143	X(11)	0.099138	X(12)	-0.047617
	X(13)	-0.340958	X(14)	-0.145560	X(15)	-0.178333	X(16)	0.159043
	X(17)	0.144049	X(18)	-0.034787	X(19)	0.176139	X(20)	0.236872
	X(21)	0.352839	X(22)	0.050509	X(23)	0.116673	X(24)	0.336175
	X(25)	-0.083651	X(26)	0.192281	X(27)			

Table 8 Independent Variables Used in the Final Multiple
Linear Regression Analysis for the One-Hundred
Sections

Number	Variable Description
1	Volume (ADT) on the arterial section in thousands of vehicles
3	Heavy volume intersections per mile
4	Medium volume intersections per mile
5	Traffic Signals per mile
6	Driveways per mile
9	Light volume commercial and residential driveways per mile
10	Friction points per mile
11	Street width
16	Parking allowed on one side only
23	3 way intersections per mile
24	Urban design of Pavement Cross Section

Table 9 Coefficients for Multiple Linear Regression
Equations for the One-Hundred Sections

Dependent Variables Independent Variables	Accidents per 100 million vehicle miles		Accidents per mile
	Y_1	Y_2^*	Y_2
Constant	468.093	-0.261	0.576
X_1	<u>-26.856</u> **	<u>1.256</u> **	<u>1.661</u> **
X_3	70.040	3.909	2.994
X_4			1.166
X_5	<u>118.195</u> **	<u>6.086</u> **	<u>6.391</u> **
X_6			0.267
X_9	-7.278		-0.341
X_{10}	6.200		
X_{11}			-0.468
X_{16}	217.246		
X_{23}			-0.833
X_{24}			8.519
R	0.724	0.859	0.895
R^2	0.52	0.74	0.80

* This equation represents the simplified prediction equation. None is shown for Y_1 as the two equations were the same.

**The coefficients underlined represent the most significant variables in the regression equation.

$$Y_1 = 468.093 - 26.856X_1 + 70.040X_3 + 118.195X_5 - 7.278X_9 \\ + 6.200X_{10} + 217.246X_{16}$$

The multiple correlation coefficient, R , equals 0.724; and the coefficient of determination, R^2 , is 0.52 or approximately 52 percent of the variation in the accident rate is explained by the regression equation. The variables that were most significant in this regression analysis are the number of traffic signals per mile (X_5) and the volume on the arterial (X_1). Other variables used in this equation are the number of heavy volume intersections per mile (X_3), the number of light volume commercial and residential driveways per mile (X_9), the total number of friction points per mile (X_{10}), and whether parking was prohibited or allowed on only one side (X_{16}). These independent variables had the following simple correlation coefficients with the dependent variable, accidents per 100 million vehicle miles.

Independent Variable	Simple Correlation Coefficients
X_1	-0.0004
X_3	0.532
X_5	0.478
X_9	-0.109
X_{10}	0.271
X_{16}	0.159

No simplified equation was developed for this regression equation because the break-off point using the previously mentioned F -test coincided with the last variable used in

the above equation.

Accidents per Mile (Y_2)

The prediction equation utilizing the independent variables used in the final analysis for Y_2 , the number of accidents per miles, is as follows:

$$Y_2 = 0.576 + 1.661X_1 + 2.994X_3 + 1.166X_4 + 6.391X_5 + 0.267X_6 \\ - 0.341X_9 - 0.468X_{11} - 0.833X_{23} + 8.519X_{24}$$

The multiple correlation coefficient, R , is equal to 0.895, and the coefficient of determination, R^2 , is 0.80. This means that 80 percent of the variation in the number of accidents per mile is explained by the combination of the variables in the above equation. Again the variables that were most significant in the regression analysis are the number of traffic signals per mile (X_5) and the A.D.T. on the arterial (X_1). Other variables that were used in these equations are the number of heavy volume intersections per mile (X_3), the number of medium volume intersections per mile (X_4), the number of driveways per mile (X_6), the number of light volume commercial and residential driveways per mile (X_9), the street width (X_{11}), the number of three-way intersections per mile (X_{23}), and the type of pavement cross-section (urban or rural) (X_{24}). These independent variables had the following simple correlation coefficients with the dependent variable, accidents per mile.

Independent Variable	Simple Correlation Coefficients
X_1	0.684
X_3	0.678
X_4	-0.046
X_5	0.796
X_6	0.145
X_9	-0.209
X_{11}	0.497
X_{23}	0.104
X_{24}	0.354

The simplified regression equation for predicting the number of accidents per mile for these one-hundred sections is as follows:

$$Y_2 = -0.261 + 1.256X_1 + 3.909X_3 + 6.086X_5$$

The multiple correlation coefficient, R , equals 0.859; and the coefficient of determination, R^2 , is 0.74, or 74 percent of the variability in the dependent variable is explained by these three variables; volume or ADT, (X_1), number of heavy volume intersections per mile, (X_3), and the number of traffic signals per mile, (X_5).

Phase II - Thirty-five Low Volume Sections

The variables listed in Table 3 represent the independent variables which were considered in the analysis for predicting the two accident rates, Y_1 and Y_2 , for thirty-five sections with an ADT range from 1200 to 5800. All of these sections were two-lane facilities. The means and standard deviations for each of the independent variables are shown in Table 10. The means and standard deviations for the dependent variables in this phase are as follows:

Dependent Variable	Mean	Standard Deviation
Y_1	665.80	393.43
Y_2	9.40	6.48

Table 11 shows the simple correlation coefficients between each variable and all other variables. The independent variables used in the final multiple linear regression analysis to obtain the separate prediction equations for Y_1 and Y_2 are listed in Table 12. The coefficients of the variables used in these multiple regression equations appear in Table 13.

Accidents per 100 Million Vehicle Miles (Y_1)

The prediction equation using the final independent variables for the determination of Y_1 , the number of accidents per 100 million vehicle miles on the thirty-five lowest volume sections, is the following:

Table 10 Variable Means and Standard Deviations for the
Thirty-five Low Volume Sections.

Variable	Mean	Standard Deviation
1	3.903	1.425
2	11.57	3.24
3	1.17	1.10
4	7.88	3.39
5	0.43	0.88
6	48.11	15.31
7	18.03	11.62
8	16.60	11.71
9	31.40	16.14
10	72.23	18.01
11	28.34	8.30
12	2.00	0.00
13	30.29	1.69
14	1.29	0.57
15	1.00	0.73
16	0.14	0.36
17	0.31	0.47
18	0.63	0.49
19	0.23	0.43
20	1.09	0.82
21	5.83	2.90
22	0.00	0.00
23	5.71	3.76
24	0.57	0.50
25	0.31	0.72
26	38.86	22.06

TABLE II

SIMPLE CORRELATION COEFFICIENTS BETWEEN
EACH VARIABLE AND ALL OTHER VARIABLES
FOR THE THIRTY-FIVE LOW VOLUME SECTIONS

TABLE II (CONT'D)

(9,13)	0.1358426E-00	(9,14)	-0.140038E-00	(9,15)	-0.2980452E-00	(9,16)	0.1488531F-00
(9,17)	-0.1098808E-00	(9,18)	0.2497996E-00	(9,19)	-0.9495798E-01	(9,20)	0.2446534E-00
(9,21)	-0.3434911E-00	(9,22)	0.	(9,23)	0.3013178E-00	(9,24)	0.1088845E-00
(9,25)	-0.4521788E-01	(9,26)	-0.7343329E 00	(10,12)	0.	(10,13)	-0.6985061E-01
(10,10)	0.1C00000E 01	(10,11)	0.1982370E-00	(10,16)	0.2017696E-00	(10,17)	0.9531607E-01
(10,14)	-0.2946924E-00	(10,15)	-0.444838E-00	(10,20)	0.3101815E-00	(10,21)	0.2250976E-00
(10,18)	C.1498355E-00	(10,19)	0.1156725E-00	(10,24)	0.2741918E-01	(10,25)	0.4430913E-01
(10,22)	0.	(10,23)	0.2437104E-00	(11,13)	-0.1329828E-00	(11,14)	-0.1503375E-C1
(10,26)	-0.8C902335E-01	(11,12)	0.	(11,17)	0.7616445E 00	(11,18)	-0.2280180E-00
(11,11)	C.1C00000E 01	(11,16)	0.1126509E-00	(11,21)	0.4148105E-00	(11,22)	0.
(11,15)	-0.9741165E-02	(11,20)	0.3421875E-00	(11,25)	-0.5807592E-01	(11,26)	0.2885806E-00
(11,19)	0.3265450E-00	(11,24)	0.5444854E 00	(12,14)	0.	(12,15)	0.
(11,23)	-0.3161295E-00	(12,13)	0.	(12,18)	0.	(12,19)	0.
(12,12)	C.	(12,17)	0.	(12,22)	0.	(12,23)	0.
(12,16)	0.	(12,21)	0.	(12,26)	0.	(13,16)	-0.7001385E-01
(12,24)	C.	(12,25)	0.	(13,15)	0.	(13,20)	-0.2309866E-00
(13,13)	0.1000000E 01	(13,14)	-0.8684126E-01	(13,19)	-0.9335186E-01	(13,24)	-0.1980291E-00
(13,17)	-0.1161049E-00	(13,18)	-0.2231000E-00	(13,23)	-0.7929383E-01	(14,17)	0.9349470F-C1
(13,21)	-C.2253039E-00	(13,22)	0.	(14,16)	-0.2067245E-00	(14,21)	0.4799956E-01
(13,25)	0.1681067E-00	(13,26)	-0.8562096E-01	(14,20)	0.2602431E-00	(14,25)	0.2043542E-00
(14,14)	0.1C00000E 01	(14,15)	0.5648790E 00	(14,24)	0.2923528E-01	(15,18)	0.8245457E-01
(14,18)	-0.1347402E-00	(14,19)	0.8613523E-01	(15,17)	0.1716429E-00	(15,22)	0.
(14,22)	0.	(14,23)	-0.7023751E-01	(15,21)	0.1391376E-01	(15,26)	0.7511361E-01
(14,26)	-0.1526819E-00	(15,16)	-0.1138950E-00	(15,25)	0.1125495E-00	(16,19)	0.1666667E-00
(15,15)	0.1C00000E 01	(15,20)	-0.4942438E-01	(16,22)	0.	(16,23)	0.1195465E-00
(15,19)	-0.1897583E-00	(15,24)	0.8050765E-01	(16,26)	0.3647250E-01	(17,20)	0.2334131E-00
(15,23)	-0.2256555E-C0	(16,17)	-0.2763854E-00	(17,19)	0.7119018E-01	(17,24)	0.4619349E-00
(16,16)	0.1C00000E 01	(16,21)	-0.3258824E-01	(17,23)	-0.3130191E-00	(18,21)	-0.8732232E-01
(16,20)	0.5787991E-01	(16,25)	-0.1812312E-00	(18,20)	-0.6497137E-01	(18,25)	0.7159032E-02
(16,24)	C.3535534E-00	(17,18)	-0.1164568E-00	(18,24)	-0.1877669E-00	(19,22)	0.
(17,17)	0.1C00000E 01	(17,22)	0.	(19,21)	0.2702109E-00	(19,26)	0.1725311E-00
(17,21)	0.3629378E-00	(17,26)	0.1346323E-00	(20,22)	0.	(20,23)	-0.1925580E-00
(17,25)	-C.1266730E-00	(18,19)	-0.7081133E 00	(20,26)	-0.1622868E-00	(21,24)	0.8929307E-01
(18,18)	0.1C00000E 01	(18,23)	0.6834980E-01	(21,23)	-0.5670712E 00	(22,25)	0.
(18,22)	0.	(19,20)	0.5329775E 00	(22,24)	0.	(23,26)	-0.6854164E-01
(18,26)	-0.1600373E-00	(19,24)	0.3339115E-00	(23,25)	0.8863182E-01	(24,26)	0.7585374E-02
(19,19)	C.1000000E 01	(20,21)	0.3281996E-00	(24,25)	0.1397998E-00	(25,25)	C.1C00000E 01
(20,20)	C.1C00000E 01	(20,25)	0.1C29892E-00	(25,26)	0.4931009E-01	(26,26)	0.1C00000E 01
(20,24)	0.3C89546E-00	(21,22)	0.	(26,25)	0.		
(21,21)	0.1C00000E 01	(21,26)	0.2138803E-00				
(21,25)	-C.1610725E-02	(22,23)	0.				
(22,22)	C.	(23,24)	-0.2002077E-01				
(22,26)	C.	(24,25)	0.1397998E-00				
(23,23)	C.1C00000E 01	(25,26)	0.4931009E-01				
(24,24)	0.1C00000E 01						
(25,25)	C.1C00000E 01						
(26,26)	0.1C00000E 01						

X(12) IS CONSTANT
X(22) IS CONSTANT

Y(2)

X(1)	0.453549	X(2)	0.354505	X(3)	0.147158	X(4)	0.217423
X(5)	0.097526	X(6)	0.393522	X(7)	0.533817	X(8)	0.470083
X(9)	0.024854	X(10)	0.556116	X(11)	0.186553	X(12)	-0.
X(13)	-0.144965	X(14)	-0.221940	X(15)	-0.249459	X(16)	0.562362
X(17)	0.034682	X(18)	0.140692	X(19)	0.051124	X(20)	0.071017
X(21)	0.145882	X(22)	-0.	X(23)	0.203857	X(24)	0.216900
X(25)	0.029059	X(26)	C.303757	X(1)			

Table 12 Independent Variables Used in the Final Multiple Linear Regression Analysis for the Thirty-Five Low Volume Sections.

Number	Variable Description
1	Volume on the arterial section (ADT) in thousands of vehicles
8	Heavy and Medium Volume Commercial Driveways/mile
9	Light Volume Commercial and Residential Driveways/mile
11	Street width - feet
15	Quality of Street Markings
16	Parking allowed on one side only
17	Parking allowed on two sides
18	Intersectional Street Lighting only
19	Continuous Street Lighting
20	Quality of Lighting
21	4-way intersections/mile
23	3-way intersections/mile

Table 13 Coefficients for Multiple Linear Regression Equations for the Thirty-Five Low Volume Sections.

Dependent Variables Independent Variables	Accidents/ 10^8 Vehicle Miles		Accidents/Mile	
	Y_1^*	Y_1	Y_2^*	Y_2
Constant	791.602	924.951	3.789	7.381
X_1				1.030
X_8		7.035	0.252	0.309
X_9				0.107
X_{11}		- 31.862		-0.545
X_{15}	-183.906	-208.687		-1.276
X_{16}	<u>406.724**</u>	<u>718.199**</u>	<u>10.032**</u>	<u>12.731**</u>
X_{17}		544.930		8.680
X_{18}		-103.524		
X_{19}		-357.450		
X_{20}				-1.115
X_{21}		68.652		0.408
X_{23}		36.500		
R	4.583	.824	.723	.845
R^2	.29	.68	.52	.71

*Simplified prediction equation

**Underlined coefficients are the most significant variables in the regression analysis

$$\begin{aligned}
 Y_1 = & 924.951 + 7.035X_8 - 31.862X_{11} - 208.687X_{15} + 718.199X_{16} \\
 & + 544.930X_{17} - 103.524X_{18} - 357.450X_{19} + 68.652X_{21} \\
 & + 36.500X_{23}
 \end{aligned}$$

The multiple correlation coefficient, R , equals 0.824; and the coefficient of determination, R^2 , equals 0.68 or approximately 68 percent of the variability in the accident rate Y_1 is explained by the above regression equation. The variable that was most significant in the regression analysis is whether curb parking was allowed only on one side of the street or no parking was permitted (X_{16}). The other variables used in this equation are the number of heavy and medium volume commercial driveways per mile (X_8), the street width (X_{11}), the quality of the street markings (X_{15}), whether curb parking was allowed on both sides (X_{17}), whether only intersectional street lighting existed (X_{18}), whether continuous street lighting existed (X_{19}), the number of 4-way intersections per mile (X_{21}), and the number of 3-way intersections per mile (X_{23}). These independent variables had the following simple correlation coefficients with the dependent variable Y_1 :

Independent Variable	Simple Correlation Coefficients
X_8	0.175
X_{11}	-0.009
X_{15}	-0.389
X_{16}	0.414
X_{17}	0.001

Independent Variable	Simple Correlation Coefficients
X_{18}	0.147
X_{19}	-0.118
X_{21}	0.197
X_{23}	0.226

A simplified regression equation for predicting the number of accidents/100 million vehicle miles for these particular low volume sections is the following:

$$Y_1 = 791.602 - 183.906X_{15} + 406.724X_{16}$$

The multiple correlation coefficient, R , equals 0.538; and the coefficient of determination, R^2 , is 0.29, or 29 percent of the variability in the dependent variable Y_1 is explained by these two variables, the quality of the street markings (X_{15}), and whether parking was prohibited or allowed on one side (X_{16}). In this particular case, the results of applying the F-test to determine a simplified equation for the original regression equation led to a large reduction in R^2 or, in other words, the simplified equation is not adequate in comparison to the initial equation.

Accidents per Mile (Y_2)

The prediction equation utilizing the independent variables used in the final analysis for the determination of Y_2 , of accidents per mile on these low volume two-lane facilities, is as follows:

$$\begin{aligned}
 Y_2 = & 7.381 + 1.030X_1 + 0.309X_8 + 0.107X_9 - 0.545X_{11} \\
 & - 1.276X_{15} + 12.731X_{16} + 8.680X_{17} - 1.115X_{20} \\
 & + 0.498X_{21}
 \end{aligned}$$

The multiple correlation coefficient, R , is equal to 0.845; and the coefficient of determination, R^2 , equals 0.71. This means that 71 percent of the variability in the dependent variable (Y_2) is explained by the variables used in the regression equation. The variable that was most significant in this regression analysis is whether parking was allowed on one side only (X_{16}). The other variables used in this equation are the volume (ADT) on the arterial (X_1), the number of heavy and medium volume commercial driveways per mile (X_8), the number of light volume commercial and residential driveways per mile (X_9), the street width (X_{11}), the quality of the street markings (X_{15}), whether parking was allowed on both sides (X_{17}), the quality of the street lighting (X_{20}), and the number of 4-way intersections per mile. These independent variables had the following simple correlation coefficients with the dependent variable Y_2 :

Independent Variable	Simple Correlation Coefficients
X_1	0.454
X_8	0.470
X_9	0.025
X_{11}	0.187
X_{15}	-0.249

Independent Variable	Simple Correlation Coefficients
X ₁₆	0.562
X ₁₇	0.035
X ₂₀	0.071
X ₂₁	0.146

A simplified equation for predicting the number of accidents per mile for these low volume sections is the following:

$$Y_2 = 3.789 + 0.252X_8 + 10.032X_{16}$$

The multiple correlation coefficient, R , equals 0.723; and the coefficient of determination, R^2 , is 0.52. This means that this simplified equation explains approximately 52 percent of variability in the dependent variable (Y_2). The two independent variables in this equation are the number of heavy and medium volume commercial driveways per mile (X_8), and whether parking was permitted on only one side (X_{16}).

Phase III - Thirty-two High Volume Sections

The variables listed in Table 3 also represent the independent variables which were considered in the analysis for predicting the two accident rates, Y_1 and Y_2 , for the thirty-two high volume sections in Indianapolis, Indiana. The volume range is from an ADT of 7,000 to an ADT of 32,000, with the greater portion of the sections having ADTs over 15,000. The means and standard deviations for each of the independent variables are shown in Table 14. The means and

Table 14 Variable Means and Standard Deviations for the
 Thirty-Two High Volume Sections in Indianapolis

Variable	Mean	Standard Deviation
1	18.456	6.590
2	14.12	4.86
3	2.59	1.76
4	5.31	3.89
5	3.09	1.80
6	54.72	26.43
7	29.06	21.21
8	24.56	18.53
9	30.69	21.58
10	77.38	26.50
11	43.91	13.24
12	3.31	1.09
13	32.81	4.00
14	1.66	0.54
15	1.78	0.49
16	0.03	0.18
17	0.66	0.48
18	0.09	0.30
19	0.84	0.37
20	1.25	0.67
21	6.09	2.63
22	0.16	0.37
23	7.59	4.57
24	0.88	0.34
25	0.00	0.00
26	57.72	28.40

standard deviations for the dependent variables in this phase are the following:

Dependent Variable	Mean	Standard Deviation
Y_1	756.219	461.51
Y_2	47.834	26.85

Table 15 shows the simple correlation coefficients between each variable and all other variables. The independent variables used in the final multiple linear regression analysis to obtain the separate prediction equations for Y_1 and Y_2 are listed in Table 16. The coefficients of the variables used in these multiple regression equations are shown in Table 17.

Accidents/100 Million Vehicle Miles

The prediction equation utilizing the independent variables used in the final analysis for the determination of Y_1 , the number of accidents per 100 million vehicle miles on the thirty-two high volume sections in Indianapolis, is the following:

$$Y_1 = 728.943 + 167.458X_5 + 1.585X_6 - 4.660X_9 - 15.239X_{11} + 988.036X_{16} + 310.398X_{17}$$

The multiple correlation coefficient, R , is equal to 0.862; and the coefficient of determination, R^2 , equals 0.74. In other words, approximately 74 percent of the

TABLE 15 (CONT'D)

CORRELATION MATRIX

(1, 1)	0.100000E 01	(1, 2)	-0.3564673E-01	(1, 3)	0.2332378E 00	(1, 4)	-0.6426633E-01	(1, 5)	0.1165811E 00
(1, 6)	0.2423809E 00	(1, 7)	0.5741631E 00	(1, 8)	0.6050584E 00	(1, 9)	-0.2257059E 00	(1, 10)	0.2138890E 00
(1, 11)	0.5769372E 00	(1, 12)	0.5117898E 00	(1, 13)	0.2933489E 00	(1, 14)	0.2335395E 00	(1, 15)	0.1505162E 00
(1, 16)	-0.1767658E 00	(1, 17)	-0.4545463E-01	(1, 18)	-0.2622817E 00	(1, 19)	0.1032446E 00	(1, 20)	0.8922407E-01
(1, 21)	0.1765567E 00	(1, 22)	0.2902459E-02	(1, 23)	-0.1003024E 00	(1, 24)	0.2658513E-01	(1, 25)	0.
(1, 26)	0.3432266E 00								
(2, 2)	0.1000000E 01	(2, 3)	0.1269008E 00	(2, 4)	0.7686120E 00	(2, 5)	0.3886078E 00	(2, 6)	0.4068143E-01
(2, 7)	0.3791825E 00	(2, 8)	0.3661012E 00	(2, 9)	-0.1938432E 00	(2, 10)	0.3219427E 00	(2, 11)	-0.3137177E-01
(2, 12)	-0.3481043E 00	(2, 13)	-0.3913345E 00	(2, 14)	-0.2264458E 00	(2, 15)	-0.2313697E 00	(2, 16)	-0.1547455E 00
(2, 17)	0.3762037E 00	(2, 18)	-0.2547221E 00	(2, 19)	0.4067110E 00	(2, 20)	0.2664402E 00	(2, 21)	0.4198606E 00
(2, 22)	0.7864771E-01	(2, 23)	0.8075500E 00	(2, 24)	0.3059128E 00	(2, 25)	0.	(2, 26)	0.3325497E 00
(3, 3)	0.1000000E 01	(3, 4)	0.1041424E 00	(3, 5)	0.8373696E 00	(3, 6)	-0.1102059E 00	(3, 7)	0.275074CE 00
(3, 8)	0.2569548E 00	(3, 9)	-0.3964963E 00	(3, 10)	0.3178434E-01	(3, 11)	0.4836665E 00	(3, 12)	0.5154797E-01
(3, 13)	-0.3546679E 00	(3, 14)	0.1788399E-01	(3, 15)	-0.2559597E 00	(3, 16)	0.4218801E-01	(3, 17)	0.3625938E 00
(3, 18)	-0.4233651E 00	(3, 19)	0.4463150E 00	(3, 20)	0.1160984E 00	(3, 21)	0.4898004E 00	(3, 22)	0.1508451E 00
(3, 23)	-0.1818556E 00	(3, 24)	0.4029299E 00	(3, 25)	0.	(3, 26)	0.3938877E 00		
(4, 4)	0.1000000E 01	(4, 5)	0.3408118E 00	(4, 6)	-0.1124416E 00	(4, 7)	0.1898131E 00	(4, 8)	0.1447804E 00
(4, 9)	-0.1736934E 00	(4, 10)	0.9743533E-01	(4, 11)	-0.1603603E 00	(4, 12)	-0.2214986E 00	(4, 13)	-0.4311934E 00
(4, 14)	-0.2623397E 00	(4, 15)	-0.1320193E 00	(4, 16)	-0.6158308E-01	(4, 17)	0.4868038E 00	(4, 18)	-0.3063408E 00
(4, 19)	0.4398493E 00	(4, 20)	0.3394221E 00	(4, 21)	0.2397215E 00	(4, 22)	0.5480551E-01	(4, 23)	0.7041739E 00
(4, 24)	0.3023942E 00	(4, 25)	0.	(4, 26)	0.2914264E 00				
(5, 5)	0.1000000E 01	(5, 6)	-0.1099057E 00	(5, 7)	0.2968474E 00	(5, 8)	0.2717475E 00	(5, 9)	-0.3624782E 00
(5, 10)	0.1012301E 00	(5, 11)	0.4045905E 00	(5, 12)	-0.6460995E-01	(5, 13)	-0.3953281E 00	(5, 14)	-0.3179220E-01
(5, 15)	-0.2677557E 00	(5, 16)	-0.9490962E-02	(5, 17)	0.574549E 00	(5, 18)	-0.5004447E 00	(5, 19)	0.563768E 00
(5, 20)	0.1930718E 00	(5, 21)	0.5692887E 00	(5, 22)	0.2198217E 00	(5, 23)	0.5566895E-01	(5, 24)	0.4460624E 00
(5, 25)	0.	(5, 26)	0.4340843E 00						
(6, 6)	0.1000000E 01	(6, 7)	0.5587571E 00	(6, 8)	0.5521096E 00	(6, 9)	0.7001027E 00	(6, 10)	0.9382005E 00
(6, 11)	0.1065993E 00	(6, 12)	0.4407271E 00	(6, 13)	0.3649709E 00	(6, 14)	0.7589090E-01	(6, 15)	-0.5960294E-01
(6, 16)	-0.1499599E 00	(6, 17)	-0.1368240E 00	(6, 18)	0.6530097E-01	(6, 19)	0.4497733E-01	(6, 20)	0.9308424E-01
(6, 21)	-0.1213073E-01	(6, 22)	-0.2501153E 00	(6, 23)	0.1325365E 00	(6, 24)	-0.9853307E-01	(6, 25)	0.
(6, 26)	-0.3345273E 00								
(7, 7)	0.1000000E 01	(7, 8)	0.9751786E 00	(7, 9)	-0.1681231E 00	(7, 10)	0.6298084E 00	(7, 11)	0.3053895E 00
(7, 12)	0.3114911E 00	(7, 13)	0.1517171E 00	(7, 14)	-0.2156209E 00	(7, 15)	-0.3332837E 00	(7, 16)	-0.1381925E 00
(7, 17)	-0.5141225E-01	(7, 18)	-0.2628793E 00	(7, 19)	0.2115477E 00	(7, 20)	0.5657872E-02	(7, 21)	0.1056448E 00
(7, 22)	-0.1620749E 00	(7, 23)	0.3789100E 00	(7, 24)	-0.1301311E 00	(7, 25)	0.	(7, 26)	0.5529672E 00
(8, 8)	0.1000000E 01	(8, 9)	-0.1886859E 00	(8, 10)	0.6207644E 00	(8, 11)	0.3035289E 00	(8, 12)	0.3326682E 00
(8, 13)	0.1671719E 00	(8, 14)	-0.1462782E 00	(8, 15)	-0.2875595E 00	(8, 16)	-0.1532787E 00	(8, 17)	-0.9674712E-01
(8, 18)	-0.2980218E 00	(8, 19)	0.2162339E 00	(8, 20)	-0.2461452E-01	(8, 21)	0.2732136E-01	(8, 22)	-0.1879141E 00
(8, 23)	0.3802813E 00	(8, 24)	-0.1593466E 00	(8, 25)	0.	(8, 26)	0.5418728E 00		
(9, 9)	0.1000000E 01	(9, 10)	0.5793576E 00	(9, 11)	-0.1781864E 00	(9, 12)	0.1961747E 00	(9, 13)	0.1971999E 00
(9, 14)	0.1852095E 00	(9, 15)	0.2065282E 00	(9, 16)	-0.6500899E-01	(9, 17)	-0.6021475E-01	(9, 18)	0.3277966E 00

TABLE I5 (CONT'D)

(9,19)	-0.127900E 0	(9,20)	0.101214E 0	(9,21)	-0.131246E 00	(9,22)	-0.147655E 00	(9,23)	-0.0771762E-01
(9,24)	0.1668354E-1	(9,25)	0.	(9,26)	-0.045938E 00	(9,27)	0.	(9,28)	0.
(10,10)	0.150000E 01	(10,11)	0.1321023E 0	(10,12)	0.3984647E 00	(10,13)	0.1311410E 00	(10,14)	-0.1311618E-01
(10,15)	-0.1720738E 00	(10,16)	-0.1816445E 0	(10,17)	0.4303512E-01	(10,18)	-0.4162421E-01	(10,19)	0.2075017E 00
(10,20)	0.2228316E 00	(10,21)	0.2277762E 00	(10,22)	-0.200913E 00	(10,23)	0.3901312E 00	(10,24)	0.3804441E-01
(10,25)	0.	(10,26)	-0.205 696E 0	(10,27)	0.	(10,28)	0.	(10,29)	0.
(11,11)	0.1000000E 01	(11,12)	0.5762894E 0	(11,13)	0.5991401E-01	(11,14)	0.4243610E 00	(11,15)	0.1754008E 00
(11,16)	0.5642958E-01	(11,17)	0.4297616E 0	(11,18)	-0.659944E 00	(11,19)	0.432600E 00	(11,20)	0.2782932E 00
(11,21)	0.359844E 00	(11,22)	0.9701630E-02	(11,23)	-0.195759E 00	(11,24)	0.345376E 00	(11,25)	0.
(11,26)	0.1770240E 00	(11,27)	0.	(11,28)	0.	(11,29)	0.	(11,30)	0.
(12,12)	0.1000000E 01	(12,13)	0.3832380E 00	(12,14)	0.4576271E 00	(12,15)	0.1920703E 00	(12,16)	0.1150273E 00
(12,17)	-0.9576857E-01	(12,18)	-0.3932511E 00	(12,19)	0.255499E 00	(12,20)	0.6601781E-01	(12,21)	-0.2177413E-01
(12,22)	-0.459876E-01	(12,23)	-0.264887E 00	(12,24)	0.110027E 00	(12,25)	0.	(12,26)	-0.7726330E-01
(13,13)	0.1000000E 01	(13,14)	0.8772917E-01	(13,15)	-0.5129624E-02	(13,16)	-0.1281924E 00	(13,17)	-0.3182917E 00
(13,18)	-0.9352646E-01	(13,19)	-0.2388925E 00	(13,20)	-0.092360E-01	(13,21)	-0.362604E 00	(13,22)	-0.8873152E-01
(13,23)	-0.1911449E 0	(13,24)	-0.3297199E 00	(13,25)	0.	(13,26)	-0.1233281E 00	(13,27)	0.
(14,14)	0.1000000E 01	(14,15)	0.6741231E 00	(14,16)	0.1150273E 00	(14,17)	0.2681524E-01	(14,18)	-0.3932511E 00
(14,19)	0.2054479E 00	(14,20)	-0.220594E-01	(14,21)	0.1805145E 00	(14,22)	0.1152524E 00	(14,23)	-0.3613576E 00
(14,24)	0.4621248E 00	(14,25)	0.	(14,26)	0.	(14,27)	0.	(14,28)	0.
(15,15)	0.1000000E 01	(15,16)	0.8132391E-01	(15,17)	-0.5932716E-01	(15,18)	-0.7628411E-01	(15,19)	-0.1670150E-01
(15,20)	-0.3178304E 00	(15,21)	-0.1084691E 00	(15,22)	0.1948504E 00	(15,23)	-0.2277932E 00	(15,24)	0.2200364E 00
(15,25)	0.	(15,26)	-0.3308459E 00	(15,27)	0.	(15,28)	0.	(15,29)	0.
(16,16)	0.1000000E 01	(16,17)	-0.2481604E 00	(16,18)	-0.5776713E-01	(16,19)	0.7128981E-01	(16,20)	-0.6788442E-01
(16,21)	0.1321719E 00	(16,22)	-0.7728982E-01	(16,23)	-0.2233178E 00	(16,24)	0.678944E-01	(16,25)	0.
(16,26)	-0.1202762E 00	(16,27)	0.	(16,28)	0.	(16,29)	0.	(16,30)	0.
(17,17)	0.1000000E 01	(17,18)	-0.4444009E 00	(17,19)	0.5945884E 00	(17,20)	0.5719694E 00	(17,21)	0.4833941E 00
(17,22)	0.3114511E 00	(17,23)	0.9551511E-01	(17,24)	0.5222330E 00	(17,25)	0.	(17,26)	0.3508698E-01
(18,18)	0.1000000E 01	(18,19)	-0.7474093E 00	(18,20)	-0.2836543E 00	(18,21)	-0.3427491E 00	(18,22)	-0.1384091E 00
(18,23)	-0.424470E-01	(18,24)	-0.5267860E 00	(18,25)	0.	(18,26)	-0.2882631E 00	(18,27)	0.
(19,19)	0.1000000E 01	(19,20)	0.5530100E 00	(19,21)	0.5139588E 00	(19,22)	0.1951854E 00	(19,23)	0.1141822E 00
(19,24)	0.6180701E 00	(19,25)	0.	(19,26)	0.8188347E-01	(19,27)	0.	(19,28)	0.
(20,20)	0.1000000E 01	(20,21)	0.4605347E 00	(20,22)	-0.162650E 00	(20,23)	0.9713694E-01	(20,24)	0.4285714E 00
(20,25)	0.	(20,26)	-0.1736706E 00	(20,27)	0.	(20,28)	0.	(20,29)	0.
(21,21)	0.1000000E 01	(21,22)	0.2502305E 00	(21,23)	-0.1281236E 00	(21,24)	0.4878934E 00	(21,25)	0.
(21,26)	0.2522117E-02	(21,27)	0.	(21,28)	0.	(21,29)	0.	(21,30)	0.
(22,22)	0.1000000E 01	(22,23)	-0.2098321E 00	(22,24)	0.1626500E 00	(22,25)	0.	(22,26)	-0.2030248E-01
(23,23)	0.1000000E 01	(23,24)	0.2887855E-01	(23,25)	0.	(23,26)	0.3271031E 00	(23,27)	0.
(24,24)	0.1000000E 01	(24,25)	0.	(24,26)	-0.1322601E 00	(24,27)	0.	(24,28)	0.
(25,25)	0.	(25,26)	0.	(25,27)	0.	(25,28)	0.	(25,29)	0.
(26,26)	0.1000000E 01	(26,27)	0.	(26,28)	0.	(26,29)	0.	(26,30)	0.

X(25) IS CONSTANT
X(25) DELETED TO AVOID SINGULARITY

Table 16 Independent Variables Used in the Final Multiple Linear Regression Analysis for the Thirty-Two High Volume Sections in Indianapolis.

Number	Variable Description
3	Heavy Volume Intersections/mile
5	Traffic Signals/mile
6	Driveways/mile
8	Heavy and Medium Volume Commercial Driveways/mile
9	Light Volume Commercial and Residential Driveways/mile
10	Friction Points/mile
11	Street Width
15	Quality of Street Markings
16	Parking Allowed on One Side Only
17	Parking Allowed on Two Sides
20	Quality of Street Lighting
21	4-way Intersections/mile

Table 17 Coefficients for Multiple Linear Regression
Equations for the Thirty-Two High Volume Sections
in Indianapolis

Dependent Variables Independent Variables	Accidents/ 10^8 Vehicle Miles		Accidents/mile	
	Y_1^*	Y_1	Y_2^*	Y_2
Constant	553.163	728.943	1.630	-17.060
X_3			<u>7.222</u>	<u>7.988**</u>
X_5	<u>219.889</u>	<u>167.458**</u>		
X_6		1.585		
X_8				0.827
X_9		-4.660		
X_{10}				-0.332
X_{11}	-11.416	-15.239		-0.555
X_{15}				15.864
X_{16}	768.135	988.036		
X_{17}		310.398		
X_{20}				17.690
X_{21}		4.510		3.858
R	0.830	0.862	0.790	0.888
R^2	0.69	0.74	0.62	0.79

*Simplified prediction equation

**Underlined coefficients are the most significant variables
in the regression analysis.

variability in the accident rate Y_1 is explained by this regression equation. The variable that was most significant in the regression analysis was the number of traffic signals per mile (X_5). The other variables in the equation are the number of driveways per mile (X_6), the number of light volume commercial and residential driveways per mile (X_9), the street width (X_{11}), whether parking was allowed on one side only (X_{16}), and whether parking was allowed on both sides (X_{17}). These independent variables had the following simple correlation coefficients with the dependent variable Y_1 :

Independent Variables	Simple Correlation Coefficients
X_3	0.611
X_5	0.724
X_6	-0.281
X_8	0.020
X_9	-0.358
X_{11}	0.037
X_{16}	0.268
X_{17}	0.408
X_{21}	0.523

A simplified regression equation for predicting the number of accidents/100 million vehicle miles for these thirty-two high volume sections is as follows:

$$Y_1 = 553.163 + 219.889X_5 - 11.416X_{11} + 768.135X_{16}$$

The multiple correlation coefficient, R , equals 0.830; and the coefficient of determination, R^2 , is 0.69. This is to say that approximately 69 percent of the variability in the dependent variable Y_1 is explained by these three variables; the number of traffic signals per mile (X_5), the street width (X_{11}), and whether parking was allowed on only one side (X_{16}).

Accidents per Mile (Y_2)

The prediction equation utilizing the independent variables used in the final analysis for the determination of Y_2 , the number of accidents per mile on the thirty-two high volume sections in Indianapolis, is as follows:

$$Y_2 = -17.060 + 7.988X_3 + 0.827X_8 - 0.332X_{10} - 0.555X_{11} \\ + 15.864X_{15} + 17.690X_{20} + 3.858X_{21}$$

The multiple correlation coefficient, R , is 0.888; and the coefficient of determination, R^2 , equal 0.79, or approximately 79 percent of the variability in the dependent variable (Y_2) is explained by this regression equation. The variable that was most significant in this analysis is the number of heavy volume intersections per mile (X_3). The other independent variables in the equation are the number of heavy and medium volume commercial driveways per mile (X_8), the number of friction points

per mile (X_{10}), the street width (X_{11}), the quality of the street markings (X_{15}), the quality of the street lighting (X_{20}), and the number of 4-way intersections per mile (X_{21}). These independent variables had the following simple correlation coefficients with the dependent variable Y_2 :

Independent Variable	Simple Correlation Coefficients
X_3	0.689
X_8	0.352
X_{10}	0.142
X_{11}	0.422
X_{15}	-0.181
X_{20}	0.422
X_{21}	0.674

A simplified equation for predicting the number of accidents per mile for these thirty-two high volume sections is as follows:

$$Y_2 = 1.630 + 7.222X_3 + 4.510X_{21}$$

The multiple correlation coefficient, R , is 0.790; and the coefficient of determination, R^2 , equals 0.62. This means that approximately 62 percent of the variability in the dependent variable (Y_2) is explained by the simplified regression equation. The independent variables in this equation are the number of heavy volume intersections

per mile (X_3) and the number of four-way intersections per mile (X_{21}). In this particular case, it seems very advantageous to use the simplified equation because it gives adequate results with easily collected data.

Phase IV - Two Lane Sections

The variables listed in Table 3 also represent the independent variables which were considered in the analysis for predicting the two accident rates, Y_1 and Y_2 , for the sixty-eight two lane facilities used in this study. The volume range was from an ADT of 1,200 to one of 20,800, but the majority of the sections had an ADT of less than 9,000. The means and standard deviations for each of the independent variables are shown in Table 18. The means and standard deviations for the dependent variables in this phase are the following:

Dependent Variables	Mean	Standard Deviation
Y_1	750.574	430.847
Y_2	18.309	17.093

Table 19 shows the simple correlation coefficients between each variable and all other variables. The independent variables used in the final multiple linear regression analysis to obtain the separate prediction equations for Y_1 and Y_2 are listed in Table 20. The coefficients of the variables used in these multiple regression equations are shown in Table 21.

Table 18 Variable Means and Standard Deviations for the
Sixty-Eight Two Lane Sections

Variable	Mean	Standard Deviations
1	6.653	3.994
2	12.40	4.50
3	1.41	1.50
4	8.28	4.23
5	0.79	1.46
6	48.12	18.76
7	19.29	13.31
8	17.63	12.95
9	30.71	19.35
10	72.90	20.91
11	30.06	8.05
12	2.00	0.00
13	30.81	2.81
14	1.34	0.59
15	1.16	0.74
16	0.19	0.39
17	0.41	0.50
18	0.54	0.50
19	0.37	0.49
20	1.18	0.75
21	5.74	3.27
22	0.00	0.00
23	6.63	4.41
24	0.66	0.48
25	0.19	0.55
26	42.57	26.92

TABLE 19 SIMPLE CORRELATION COEFFICIENTS BETWEEN
EACH VARIABLE AND ALL OTHER VARIABLES
FOR THE SIXTY-EIGHT TWO LANE SECTIONS

XY CORRELATION COEFFICIENTS

Y (1)	X (2)	X (3)	X (4)	X (5)	
X (1)	0.345265E CC	C.4927831E CC	C.2339632E CC	X (1)	C.4515C79E CC
X (6)	0.1519374E CC	C.156275E 00	-C.8368895E-01	X (1C)	C.2351608E CC
X (11)	-C.2597214E CC	X (13)	-C.1914390E CC	X (15)	C.2372497E CC
X (16)	C.1966982E CC	X (18)	C.2839227E-C2	X (2C)	C.1311C65E CC
X (21)	C.2301244E 00	X (23)	C.1890145E CC	X (25)	-C.9C05C56E-01
X (26)	C.1670323E 00				

XY CORRELATION COEFFICIENTS

	X(2)	X(3)	X(4)	X(5)
X(1)	C.6283558E CC	0.3125566E 00	0.5170411E 00	0.909C033E-01
X(6)	-0.1262877E 00	0.2550506E 00	0.2524611E 00	0.1666740E-01
X(11)	0.2837828E 00	0.1017887E CC	0.2524611E 00	0.2648061E-01
X(16)	0.7270701E-01	X(18)	-0.1417075E 00	0.1942749E 00
X(21)	0.1115958E 00	X(23)	0.2218148E 00	-0.1404709E 00
X(26)	0.3614550E CC			

TABLE 19 (CONT'D)

CORRELATION MATRIX

(1, 1)	C.1CCCC00E C1	(1, 2)	0.8851748E-01	(1, 3)	0.1172465E 00	(1, 4)	-0.8034996E-01	(1, 5)	0.3588431E 00
(1, 6)	-0.1457050E 00	(1, 7)	0.2339677E 00	(1, 8)	0.1945260E 00	(1, 9)	-0.2299392E 00	(1, 10)	-0.1839256E 00
(1, 11)	0.8376872E-C1	(1, 12)	0.	(1, 13)	0.4634445E CC	(1, 14)	0.1575775E-01	(1, 15)	0.2723425E 00
(1, 16)	-C.1120907E-01	(1, 17)	0.1079154E C0	(1, 18)	-0.1516322E 00	(1, 19)	0.2275426E 00	(1, 20)	0.6691827E-01
(1, 21)	-0.1361633E 00	(1, 22)	0.	(1, 23)	0.1833987E CC	(1, 24)	0.3150085E-01	(1, 25)	-0.1410702E 00
(1, 26)	C.4C51861E CC								
(2, 2)	C.1CCCC00E 01	(2, 3)	0.3273527E CC	(2, 4)	0.6861055E 00	(2, 5)	0.2645559E 00	(2, 6)	0.9615349E-01
(2, 7)	C.8498C15E-01	(2, 8)	C.4891343E-01	(2, 9)	0.1208494E 00	(2, 10)	0.4714180E 00	(2, 11)	0.2832104E 00
(2, 12)	0.	(2, 13)	-0.4265705E 00	(2, 14)	0.2175401E-01	(2, 15)	-0.2834094E-01	(2, 16)	0.1577492E 00
(2, 17)	0.2668404E 00	(2, 18)	-C.9051881E-01	(2, 19)	0.2600152E 00	(2, 20)	0.1995650E 00	(2, 21)	0.3920611E 00
(2, 22)	C.	(2, 23)	0.7141417E CC	(2, 24)	0.3837216E 00	(2, 25)	0.3500051E-C1	(2, 26)	-0.3382845E-01
(3, 3)	C.1CCCC00E C1	(3, 4)	C.3103552E-C1	(3, 5)	C.5162510E 00	(3, 6)	-0.2501772E 00	(3, 7)	-0.5852476E-01
(3, 8)	-0.6284402E-01	(3, 9)	-0.1985467E CC	(3, 10)	-0.2482120E-01	(3, 11)	0.2465833E 00	(3, 12)	0.
(3, 13)	-0.8C15611E-C1	(3, 14)	C.1442568E CC	(3, 15)	-0.7074175E-C2	(3, 16)	-0.3401375E-01	(3, 17)	0.3107610E 00
(3, 18)	-0.1237667E CC	(3, 19)	0.159029E CC	(3, 20)	0.1597205E CC	(3, 21)	0.3609479E 00	(3, 22)	0.
(3, 23)	0.6618827E-C1	(3, 24)	0.2396668E CC	(3, 25)	-0.2435120E-01	(3, 26)	0.7583013E-01		
(4, 4)	C.1CCCC00E 01	(4, 5)	-C.3885580E-C1	(4, 6)	C.1758780E 00	(4, 7)	0.1488579E 00	(4, 8)	0.1662966F 00
(4, 9)	C.9515277E-01	(4, 10)	0.4591489E 00	(4, 11)	0.3248209E CC	(4, 12)	0.	(4, 13)	-0.3266370E 00
(4, 14)	0.1293636E 00	(4, 15)	-C.1092823E CC	(4, 16)	0.1280309E CC	(4, 17)	0.2646922E 00	(4, 18)	-0.3052202E-01
(4, 19)	C.1051176E 00	(4, 20)	C.1508263E CC	(4, 21)	0.3468550E 00	(4, 22)	0.	(4, 23)	0.4380560E 00
(4, 24)	C.2179466E 00	(4, 25)	0.1107990E CC	(4, 26)	-0.1050371E CC				
(5, 5)	C.1CCCC00E 01	(5, 6)	-0.1123170E 00	(5, 7)	-0.8347154E-C2	(5, 8)	-0.3087372E-01	(5, 9)	-0.43333670E-01
(5, 10)	-0.5353224E-C1	(5, 11)	0.1849472E CC	(5, 12)	0.	(5, 13)	-0.6777964E-01	(5, 14)	-0.1780587E 00
(5, 15)	-C.1333862E CC	(5, 16)	-0.3411838E-01	(5, 17)	0.2835083E CC	(5, 18)	-0.2316638E 00	(5, 19)	0.3184432E 00
(5, 20)	0.1825454E CC	(5, 21)	0.1654713E-01	(5, 22)	0.	(5, 23)	0.2637652E 00	(5, 24)	0.2842074E 00
(5, 25)	-C.1536131E CC	(5, 26)	0.1453195E CC						
(6, 6)	C.1CCCC00E 01	(6, 7)	C.2590518E 00	(6, 8)	0.2795270E 00	(6, 9)	0.7698404E 00	(6, 10)	0.8264601E 00
(6, 11)	C.7484251E-01	(6, 12)	0.	(6, 13)	-0.2039627E 00	(6, 14)	-0.2049969E 00	(6, 15)	-0.2980929E 00
(6, 16)	0.2057862E 00	(6, 17)	-C.8550789E-01	(6, 18)	0.3149462E CC	(6, 19)	-0.1472958E 00	(6, 20)	0.4717192E-01
(6, 21)	-0.2015655E 00	(6, 22)	0.	(6, 23)	0.2519272E 00	(6, 24)	0.7628841E-01	(6, 25)	0.1070041E 00
(6, 26)	-C.2684881E CC								
(7, 7)	C.1CCCC00E 01	(7, 8)	0.9782567E CC	(7, 9)	-0.3416977E 00	(7, 10)	0.2913608E 00	(7, 11)	0.2143881E 00
(7, 12)	0.	(7, 13)	0.234508E-01	(7, 14)	-0.1918821E 00	(7, 15)	-0.1913721E 00	(7, 16)	0.7407562E-01
(7, 17)	C.446E875E-C1	(7, 18)	-0.1984555E-C1	(7, 19)	0.1145754E 00	(7, 20)	-0.6340647E-01	(7, 21)	-0.1368015E 00
(7, 22)	0.	(7, 23)	0.1702232E 00	(7, 24)	-0.7817115E-01	(7, 25)	0.1604081E 00	(7, 26)	0.7223834E 00
(8, 8)	C.1CCCC00E 01	(8, 9)	-0.3822555E CC	(8, 10)	0.279311CE CC	(8, 11)	0.2156572E 00	(8, 12)	0.
(8, 13)	0.2057171E-01	(8, 14)	-0.1224578E CC	(8, 15)	-0.1777772E 00	(8, 16)	0.4009301E-01	(8, 17)	0.4252981E-01
(8, 18)	-C.4685724E-01	(8, 19)	C.1404571E CC	(8, 20)	-0.2849417E-01	(8, 21)	-0.9158960E-01	(8, 22)	0.
(8, 23)	0.1C16714E 00	(8, 24)	-C.1C50519E CC	(8, 25)	0.1849337E CC	(8, 26)	0.6579401E 00		
(9, 9)	C.1CCCC00E C1	(9, 10)	0.6184574E CC	(9, 11)	-0.5381861E-C1	(9, 12)	0.	(9, 13)	-0.2299257E 00
(9, 14)	-0.1260851E 00	(9, 15)	-0.1467041E 00	(9, 16)	0.1670990E 00	(9, 17)	-0.8052767E-01	(9, 18)	0.3164884E 00

TABLE 19 (CONT'D)

(9,19)	-0.2128026E 00	(9,20)	C.6003737E-01	(9,21)	-0.13226E8E CC	(9,22)	0.	(9,23)	0.2317889E 00
(9,24)	0.1654440E 00	(9,25)	-0.2673018E-01	(9,26)	-0.6883717E 00				
(10,10)	C.1CCCC00E C1	(10,11)	0.1545132E 00	(10,12)	0.	(10,13)	-0.3815580E 00	(10,14)	-0.1692830E 00
(10,15)	-0.3369394E 00	(10,16)	0.2780604E 00	(10,17)	0.6604733E-01	(10,18)	0.1946037E 00	(10,19)	0.5250637E-02
(10,20)	0.1577862E 00	(10,21)	0.2597618E 00	(10,22)	0.	(10,23)	0.2819653E 00	(10,24)	0.2195726E 00
(10,25)	C.6452762E-01	(10,26)	-0.2332578E CC						
(11,11)	C.1CC0C00E 01	(11,12)	0.	(11,13)	-0.2590419E 00	(11,14)	0.1122416E 00	(11,15)	0.2823479E-01
(11,16)	0.7596760E-01	(11,17)	C.7527838E 00	(11,18)	-0.2112308E 00	(11,19)	0.3111225E 00	(11,20)	0.3852929E 00
(11,21)	C.3619954E C1	(11,22)	0.	(11,23)	0.1365479E-01	(11,24)	0.6352589E 00	(11,25)	-0.1231588E 00
(11,26)	C.915848CE-C1								
(12,12)	C.	(12,13)	0.	(12,14)	0.	(12,15)	0.	(12,16)	0.
(12,17)	0.	(12,18)	0.	(12,19)	0.	(12,20)	0.	(12,21)	0.
(12,22)	C.	(12,23)	0.	(12,24)	0.	(12,25)	0.	(12,26)	0.
(13,13)	C.1CC0C00E 01	(13,14)	C.5763618E-01	(13,15)	0.1501765E CC	(13,16)	-0.7383714E-01	(13,17)	-0.2422748E 00
(13,18)	-0.1049346E 00	(13,19)	-0.1116033E 00	(13,20)	-0.1390043E 00	(13,21)	-0.3091630E 00	(13,22)	0.
(13,23)	-0.26242571E C0	(13,24)	-C.3494011E 00	(13,25)	-C.4533753E-C2	(13,26)	0.2883826E 00		
(14,14)	C.1C00000E C1	(14,15)	C.5537459E C0	(14,16)	-0.2174042E C0	(14,17)	0.1804726E 00	(14,18)	-0.1270642E 00
(14,19)	C.8C59240E-01	(14,20)	0.1666001E 00	(14,21)	0.1946745E 00	(14,22)	0.	(14,23)	-0.1411684E 00
(14,24)	C.5465077E-C1	(14,25)	C.1192601E CC	(14,26)	-0.1132073E CC				
(15,15)	0.1C0C000E 01	(15,16)	-0.1063C09E 00	(15,17)	C.14017C6E 00	(15,18)	0.8040681E-01	(15,19)	-0.1256931E 00
(15,20)	-0.1315892E 00	(15,21)	-0.6665658E-02	(15,22)	0.	(15,23)	-0.315998E-01	(15,24)	0.3027472E-01
(15,25)	-0.3725330E-C2	(15,26)	0.5407898E-01						
(16,16)	0.1C0C000E 01	(16,17)	-C.4067610E 00	(16,18)	0.6956741E-01	(16,19)	0.1710937E-01	(16,20)	0.8547361E-01
(16,21)	0.5087333E-02	(16,22)	0.	(16,23)	0.1605128E 00	(16,24)	0.2685275E 00	(16,25)	-0.1011303E 00
(16,26)	-0.818216CE-C1								
(17,17)	C.1C0C000E 01	(17,18)	-0.1541C029E 00	(17,19)	0.22966610E 00	(17,20)	0.2825916E 00	(17,21)	0.3723307E 00
(17,22)	0.	(17,23)	-0.1164986E-01	(17,24)	0.5349871E C0	(17,25)	-0.1824058E 00	(17,26)	0.6927288E-01
(18,18)	C.1C0C000E 01	(18,19)	-C.833C207E CC	(18,20)	-0.25830323E 00	(18,21)	-0.747C910E-01	(18,22)	0.
(18,23)	-0.2567259E-01	(18,24)	-0.9269781E-01	(18,25)	0.4980486E-01	(18,26)	-0.1626970E C0		
(19,19)	C.1C0C000E 01	(19,20)	0.5552580E 00	(19,21)	0.1844859E CC	(19,22)	0.	(19,23)	0.1268053E 00
(19,24)	C.2227889E C0	(19,25)	-0.4327973E-01	(19,26)	0.1206164E 00				
(20,20)	C.1C0C000E C1	(20,21)	0.3473557E C0	(20,22)	0.	(20,23)	-0.2516416E-01	(20,24)	0.3772573E 00
(20,25)	-C.1C55042E-C1	(20,26)	-0.1894323E 00						
(21,21)	C.1C0C000E C1	(21,22)	C.	(21,23)	-0.3498884E 00	(21,24)	0.3C58515E 00	(21,25)	-0.2112434E-01
(21,26)	-0.1311328E 00								
(22,22)	C.	(22,23)	0.	(22,24)	C.	(22,25)	C.	(22,26)	0.
(23,23)	0.1C0C000E C1	(23,24)	C.1530522E CC	(23,25)	0.3536531E-01	(23,26)	0.3362994E-01		
(24,24)	C.1C0C000E C1	(24,25)	C.2247C18E-C1	(24,26)	-0.1C91356F CC				
(25,25)	C.1C0C000E 01	(25,26)	0.1557657E-C1						
(26,26)	C.1C0C000E C1								

X(12) IS CONSTANT
 X(22) IS CONSTANT
 X(12) DELETED TO AVOID SINGULARITY
 X(22) DELETED TO AVOID SINGULARITY

Table 20 Independent Variables Used in the Final
Multiple Linear Regression Analysis for
the Sixty-Eight Two Lane Sections

Number	Variable Description
1	Volume or ADT on the arterial in thousands of vehicles
3	Heavy Volume Intersections per Mile
5	Traffic Signals per Mile
9	Medium and Heavy Volume Commercial Driveways per Mile
10	Friction Points per Mile
15	Quality of Street Markings
16	Parking allowed on one side only
17	Parking allowed on two sides
19	Continuous Street Lighting

Table 21 Coefficients for Multiple Linear Regression
Equations for the Sixty-Eight Two Lane Sections

Dependent Variable Independent Variable	Accidents/ 10^8 Vehicle Miles		Accidents/Mile	
	Y_1^*	Y_1	Y_2^*	Y_2
Constant	121.628	358.452	0.894	-11.804
X_1			<u>-1.754</u>	- <u>1.917**</u>
X_3	73.626	64.800		2.334
X_5	<u>114.371</u>	<u>100.807**</u>	<u>5.990</u>	<u>4.787**</u>
X_9	-9.093	-8.549		-0.249
X_{10}	10.162	7.614		0.246
X_{15}		-112.370		
X_{16}	221.229	336.742		
X_{17}		201.878		
X_{19}	-195.904	-239.700		
R	0.719	0.753	0.790	0.860
R^2	0.52	0.57	0.62	0.74

*Simplified prediction equation

**Underlined coefficients are the most significant variables
in the regression analysis

Accidents/100 Million Vehicle Miles

The prediction equation utilizing the independent variables used in the final analysis for the determination of Y_1 , the number of accidents per 100 million vehicle miles on sixty-eight two lane sections, is the following:

$$Y_1 = 358.452 + 64.800X_3 + 100.807X_5 - 8.549X_9 + 7.614X_{10} \\ - 112.370X_{15} + 336.742X_{16} + 201.878X_{17} - 239.700X_{19}$$

The multiple correlation coefficient, R , equals 0.753; and the coefficient of determination, R^2 , is 0.57, or approximately 57 percent of the variability in the accident rate Y_1 is explained by the regression equation. The variable that was most significant in the regression analysis was the number of traffic signals per mile (X_5). The other variables in the equation are the number of heavy volume intersections per mile (X_3), the number of light volume commercial and residential driveways per mile (X_9), the number of friction points per mile (X_{10}), the quality of street markings (X_{15}), whether parking was allowed on one side only (X_{16}), whether parking was allowed on both sides (X_{17}), and whether there was continuous street lighting (X_{19}). These independent variables had the following simple correlation coefficients with the dependent variable Y_1 :

Independent Variable	Simple Correlation Coefficients
X_3	0.494
X_5	0.452
X_9	-0.084
X_{10}	0.240
X_{15}	-0.237
X_{16}	0.197
X_{17}	0.267
X_{19}	-0.072

A simplified equation for predicting the number of accidents per 100 million vehicle miles for these sixty-eight two lane sections is as follows:

$$Y_1 = 121.628 + 73.626X_3 + 114.371X_5 - 9.093X_9 + 10.162X_{10} + 221.229X_{16} - 195.904X_{19}$$

The multiple correlation coefficient, R , is 0.719, and the coefficient of determination, R^2 , equals 0.52. In other words, approximately 52 percent of the variability in the dependent variable, Y_1 , is explained by this regression equation. Only two independent variables, whether parking was allowed on two sides (X_{17}), and the quality of the street markings (X_{15}), were deleted from the initial equation to form the simplified equation.

Accidents per Mile (Y_2)

The prediction equation utilizing the independent variables used in the final analysis for the determination of Y_2 , the number of accidents per mile for the sixty-eight two lane facilities in this study, is as follows:

$$Y_2 = -11.804 + 1.917X_1 + 2.334X_3 + 4.787X_5 - 0.249X_9 + 0.246X_{10}$$

The multiple correlation coefficient, R , is equal to 0.860; and the coefficient of determination, R^2 , is 0.74. This means the 74 percent of the variability in the dependent variable Y_2 is explained by this regression equation. The variables that were most significant in this analysis are the volume on the arterial (X_1), and the number of traffic signals per mile (X_5). The other independent variables in the equation are the number of heavy volume intersections per mile (X_3), the number of light volume commercial and residential driveways per mile (X_9), and the number of friction points per mile (X_{10}). These variables had the following simple correlation coefficients with the dependent variable Y_2 :

Independent Variable	Simple Correlation Coefficients
X_1	0.628
X_3	0.517
X_5	0.672
X_9	-0.258
X_{10}	0.017

A simplified equation for predicting the number of accidents per mile for these sixty-eight two lane sections is as follows:

$$Y_2 = 0.84 + 1.754X_1 + 5.990X_5$$

The multiple correlation coefficient, R , equal 0.790; and the coefficient of determination, R^2 , equals 0.62, or approximately 62 percent of the variability in the dependent variable (Y_2) is explained by the simplified equation. The independent variables in this modified equation are the volume on the arterial (X_1) and the number of traffic signals per mile (X_5). This simplified equation adequately predicts the accident rate for these two lane sections.

Phase V - 32 Sections Four Lane or One-way Streets

Attempts were made to analyze the thirty-two sections in this study that were not two lane facilities. Included in these thirty-two sections were twenty-one four-lane undivided streets, four four-lane divided streets, and seven one-way streets. It was found that too much variance existed between these sections to analyze them as a group. And yet, they could not be analyzed separately because the individual sample sizes were too small. Therefore, it was impossible to determine by regression analysis the factors influencing the accident rate on these various types of facilities.

Case Studies

As an additional method of analysis sections with approximately the same volume but with divergent accident rates were compared in a case study approach in order to determine any differences in characteristics which might help to explain the variability in the accident rates.

In line with this technique, pairs of sections with relatively the same accident rates were analyzed to see what similarities these sections possessed.

Case Study No. 1

This was a comparison between study sections 1 and 2. Section 1 was Cherry Lane in West Lafayette, Indiana, and section 2 was State Route 18 through Galveston, Indiana. Both of these sections were two-lane facilities carrying approximately 1300 vehicles per day.

Variables	Section	
	1	2
Volume	1200	1400
Number of lanes	2	2
Accidents/mile	0	9
Accidents/100 million vehicle miles	0	1675
Intersections/mile	4	13
3-way intersections/mile	4	4
4-way intersections/mile	0	9
Driveways/mile	19	40
Residential drives/mile	17	27
Commercial drives/mile	2	13
Friction Points/mile	23	78

This particular comparison appears to indicate that accident rate increases when the number of intersections

increase and/or the roadside development becomes more intense. It should be noted, however, that these sections were in the very low volume range and that a previous study by Head gave a strong indication that accident rates on low volume roads did not have a strong relationship with any roadside feature.(11)

Case Study No. 2

This was a comparison between study sections 20 and 22. Section 20 was State Route 18, Columbia Street, through Flora, Indiana; and Section 22 was U.S. 136, Washington St., in Waynetown, Indiana. Both sections were two lane facilities with an ADT of approximately 4400.

Variable	Sections	
	20	22
Volume	4300	4500
Number of Lanes	2	2
Accidents/mile	10	9
Accidents/100 million vehicle miles	630	572
Intersections/mile	15	12
3-way intersections/mile	9	6
4-way intersections/mile	6	6
Driveways/mile	63	50
Residential drives/mile	42	28
Commercial drives/mile	21	19
Traffic Signals/mile	2	1
Friction Points/mile	91	72
Parking	2 sides	1 side

Those two sections had approximately the same accident rates and both were extensions of state highways in small towns. Section 20, with the slightly higher accident rate,

had parking on both sides and more residential driveways. The fact that the accident rates did not differ significantly even though the parking conditions were dissimilar might be an indication that parking on one or two sides has similar affects on the accident potential for low volume arterials.

Case Study No. 3

This was a comparison between study sections 40 and 43. Section 40 was located on Main Street in Delphi, Indiana; section 43 was a segment of the North River Road in West Lafayette, Indiana.

Variables	Section	
	40	43
Volume	6300	6600
Number of lanes	2	2
Accidents/mile	37	9
Accidents/100 million vehicle miles	1591	371
Intersections/mile	16	5
3-way intersections/mile	8	5
4-way intersections/mile	8	0
Driveways/mile	30	20
Residential drives/mile	6	14
Commercial drives/mile	24	6
Traffic signals/mile	0	0
Friction points/mile	63	25
Parking	2 sides	none

Both sections were two lane facilities with approximately the same volumes. The data clearly showed that these two sections differed greatly in the type of development along them and in the number and type of intersections.

The high accident rate section had more commercial development and more intersections, especially four-way intersections. Parking was allowed on section 40 while the opposite was true on the low accident section. The over-all effect of more friction points, creating a higher accident potential on the one section, together with parking on both sides appears to be the reasons for the divergence in the accident rates.

Case Study No. 4

This was a comparison between study sections 46 and 47. Section 46 was on South East Street in Indianapolis, Indiana; and section 47 was the East approach of U.S. 24 into Logansport, Indiana.

Variables	Section	
	46	47
Volume	7000	7200
Number of lanes	2	2
Accidents/mile	1378	463
Accidents/100 million vehicle miles	35	12
Intersections/mile	18	5
3-way intersections/mile	13	2
4-way intersections/mile	5	3
Driveways/mile	23	58
Residential drives/mile	4	25
Commercial drives/mile	19	32
Traffic signals/mile	4	0
Friction points/mile	55	66
Parking	2 sides	none

Both sections were two-lane facilities, carrying roughly 7000 vehicles per day. Section 47 was the safer

of the two sections even though it had more friction points per mile. This was justified by the fact that the majority of the friction points on section 47 were driveways while section 46 had over three times as many intersections per mile and some traffic signal installations. Also, parking was permitted on both sides of section 46 while it was prohibited on the other. All of these factors on section 46 led to more congestion and a decrease in the freedom of flow, which are characteristics of traffic flow usually associated with accidents.

Case Study No. 5

This was a comparison between study sections 64 and 66. Both of these sections were located on Arlington Street in Indianapolis, Indiana.

Variables	Section	
	64	66
Volume (ADT)	10,500	11,000
Number of lanes	2	2
Accidents/mile	10	8
Accidents/100 million vehicle miles	267	227
Intersections/mile	16	10
3-way intersections/mile	10	6
4-way intersections/mile	6	4
Driveways/mile	75	77
Residential drives/mile	75	63
Commercial drives/mile	0	14
Traffic signals/mile	0	0
Friction Points/mile	98	91
Parking	none	none

By looking at the data it seems obvious why these two

sections had low accident rates. Both sections were located in primarily residential development with no parking allowed; both had an above average number of intersections per mile, but over seventy-five percent of those intersections had relatively light cross traffic and were three-way intersections; and both sections did not contain a traffic signal. It is concluded that this combination of factors provides for one of the "safest" urban arterials. It reduces stop-and-go maneuvers, turning and parking movements, and cross traffic which are factors that increase the accident potential of an urban arterial.

Case Study No. 6

This was a comparison between study sections 67 and 69. Section 67 was a segment of 4th street in Lafayette, Indiana; and section 69 was on 30th street in Indianapolis, Indiana. Both were two lane facilities carrying about twelve thousand vehicles per day.

Variables	Section	
	67	69
Volume	11,400	12,300
Number of Lanes	2	2
Accidents/mile	33	103
Accidents/100 million vehicle miles	793	2301
Intersections/mile	15	17
3-way intersections/mile	4	7
4-way intersections/mile	11	10
Driveways/mile	36	36
Residential drives/mile	28	7
Commercial drives/mile	8	29
Traffic Signals/mile	3	8
Parking	2 sides	2 sides

The only major differences between these two sections were in the type of roadside development and in the number of traffic signals per mile. Both sections had a thirty-six foot pavement with parking on both sides and both had approximately the same number of intersections per mile. It did not seem feasible that the slightly higher volume on section 69, 12,300 as compared to 11,400, would result in an accident rate that was three times higher. The final conclusion was that accident rates were higher where primarily commercial development existed, as opposed to residential development, and where there were more traffic signals per mile.

Case Study No. 7

This was a comparison between study sections 72 and 76. Section 72 was a portion of Markland Street in Kokomo, Indiana; and section 76 was located on Washington Street also in Kokomo. Both of these sections were four-lane facilities with no parking permitted.

Variable	Section	
	72	76
Volume	13,500	14,500
Number of Lanes	4	4
Accidents/mile	130	127
Accidents/100 million vehicle miles	2620	2399
Intersections/mile	17	16
3-way intersections/mile	7	3
4-way intersections/mile	10	13
Driveways/mile	59	87
Residential drives/mile	11	13
Commercial drives/mile	48	74

Variables	Section	
	72	76
Traffic signals/mile	6	7
Friction Points/mile	110	116
Parking	none	none

These two sections had very high accident rates and were very similar in many ways. Both were primarily in commercial areas, with many intersections and traffic signals per mile. Although section 72 has less commercial driveways, this was compensated by the fact that several heavy traffic generators, such as four drive-in restaurants, were located on this 1.2 mile section. Section 72 was also six feet narrower than section 76 which resulted in less maneuverability to the motorists trying to get around a waiting left-turning vehicle. These two sections seem to have all characteristics except parking which were found to be associated with accidents.

Case Study No. 8

This was a comparison between study sections 76 and 78. Section 76 was on Washington Street in Kokomo, Indiana; section 78 was a segment of North Meridian Street in Indianapolis, Indiana.

Variables	Section	
	76	78
Volume	14,500	15,000
Number of lanes	4	4
Accidents/mile	127	27
Accidents/100 million vehicle miles	2,399	498
Intersections/mile	16	6
3-way intersections/mile	3	2
4-way intersections/mile	13	4
Driveways/mile	87	78
Residential drives/mile	13	76
Commercial drives/mile	74	2
Traffic signals/mile	7	3
Friction points/mile	116	89
Parking	none	2 sides
Ratios commercial driveways to total driveways	85	3

Both of these sections were four lane facilities, carrying approximately 15,000 vehicles per day, and both were highly developed. The main differences between these two sections were the number of four way intersections per mile, the number of traffic signals per mile, and the type of roadside development. Section 76 had a higher number of four-way intersections per mile plus more traffic signals per mile to go along with many high volume commercial access points. Section 78 was primarily in a residential area with very few high volume friction points. For this particular case it seems evident that accident rates increased as the number of commercial driveways per mile increased, the number of four-way intersections per mile increased, and the number of traffic signals per mile increased.

Case Study No. 9

This was a comparison between study sections 77 and 83. Section 77 was a segment of the U.S. 52 By-pass in Lafayette, Indiana; section 83 was located on Massachusetts Avenue in Indianapolis, Indiana. Both sections were two lane facilities situated primarily in a suburban environment.

Variables	Section	
	77	83
Volume	14,900	18,000
Number of lanes	2	2
Accidents/mile	19	8
Accidents/100 million vehicle miles	347	115
Intersections/mile	2	5
3-way intersections/mile	1	5
4-way intersections/mile	1	0
Driveways/mile	7	28
Residential drives/mile	1	6
Commercial drives/mile	6	22
Traffic signals/mile	1	0
Frictions points/mile	11	33
Parking	none	none

These sections had low accident rates in comparison with other sections. This fact was attributed to the lack of development along both of these sections. Section 77 had only two intersections per mile, seven driveways per mile, and an insignificant total of eleven frictions points per mile. Section 83 had a higher ADT, but a lower accident rate even though this section had more intersections per mile and more driveways per mile. It was noted that these intersections were all three-way intersections and the commercial driveways served very light traffic

generators. The freedom of flow on section 83 was further enhanced by the presence of a railroad which paralleled the route on one side and served as an access control. This case study further demonstrates the effect of access control as a safety device.

Case Study No. 10

This was a comparison between study sections 84 and 87, where both were four-lane divided facilities. Section 84 was the south half of the U.S. 31 By-pass around Kokomo, Indiana; and section 87 was located on Kentucky Avenue, State Road 67, in Indianapolis, Indiana.

Variables	Section	
	84	87
Volume	19,300	20,000
Number of lanes	4	4
Accidents/mile	35	2
Accidents/100 million vehicle miles	501	29
Intersections/mile	4	6
3-way intersections/mile	2	3
4-way intersections/mile	2	3
Driveways/mile	19	17
Residential drives/mile	9	0
Commercial drives/mile	10	17
Traffic signals/mile	1	1
Friction points/mile	24	26
Parking	none	none

Both of these sections were four-lane divided highways. From the variables it would appear that these two sections should have had about the same accident rate, but section 84 on the Kokomo by-pass had a much higher accident rate.

One possible reason for this significant variance in accident rates might be the difference in roadside development between the sections. Section 87 had a railroad running parallel to it on one side for the entire length of the section. This caused all the development to be on one side, resulting in the absence of conflicting across-the-road access points. On section 84 there were also several large industries which caused major rush-hour congestion and many short distance trips and turning movements on the route. On the other hand, section 87 was a diagonal arterial leading from the southwest section of Indianapolis to the downtown circle. It appeared that most of this traffic made very few turning movements within the section.

Another possible reason for the higher accident rate on section 84 might be the higher percentage of through traffic using this facility.

Case Study No. 11

This was a comparison between study sections 92 and 93. Section 92 was established on East Washington Street in Indianapolis, Indiana; and section 93 was located on West Washington Street also in Indianapolis. Both sections were four lane undivided facilities, which carried approximately 23,000 vehicles per day.

Variables	Sections	
	92	93
Volume	23,000	23,000
Number of lanes	4	4
Accidents/mile	60	29
Accidents/100 million vehicle miles	712	343
Intersections/mile	18	20
3-way intersections/mile	9	15
4-way intersections/mile	9	5
Driveways/mile	50	123
Residential drives/mile	24	31
Commercial drives/mile	26	92
Traffic signals/mile	4	2
Friction points/mile	80	149
Parking	2 sides	none

These two sections made an interesting comparison. Section 93 on West Washington Street had about two and one-half times as many commercial driveways which had been shown to result in a higher accident rate. However, the situation was altered because of at least twenty to twenty-five foot gravel shoulders along section 93. This extra wide shoulder permitted the driver to park diagonally in front of a commercial establishment and yet not interfere with traffic in the moving lanes when he was parking or leaving. It is felt that this did not constitute an actual parking movement since the driver had so much space to maneuver. On the other hand, curb parking was permitted on section 92. These shoulders also gave the driver very good sight distance and a feeling of freedom which was noticeably missing on section 92.

Another important factor which could have caused

a lower accident rate on section 93 was the type of intersections. Both sections had relatively the same number of intersections, but those intersections on section 93 were mostly three-way intersections carrying very light volumes.

Section 92, had double the number of traffic signals per mile. From previous case studies and other analysis performed in this research, this factor also seems to be significant.

Case Study No. 12

This was a comparison between study sections 46 and 84. Section 46 was located on South East Street in Indianapolis, Indiana; and section 84 was a segment of the U.S. 31 by-pass around Kokomo, Indiana. Both sections had the same number of accidents per mile but the volume on section 84 was almost three times that on section 46.

Variables	Section	
	46	84
Volume	7,000	19,300
Number of lanes	2	(divided) 4
Accidents/mile	35	35
Accidents/100 million vehicle miles	1,378	501
Intersections/mile	18	4
3-way intersections/mile	13	2
4-way intersections/mile	5	2
Driveways/mile	23	19
Residential drives/mile	4	9
Commercial drives/mile	19	10
Traffic signals/mile	4	1
Parking	2 sides	none

There appears to be many reasons why the number of accidents per mile were the same for these two sections, even though they carried different volumes. Section 46 had the lower volume, but it had more intersections per mile, more traffic signals per mile, and parking allowed on both sides. Also, section 46 was a two lane facility while section 84 was a four-lane divided route.

Case Study No. 13

This was a comparison between study sections 17 and 83. Section 17 was Division Street, U.S. 24, through Remington, Indiana; and section 83 was a portion of Massachusetts Avenue in Indianapolis, Indiana. Both sections were two-lane facilities with parking prohibited on both sides.

Variables	Section	
	17	83
Volume	4,000	18,000
Number of lanes	2	2
Accidents/mile	8	8
Accidents/100 million	540	115
Intersections/mile	13	5
3-way intersections/mile	7	5
4-way intersections/mile	6	0
Driveways/mile	52	28
Residential drives/mile	14	6
Commercial drives/mile	38	22
Friction points/mile	77	33

From the variance in volumes it does not seem possible that these sections had the same number of accidents per mile. This phenomenon was attributed to the fact that section 17 had more intersections per mile, more four-way

intersections per mile, more driveways per mile, and more total friction points per mile. It was also noted that the friction points that were located on section 83 served very light traffic generators.

Case Study No. 14

This was a comparison between study section 91 and 94. Section 91 was on North Meridian Street in Indianapolis, Indiana; and section 94 was located on 38th Street also in Indianapolis.

Variables	Section	
	91	94
Volume	21,900	24,000
Number of lanes	4	4
Accidents/mile	51	54
Accidents/100 million vehicle miles	640	619
Intersections/mile	8	11
3-way intersections/mile	3	6
4-way intersections/mile	5	5
Driveways/mile	50	48
Residential driveways/mile	26	22
Commercial driveways/mile	24	26
Friction points/mile	63	64
Traffic signals/mile	2	1
Parking	2 sides	none
Street width	56'	36'

Even though parking was allowed on section 91, the accident rates for these two sections were similar. The effect of parking on the accident rate was minimized on section 91 because of the wide pavement width which offered the driver added freedom. Except for the parking control, these sections were similar in almost every detail and this

was reflected in their similar accident rates, which were average rates in this study.

Case Study No. 15

This was a comparison between study sections 36 and 38. Section 36 was on State Route 32 East in Lebanon, Indiana; and section 38 was located on Sycamore Street in Kokomo, Indiana. Both sections were two-lane facilities, with parking on one side only; and both possessed high accident rates based on accidents per 100 million vehicle miles.

Variables	Section	
	36	38
Volume	6,000	6,100
Accidents/mile	20	22
Accidents/100 million vehicle miles	932	966
Intersections/mile	8	13
3-way intersections/mile	5	8
4-way intersections/mile	3	5
Driveways/mile	52	98
Residential drives/mile	20	92
Commercial drives/mile	32	6
Friction points/mile	73	116
Traffic signals/mile	1	1

Section 38 had more intersections per mile and more driveways per mile, but most of the driveways were residential driveways. On the other hand, section 36 had more highly used commercial driveways per mile which compensated the extra intersections on section 38. Both sections had high accident rates because of the large number of friction points per mile.

CONCLUSIONS

The following conclusions concerning traffic accidents on the urban arterial street system in Indiana summarize the findings of this research.

1. Where one or more of the following conditions occur, traffic accidents per mile on urban arterials will most likely decrease:
 - a. Parking is eliminated,
 - b. The number of traffic signals per mile is reduced,
 - c. The number of high volume intersections per mile is reduced,
 - d. Traffic volume is reduced,
 - e. The number of heavily used driveways is reduced,
 - f. The number of friction points per mile - sum of the number of approaches to the arterial, intersections and driveways - is reduced,
 - g. The quality of signing and pavement markings is improved.
2. Traffic accidents per 100 million vehicle miles, as an exposure rate, also will most likely decrease as above for traffic accidents per mile. However, traffic volume is not an important factor.

3. This research substantiates the importance of control of access as an accident reduction tool. The dual purpose of many urban arterials to move traffic and to serve an access function for abutting property makes control of access impractical for many of this type facility. However, every effort to minimize the number of access points or friction points on such facilities should be attempted.
4. Intersections or major driveways are the usual sites of most accidents on urban arterials. Those intersections with four approaches typically are the sites of many more accidents than intersections with three approaches.
5. Multiple linear regression equations were developed to predict accidents per mile and accidents per 100 million vehicle miles for two lane urban arterials. Separate models were also developed for high volume and low volume urban arterials.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. American Association of State Highway Officials, A Policy on Arterial Highway in Urban Areas. American Association of State Highway Officials, 1957.
2. American City, "The Safety and Economy of One-Waying," Vol. 75, No. 3 March, 1960.
3. Anderson, V.L., Statistical Analysis. Class Notes for Statistics 601, September, 1962.
4. Automotive Safety Foundation and Bureau of Public Roads, Traffic Control and Roadway Elements: Their Relationship to Highway Safety, 1963.
5. Baerwald, John E., Traffic Engineering Handbook, Institute of Traffic Engineers, 1965.
6. Baldwin, David M., "Traffic-Accident Trends," Bulletin 74, Highway Research Board, 1953.
7. Brownlee, K.A., Statistical Theory and Methodology in Science and Engineering, New York, Wiley and Sons, Inc., December, 1961.
8. Bureau of Public Roads, Increasing the Traffic-Carrying Capability on Urban Arterial Streets, Bureau of Public Roads, 1962.
9. Bureau of Public Roads, The Federal Role in Highway Safety, Washington, U.S. Government Printing Office, 1959.
10. Burrage, R.H., and E.G. Mogren, Parking, The Eno Foundation for Highway Traffic Control, 1957.
11. Head, J.A., "Predicting Traffic Accidents from Roadway Elements on Urban Extensions of State Highways," Bulletin 208, Highway Research Board, 1958.
12. Indiana Traffic Crash Facts, Indiana Office of Traffic Safety, 1961, 1962, 1963, 1964.
13. Institute of Traffic Engineers, Traffic Engineering, February, 1966. Pg. 15.

14. Kipp, O.L., "Final Report on the Minnesota Roadside Study," Bulletin 55, Highway Research Board, 1952.
15. McCracken, Dwight M., One-way Streets and Their Values, Traffic Engineering, Vol. 13, No. 3, July, 1941.
16. McGillivray, R.K., "One Way Traffic System Reduces Accidents and Traffic Congestion," Traffic Engineering, Institute of Traffic Engineers, Vol. 15, No. 5, Feb. 1945.
17. McMonagle, J.C., "Relation of Traffic Signals to Intersection Accidents," Bulletin 74, Highway Research Board, 1953.
18. McMonagle, J. Carl, "Traffic Accidents and Roadside Features," Bulletin 55, Highway Research Board, 1952.
19. May, Adolf D., Jr. "The Permanence of Limited Access Highways " Road School Bulletin, Purdue University, 1955.
20. Matson, T.M., W.S. Smith, and F.W. Hurd, Traffic Engineering, New York, McGraw-Hill Book Company, Inc., 1955.
21. Murphy, Charles J. "Baltimore's One-way Streets," Traffic Quarterly, Vol. 4, No. 3, July 1950.
22. National Committee on Uniform Traffic Laws and Ordinances, Uniform Vehicle Code. Bureau of Public Roads, 1962.
23. National Safety Council, Accident Facts, 1964 Edition.
24. Oglesby, C.H., and L.I. Hewes, Highway Engineering, New York, John Wiley and Sons, 1963.
25. Oregon Highway Department - Traffic Engineering Division, "One-way Street Routings on Urban Highways," Traffic Engineering, Vol. 21, No. 9, June 1951.
26. Peterson, Arvid O., "Analysis of Traffic Engineering on a High-Volume Highway," MSCE Thesis, Purdue University, 1965.
27. Prisk, C.W., "How Access Control Affects Accident Experience," Traffic Engineering, Institute of Traffic Engineers, Vol. 28, March, 1958.
28. Schoene, George, Effects of a Change in the Control Device on Intersection Accidents, MSCE Thesis, Purdue University, 1966.

29. Schoppert, D.W., "Predicting Traffic Accidents From Roadway Elements of Rural Two-Lane Highways with Gravel Shoulders," Bulletin 158, Highway Research Board, 1957.
30. Shaw, Robert B., "Evaluation of Delays and Accidents at Intersections to Warrant Construction of a Median Lane," MS Thesis, Purdue University, 1966.
31. Smeed, R.J., "Methods Available to Reduce the Numbers of Road Casualties," International Road Safety and and Traffic Review, Autumn, 1964.
32. Smith, Wilbur S., "Influence of Parking on Accidents," Traffic Quarterly, April 1947.
33. Solomon, David, "Accidents on Main Rural Highways Related to Speed, Driver, and Vehicle," U.S. Department of Commerce, Bureau of Public Roads, U.S. Government Printing Office, Washington, D.C., July, 1964.
34. Solomon, David, "Traffic Signals and Accidents in Michigan," Public Roads, U.S. Department of Commerce Bureau of Public Roads, U.S. Government Printing Office, Washington, D.C., Vol. 30, No. 10, October, 1959. pp. 234-237.
35. "Tearing Down Regression," WRAP, Statistical Laboratory, Library Program, Purdue University.
36. Woo, John C.H., "Correlation of Accident Rates and Roadway Factors," Thesis, Purdue University, 1957.

APPENDIX A
INVENTORY FORMS

APPENDIX A - INVENTORY FORMS

IDENTIFICATION

1. CITY _____ 2. POPULATION _____
 3. COUNTY _____
 4. SECTION OR ROUTE NUMBER _____
 5. SECTION LENGTH _____ FEET
 6. SECTION FROM _____ TO _____

EXISTING STREET AND TRAFFIC DATA

7. VOLUME _____ ADT (1964)
 8. POSTED SPEED LIMIT _____ MILES PER HOUR
 9. NUMBER OF INTERSECTIONS:
 3 WAY _____ 4 WAY _____ 5 WAY (OR MORE) _____
 10. NUMBER OF DRIVEWAYS:
 RESIDENTIAL _____ COMMERCIAL _____
 11. SURFACE CONDITIONS:
 GOOD _____ FAIR _____ POOR _____
 12. SIGNING:
 GOOD _____ FAIR _____ POOR _____
 13. STREET MARKINGS:
 GOOD _____ FAIR _____ POOR _____
 14. CURBS:
 ONE SIDE _____ BOTH SIDES _____ NONE _____
 15. SIDEWALKS:
 ONE SIDE _____ BOTH SIDES _____ NONE _____
 16. PARKING:
 ONE SIDE _____ BOTH SIDES _____ NONE _____
 PARALLEL _____ DIAGONAL _____
 CONDITIONAL _____
 17. WIDTH OF STREET _____ FEET
 TOTAL NUMBER OF MOVING LANES _____
 NUMBER OF MOVING LANES EACH WAY _____
 18. STREET LIGHTS
 NONE _____ INTERSECTIONAL _____ CONTINUOUS _____
 19. NUMBER OF TRAFFIC SIGNALS _____
 FIXED TIME _____ PROGRESSIVE _____
 TRAFFIC ACTUATED _____ PEDESTRIAN ACTUATED _____
 20. STOP SIGNS DIRECTED TO ARTERIAL TRAFFIC
 (NUMBER OF APPROACHES)
 3 WAY _____ 4 WAY _____ 5 WAY _____

FIGURE 8 - INVENTORY FORM - PAGE 1

21. STREET OPERATION: ONE WAY _____ TWO WAY _____
22. TYPE OF ACCESS CONTROL: NONE _____ PARTIAL _____
23. TURNING LANES LEFT TURN : YES _____ NO _____
 RIGHT TURN : YES _____ NO _____
24. COMPOSITION OF TRAFFIC: %T = _____
25. EXISTING STRUCTURES: BRIDGES _____
 UNDERPASSES _____
26. EXISTANCE OF MEDIAN:
 TYPE _____
 WIDTH _____ FEET
27. INFLUENCING CROWN: YES _____ NO _____
28. TYPE OF SURFACE _____
29. CHANNELIZATION AT INTERSECTIONS: YES _____ NO _____
30. MISCELLANEOUS REMARKS:

INTERSECTIONS				
	TRAFFIC VOLUME			
	LIGHT	MEDIUM	HEAVY	
3 WAY				
4 WAY				
5 WAY				

DRIVEWAYS				
	TRAFFIC VOLUME			
	LIGHT	MEDIUM	HEAVY	
RESIDENTIAL				
COMMERCIAL				

LIGHTING				
	INTERSECTIONAL			CONTINUOUS
FILAMENT				
OTHERS				
	NONE	POOR	FAIR	GOOD
FILAMENT				
OTHERS				

FIGURE 10 - INVENTORY FORM - PAGE 3

APPENDIX B

CHARACTERISTICS OF THE 100 SECTIONS

APPENDIX B

CHARACTERISTICS OF THE 100 SECTIONS

Table 22 Variable Listed in Appendix B

CODE	VARIABLE
A - - -	Volume (1000)
B - - -	Accidents/Mile
C - - -	Accidents/100 Million Vehicle Miles
D - - -	Intersections/Mile
E - - -	Three-way Intersections/Mile
F - - -	Four-way Intersections/Mile
G - - -	Heavy Volume Intersections/Mile
H - - -	Driveways/Mile
I - - -	Residential Driveways/Mile
J - - -	Commercial Driveways/Mile
K - - -	Traffic Signals/Mile
L - - -	Friction Points/Mile
M - - -	Number of Sides Parking Allowed
N - - -	Street Width
O - - -	Quality of Signing (P = poor, A = average, G = good)
P - - -	Quality of Street Markings (P = poor, A = average, G = good)
Q - - -	Quality of Street Lighting (P = poor, A = average, G = good)

Table 23 Characteristics of the Sixty-Eight Two-Lane Sections

CODE	1	2	3	4	SECTION						8	9	10
					5	6	7	8	9	10			
A	1.2	1.4	1.4	1.5	1.8	2.1	2.1	2.4	2.4	3.2			
B	0	9	5	4	4	2	5	5	6	6			
C	0	1675	969	782	599	318	713	624	685	493			
D	4	13	16	10	8	13	16	11	13	6			
E	4	4	11	4	8	7	7	5	6	4			
F	0	9	5	6	0	6	9	6	7	2			
G	0	1	3	0	0	1	2	1	2	1			
H	19	40	51	54	79	41	31	35	48	61			
I	17	27	35	51	0	30	16	29	44	49			
J	2	13	16	3	0	11	15	6	4	12			
K	0	0	0	0	4	0	0	0	0	0			
L	23	78	73	70	87	73	75	60	79	73			
M	0	0	0	2	0	0	2	0	0	0			
N	20	20	20	30	22	20	36	22	20	22			
O	G	A	A	G	A	A	G	A	G	A			
P	G	P	P	G	P	A	G	P	A	A			
Q	P	P	A	G	A	A	P	A	G	G			

Table 23 (Continued)

CODE	SECTION									
	11	12	13	14	15	16	17	18	19	20
A	3.4	3.7	3.8	3.9	4.0	4.0	4.0	4.2	4.3	4.3
B	9	6	10	15	12	22	8	15	4	10
C	708	466	725	721	791	1489	540	964	224	630
D	12	9	13	19	12	16	13	7	9	15
E	4	0	0	16	5	14	6	3	4	9
F	8	9	13	3	7	2	7	4	5	6
G	2	1	3	3	0	2	2	1	0	1
H	34	25	35	56	54	59	52	49	56	63
I	22	16	25	41	33	43	14	27	33	42
J	12	9	10	15	21	16	38	22	23	21
K	1	1	0	0	0	2	0	0	0	2
L	54	43	80	86	96	82	77	60	74	91
M	2	0	2	0	0	1	0	2	0	2
N	40	22	36	24	22	27	24	30	24	38
O	A	G	A	G	P	P	A	G	A	A
P	A	A	A	A	A	P	A	G	A	P
Q	A	A	G	P	P	P	P	A	A	G

Table 23 (Continued)

CODE	SECTION									
	21	22	23	24	25	26	27	28	29	30
A	4.4	4.5	4.6	4.9	5.0	5.0	5.0	5.2	5.2	5.4
B	10	9	9	22	23	3	6	4	9	9
C	624	572	537	1225	1258	152	322	203	451	472
D	12	12	10	12	11	10	11	13	10	9
E	4	6	1	1	7	1	5	6	3	6
F	8	6	9	11	4	9	6	7	7	3
G	2	1	3	3	0	1	0	1	0	0
H	46	47	40	52	46	65	55	40	24	29
I	31	28	26	34	6	26	34	19	3	6
J	15	19	14	18	40	39	21	21	21	23
K	0	1	0	1	0	0	0	1	0	0
L	66	72	72	89	73	75	76	64	47	45
M	0	1	2	1	1	2	2	0	0	2
N	30	36	36	30	30	58	33	24	24	36
O	G	G	G	A	A	A	A	G	A	A
P	G	G	G	P	A	P	G	A	G	A
Q	G	G	A	G	A	G	G	G	P	P

Table 23 (Continued)

CODE	SECTION											
	31	32	33	34	35	36	37	38	39	40		
A	5.5	5.6	5.7	5.7	5.8	6.0	6.0	6.1	6.2	6.3		
B	17	27	4	5	15	20	23	22	5	37		
C	928	1319	177	234	712	932	1042	966	222	1591		
D	17	13	6	13	11	8	10	13	18	16		
E	14	4	4	8	6	5	3	8	0	8		
F	3	9	2	5	5	3	7	5	18	8		
G	0	0	1	0	3	1	0	2	3	6		
H	64	83	54	26	71	52	66	98	30	30		
I	33	27	39	8	60	21	57	92	22	6		
J	31	56	15	18	11	31	9	6	8	24		
K	0	0	0	0	2	1	0	1	0	0		
L	87	124	65	50	83	73	86	116	95	63		
M	0	2	0	0	1	1	2	1	2	2		
N	22	40	22	22	30	36	40	30	30	20		
O	G	A	A	A	A	A	G	A	G	G		
P	A	P	A	A	A	A	G	A	A	G		
Q	G	G	P	A	A	A	A	A	G	A		

Table 23 (Continued)

CODE	SECTION										
	41	42	43	44	45	46	47	48	49	51	
A	6.4	6.5	6.6	6.6	7.0	7.0	7.2	7.2	7.2	7.6	
B	20	13	9	11	27	35	12	19	20	37	
C	855	556	371	459	1067	1378	463	737	748	1332	
D	17	11	5	11	13	18	5	18	10	12	
E	13	5	5	8	5	13	3	14	7	3	
F	4	6	0	3	8	5	2	4	3	9	
G	0	3	0	1	0	3	1	0	2	1	
H	67	57	20	60	53	23	58	55	70	36	
I	40	24	15	43	26	14	26	39	49	24	
J	27	33	5	17	27	19	32	16	21	12	
K	0	0	0	1	0	4	0	0	2	0	
L	88	83	25	74	80	55	66	86	88	69	
M	1	2	0	2	2	2	0	1	2	2	
N	30	36	24	40	40	30	24	30	40	36	
O	A	G	A	G	G	A	A	A	A	G	
P	A	G	A	G	A	A	A	G	P	A	
Q	A	P	A	G	A	G	G	A	G	G	

Table 23 (Continued)

CODE	SECTION									
	52	53	54	57	59	61	62	63	64	66
A	8.0	3.0	8.5	9.1	9.7	10.0	10.2	10.3	10.5	11.0
B	25	23	32	21	52	21	35	30	10	8
C	862	784	1047	629	1461	564	945	798	268	227
D	13	11	18	15	15	12	18	23	16	10
E	6	0	2	12	7	8	16	13	10	6
F	7	11	16	3	8	4	2	10	6	4
G	2	0	1	1	4	1	2	2	0	1
H	44	37	78	72	24	71	66	30	75	77
I	17	33	62	17	4	7	38	23	75	63
J	27	4	16	55	20	64	28	7	0	14
K	0	0	0	1	4	0	2	0	0	1
L	71	83	101	101	63	96	93	79	98	91
M	1	1	2	1	2	0	2	1	0	0
N	33	30	36	33	36	24	36	32	18	16
O	G	A	A	P	A	G	A	G	G	A
P	G	P	A	P	G	A	P	G	G	G
Q	G	G	A	A	A	P	G	G	A	P

Table 23 (Continued)

CODE	SECTION									
	67	69	71	74	77	80	83	88		
A	11.4	12.3	13.0	13.7	14.9	16.5	18.0	20.8		
B	33	103	21	50	19	45	8	70		
C	793	2301	439	999	345	739	115	920		
D	14	17	19	15	2	26	5	4		
E	4	7	13	8	1	21	5	2		
F	10	10	6	7	1	5	0	2		
G	1	7	1	6	1	1	0	1		
H	36	36	45	4	7	42	28	41		
I	28	7	45	4	0	1	6	1		
J	8	29	12	0	7	41	22	40		
K	3	8	1	4	1	4	0	1		
L	61	77	74	26	11	77	33	47		
M	2	2	2	2	0	2	0	0		
N	36	36	48	36	22	34	18	22		
O	A	A	G	G	G	A	P	G		
P	G	P	G	G	G	G	A	G		
Q	A	G	G	G	P	A	A	A		

Table 24 Characteristics of the Twenty-One Four-Lane Undivided Sections

CODE	SECTION									
	55	60	65	68	70	72	73	76	78	79
A	9.0	9.8	11.0	12.0	13.0	13.5	13.5	14.5	15.0	15.0
B	29	28	24	63	34	129	50	127	27	30
C	877	770	604	1433	826	2629	1005	2399	498	551
D	8	14	10	10	13	17	21	16	6	11
E	6	10	3	2	9	7	15	3	2	6
F	2	4	7	8	4	10	6	13	4	5
G	2	3	2	3	3	5	2	9	2	1
H	20	63	85	33	85	59	45	87	78	63
I	8	50	70	20	53	10	12	13	76	63
J	12	13	15	13	32	49	33	74	2	0
K	2	1	3	3	3	6	2	7	3	1
L	31	81	102	51	101	110	75	116	86	79
M	0	0	2	1	0	0	2	0	2	2
N	44	48	48	48	36	36	48	42	48	48
O	G	A	G	G	G	P	A	A	G	G
P	G	G	G	G	G	P	A	G	G	G
Q	G	G	A	A	A	G	G	G	G	G

Table 24 (Continued)

SECTION

CODE	81	89	91	92	93	94	95	96	97	98	99
A	16.5	21.0	21.9	23.0	23.0	24.0	25.0	26.2	28.0	30.0	30.0
B	85	35	51	60	29	54	26	55	81	99	95
C	1408	456	640	712	343	619	283	573	796	900	863
D	20	11	8	18	20	11	11	15	18	15	15
E	11	7	3	10	15	6	8	10	7	6	9
F	9	4	5	8	5	5	3	5	11	9	6
G	3	5	2	1	1	1	2	2	5	2	6
H	49	46	50	50	124	48	63	85	115	60	65
I	7	3	26	25	32	22	22	30	28	24	9
J	42	43	24	25	92	26	41	55	87	36	56
K	6	4	2	4	2	1	2	3	5	2	5
L	77	61	63	80	149	64	76	108	145	84	85
M	2	0	2	2	0	0	0	2	2	0	2
N	50	48	56	50	40	36	48	50	64	36	60
O	G	G	G	G	A	G	G	G	A	G	G
P	A	G	G	G	A	G	G	G	A	G	G
Q	A	P	G	G	A	G	P	G	G	G	A

Table 25 Characteristics of the Four Four-Lane Divided
Sections

CODE	SECTIONS			
	58	84	87	100
A	9.6	19.3	20.0	32.0
B	7	35	2	78
C	213	501	29	665
D	4	4	6	12
E	2	2	3	2
F	2	2	3	10
G	0	2	1	6
H	4	19	17	42
I	2	9	0	14
J	2	10	17	28
K	0	1	1	5
L	9	24	26	70
M	0	0	0	2
N	43	43	54	80
O	P	A	G	G
P	A	P	G	G
Q	P	P	P	G

Table 26 Characteristics of the Seven One-Way Street
 Sections

CODE	SECTIONS						
	50	56	75	82	85	86	90
A	7.4	9.0	14.0	17.5	20.0	20.0	21.0
B	22	29	46	61	63	55	46
C	829	877	893	963	862	750	599
D	14	14	13	17	11	19	15
E	2	0	1	4	6	12	4
F	12	14	12	13	5	7	11
G	1	1	3	3	3	4	3
H	35	29	32	27	79	26	34
I	10	21	21	11	43	8	9
J	25	8	11	16	36	18	25
K	0	0	4	3	4	5	4
L	67	62	51	47	98	59	71
M	2	2	2	2	2	2	2
N	33	50	40	34	54	48	45
O	A	G	G	G	G	A	G
P	A	G	G	G	G	G	G
Q	G	G	A	A	A	A	A