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

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by

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Technical Paper

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

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

December 28, 1967

File No: 8-5-8

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

Project No: C-36-59H

Attached is a Technical Paper "Correlation of Design Characteristics and Operational Controls with Accident Rates on Urban Arterials." This paper has been authored by Mr. Thomas Mulinazzi, Graduate Assistant, and Professor Harold Michael of our staff. The paper is from research previously reported to the Board as a research report of the same title. The paper was presented to the 1967 Annual Purdue Road School and has been submitted for publication in the Proceedings.

The paper reports on the design and control factors which the research through regression analysis and case study approaches found to be correlated with accidents on urban arterials. The case study analysis is emphasized in the paper as it provides understandable comparison between sections of arterials carrying similar volume of traffic but having similar or very different number of accidents per mile.

The paper is presented for approval of publication.

Respectfully submitted,

Harold L. Michael/jgp
Harold L. Michael
Associate Director

HLM:nf

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Technical Paper

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by

Thomas E. Mulinazzi, Graduate Assistant
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File No: 8-5-8
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Purdue University
Lafayette, Indiana

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INTRODUCTION

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."(3)

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.(4) Since that event the number of traffic deaths each year has reached epidemic conditions. However, one should not look only at the spectacular fatal accident because the factors which cause any accident are similar to those for fatal accidents, especially in urban areas where speeds are slower.

In the past much of accident research has been concentrated on rural accidents because a large percentage of fatal accidents occur on rural highways where higher speeds increase the severity. Nevertheless, a majority of all non-fatal injury collisions happen in urban areas where about one-half of the total vehicle miles are driven annually. It seems apparent that much accident research is also needed in urban areas, especially with the multitude and magnitude of urban areas forecast for the future.

Most current highway activity in urban areas is focused on the development of freeways and expressways, while the important role of other major urban streets as arterial highways is often forgotten.

By necessity the main function of these urban arterials 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) (3) (9)

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:(5)

> "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 1 shows some significant results from available data.

Because of the dual function of most urban arterials, control of access is not practical on all of them and improvements in highway safety must be sought in design characteristics and operational controls if

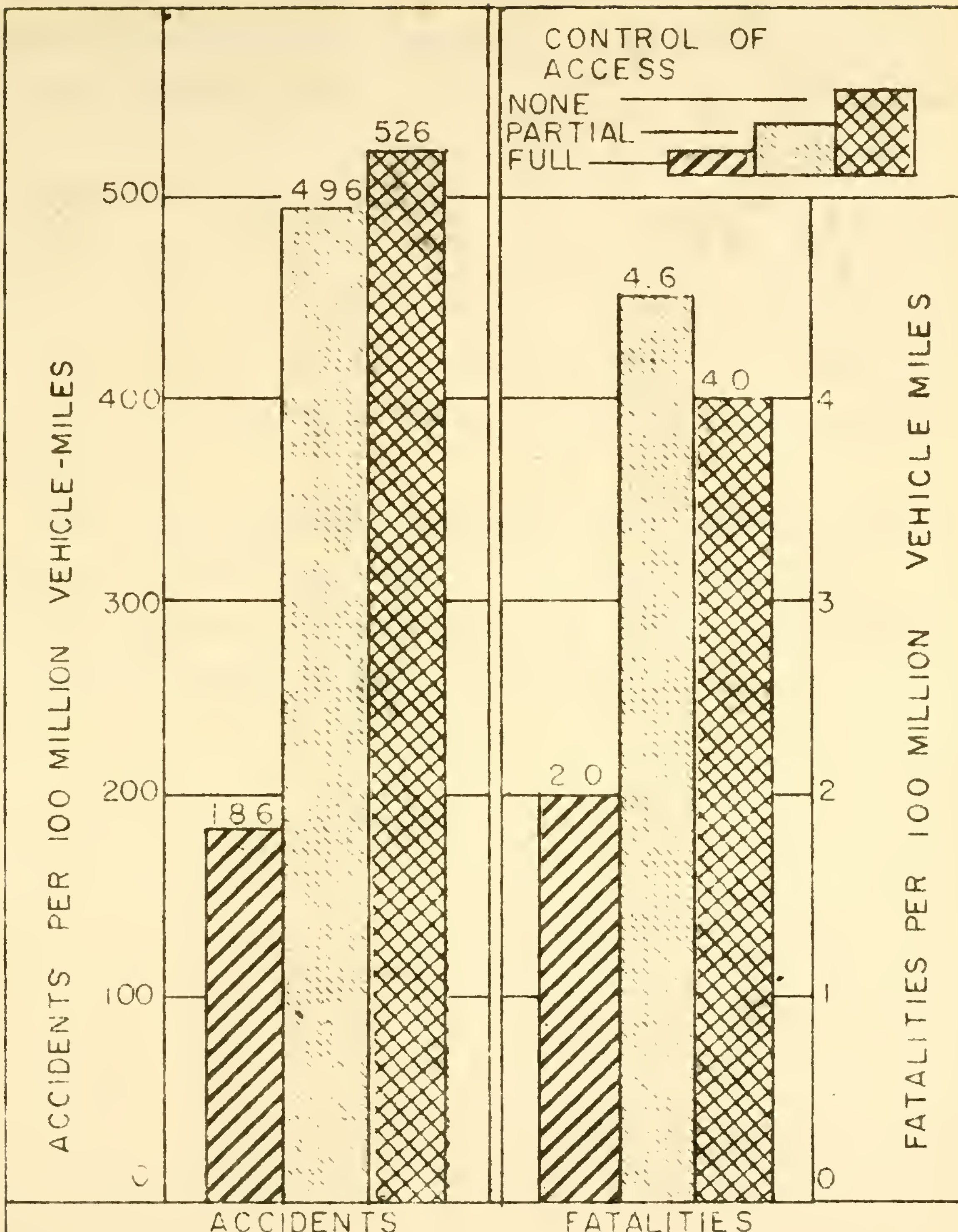

FIGURE 1 - EFFECT OF CONTROL OF ACCESS ON ACCIDENTS AND FATALITIES IN URBAN AREAS

accidents are to be reduced. These improvements may be in such areas as 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.(6) 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 (Figure 2) are being driven more miles (Figure 3) which leads to congestion and greater potentials for accidents.

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)

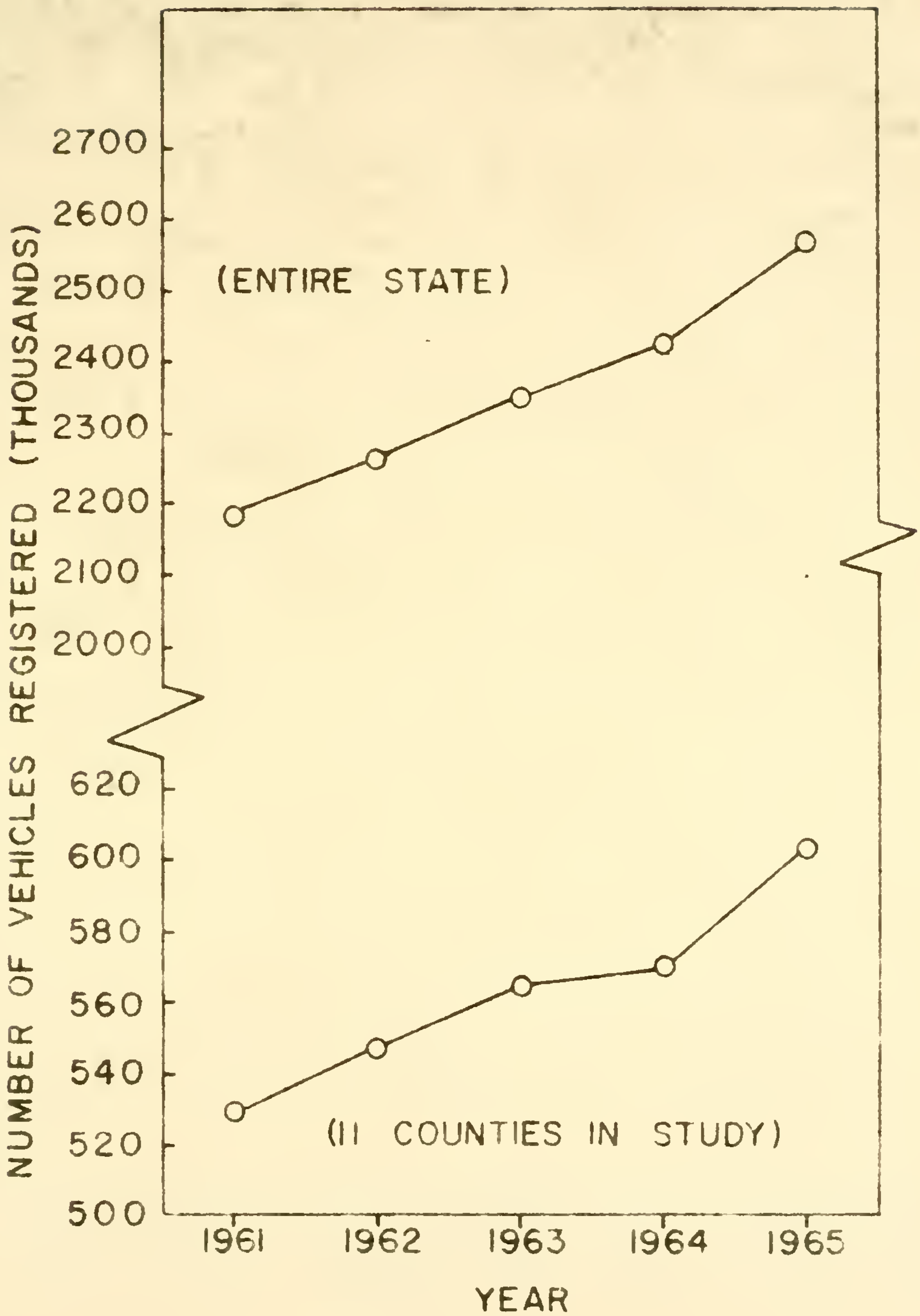

FIGURE 2 - VEHICLE REGISTRATION

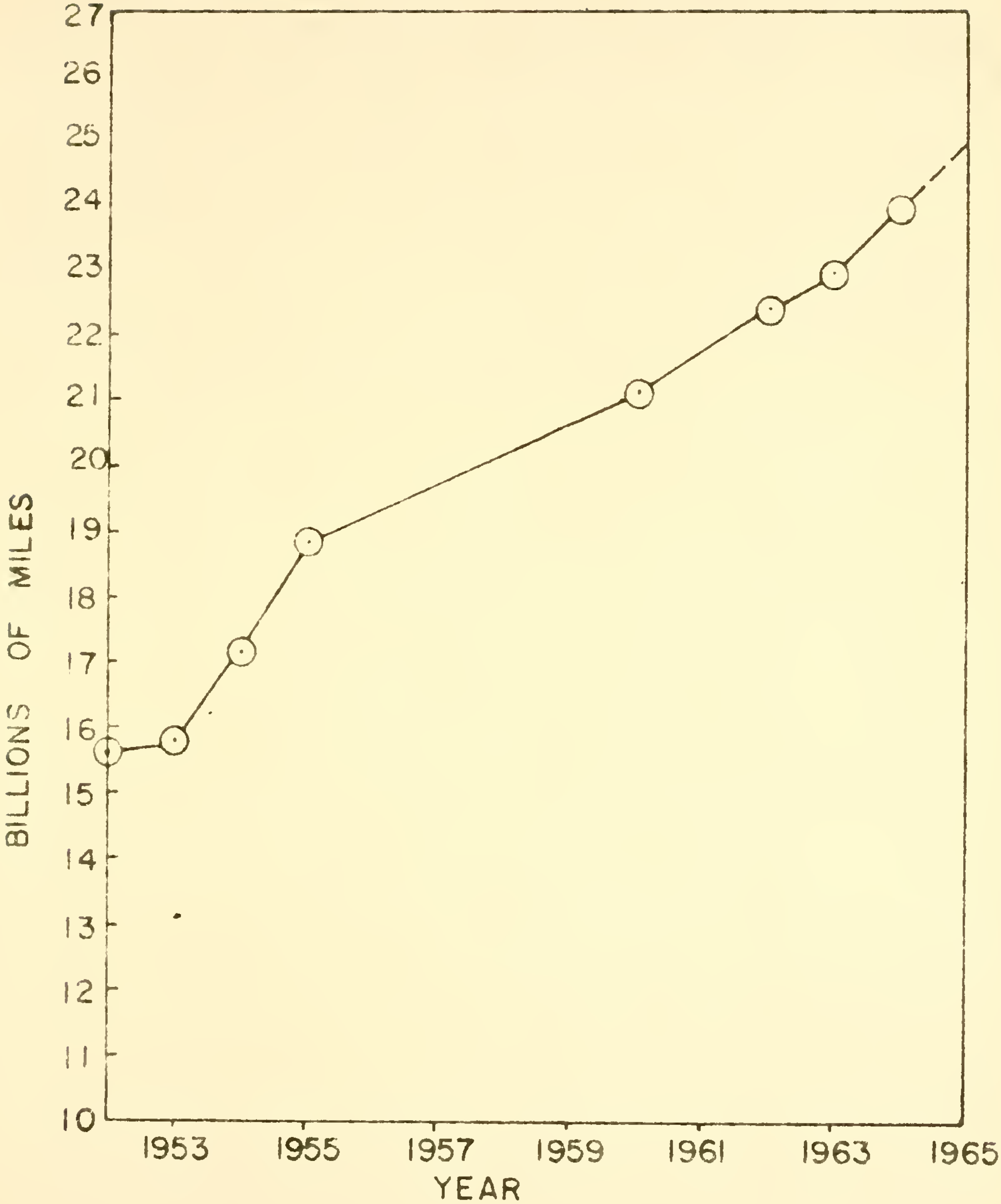

FIGURE 3 - MILES DRIVEN IN INDIANA

(SOURCE : INDIANA TRAFFIC CRASH FACTS)

THE STUDY LOCATIONS

One-hundred sections of urban arterials, 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 in urban areas 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 4. Most of the sections were chosen on urban extensions of state highways because of the availability of volume and accident data.

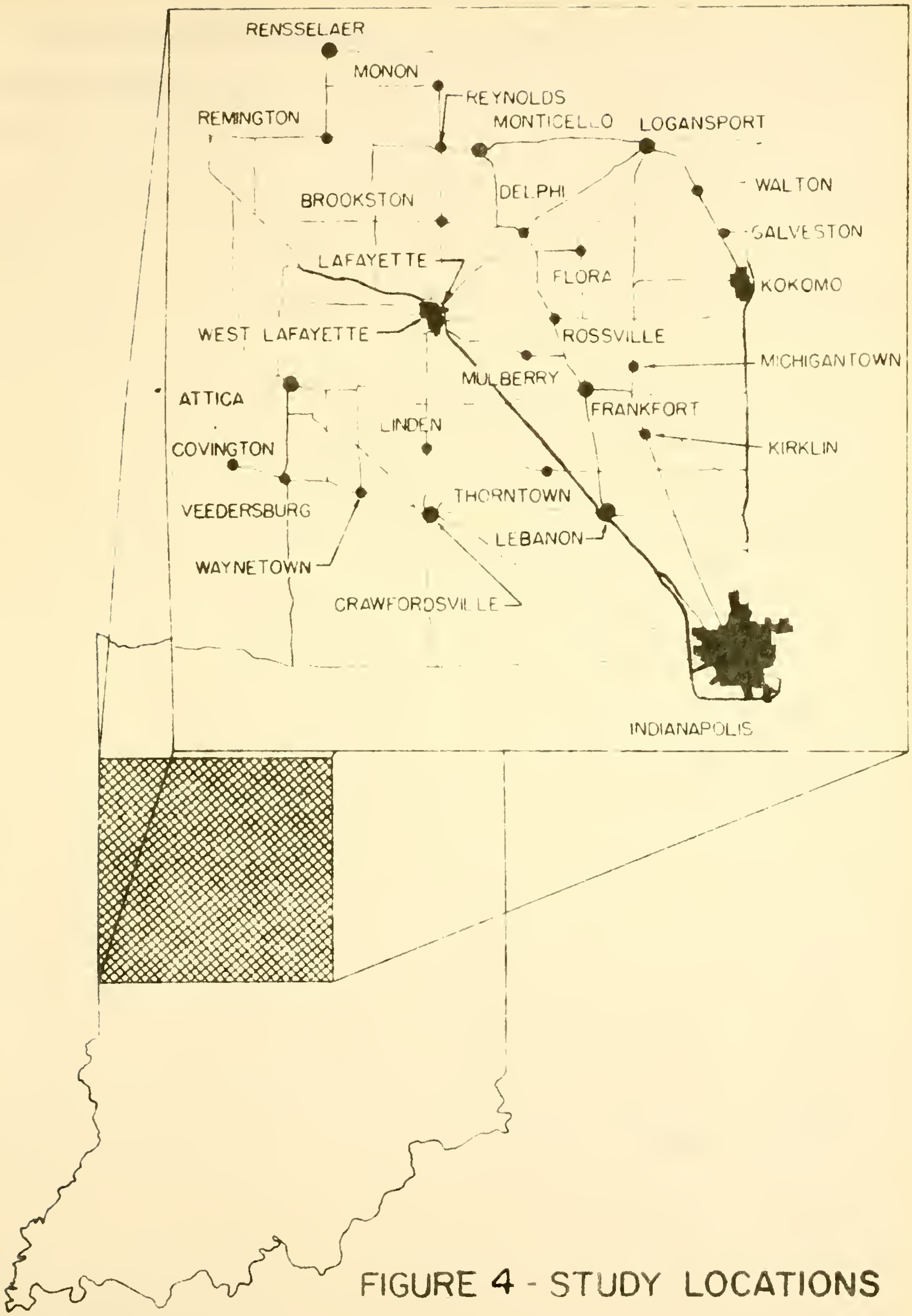

FIGURE 4 - STUDY LOCATIONS

DATA COLLECTION

The method of investigation used in this study consisted of obtaining and analyzing a large amount of pertinent accident data. It was believed that an informative pattern of accident occurrence would result on the large number of sections chosen. This is basically the same procedure used in the Michigan Study of the late 1940's.(8)

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

1. To obtain maps of each city and make an initial survey.
2. To establish definite section boundaries and collect pertinent information such as section length, number of intersections, number of driveways, parking conditions, width of street, etc.
3. To note relative traffic 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 was 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 on which data were collected and that were analyzed for their effects on the accident rate are shown in Table 2.

TABLE 2. Independent Variables

Number	Variable Description
1	Volume (ADT) on the Arterial in Thousands of Vehicles
2	Number of Intersections per mile
3	Number of Heavy Volume Intersections per Mile (Intersections with Arterial Streets)
4	Number of Medium Volume Intersections per mile (All Cross Streets Except Arterials and Low Volume Local)
5	Number of Traffic Signals per Mile
6	Number of Driveways per Mile
7	Number of Commercial Driveways per Mile
8	Number of Medium and Heavy Volume Commercial Driveways per Mile (Rated on Basis of Commercial Activity)
9	Number of Light Volume Commercial and Residential Driveways per Mile
10	Number of Friction Points per Mile
11	Street Width (in feet)
12	Number of Moving Lanes
13	Posted Speed Limit
14	Quality of Signing (0,1,2) (poor, fair, good)
15	Quality of Street Markings (0,1,2) (poor, fair, good)
16	Parking Allowed on One Side Only (0,1) (none or on one side)
17	Parking Allowed on Two Sides (0,1) (none or on two sides)
18	Intersectional Street Lighting Only (0,1) (none or intersectional)
19	Continuous Street Lighting (0,1) (none or continuous)
20	Quality of Street Lighting (0,1,2) (poor, fair, good)
21	Number of Four-way Intersections per Mile
22	One-way Street Operation (1,0) (one way, two-way)
23	Number of Three-way Intersections per Mile
24	Urban Design of Pavement Cross-Section (0,1) (curbed, uncurbed)
25	Number of Yellow Flashers per Mile
26	Ratio - Commercial Driveways per Mile to Total Number of Driveways per Mile

Volume Data

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

Several traffic volume counts were usually available for each section. Every one of these counts was updated and converted to a 1964 ADT (the midyear of the accident data). To obtain an estimate of the average volume on any particular section, the 1964 volumes at each of the several locations on the arterial were noted and a representative value for the average volume on the arterial was chosen. This was not too difficult as each section was selected on the basis of having similar volumes and characteristics throughout its length.

The volume data for the sections in the Indianapolis area, Marion County, were acquired through the Bureau of Traffic Engineering for Indianapolis. The data received were the 1964 volume counts used by the Indianapolis Regional Transportation and Development Study. Thirty-two sections, with an ADT range from 7,000 to 32,000, were selected in Indianapolis 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 variables 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.(3) 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.

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 annual 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 square 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 annual accidents per mile using the twenty-six independent variables shown in Table 2.

Almost all of the regression equations thus developed for estimating accidents per 100 million vehicle miles explained less than fifty percent of the variability in such accident rate on the sections of highway in the study. Furthermore the resulting equations were often illogical and contradictory. It was apparent that important factors other than those analyzed in this research were involved. As a consequence the regression equations developed for accidents per 100 million vehicle miles are not reported here.

The regression equations which were developed for annual accidents per mile, however, explained greater than fifty percent of the variability in number of accidents on the study sections (up to as much as 79 percent). The resulting simplified regression equations for estimating the annual number of accidents per mile on urban arterials are as follows:

1. Using data from all 100 study sections

$$Y = -0.261 + 1.256X_1 + 3.909X_3 + 6.036X_5$$

where

Y = Number of accidents per mile annually

X_1 = Volume (ADT) on the section in thousands of vehicles

X_3 = Number of heavy volume intersections per mile

X_5 = Number of traffic signals per mile

R^2 = 0.74

2. Using data from the 35 low volume sections (ADT between 1200 and 5800)

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

where

X_8 = Number of heavy end medium volume commercial drives per mile

X_{16} = Parking allowed

$R^2 = 0.52$

3. Using data from the 32 high volume sections in Indianapolis

$$Y = 1.630 + 7.222X_2 + 4.510X_{21}$$

where

X_3 = Number of heavy volume intersections per mile

X_{21} = Number of 4-way intersections per mile

$R^2 = 0.62$

4. Using data from the 68 two-lane sections

$$Y = 0.894 - 1.754X_1 + 5.990X_5$$

where

X_1 = Volume (ADT) on the section in thousands of vehicles

X_5 = Number of traffic signals per mile

$R^2 = 0.62$.

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	Section 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.

	Sections	
Variable	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.

	Section	
Variables	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	Section 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.

	Section	
Variables	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.

	Section	
Variables	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.

	Section	
Variable	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	Section 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	Section 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.

	Section	
Variables	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.

	Section	
Variables	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.

	Section	
Variables	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.

	Section	
Variables	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.

	Section	
Variables	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	Section 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, an exposure rate, also will most likely decrease, where one or more of the conditions given above, except that of traffic volume reduction, occur.

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. The multiple linear regression equations developed to predict accidents per mile should be useful in evaluating possible safety benefits from proposed design and control changes.

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