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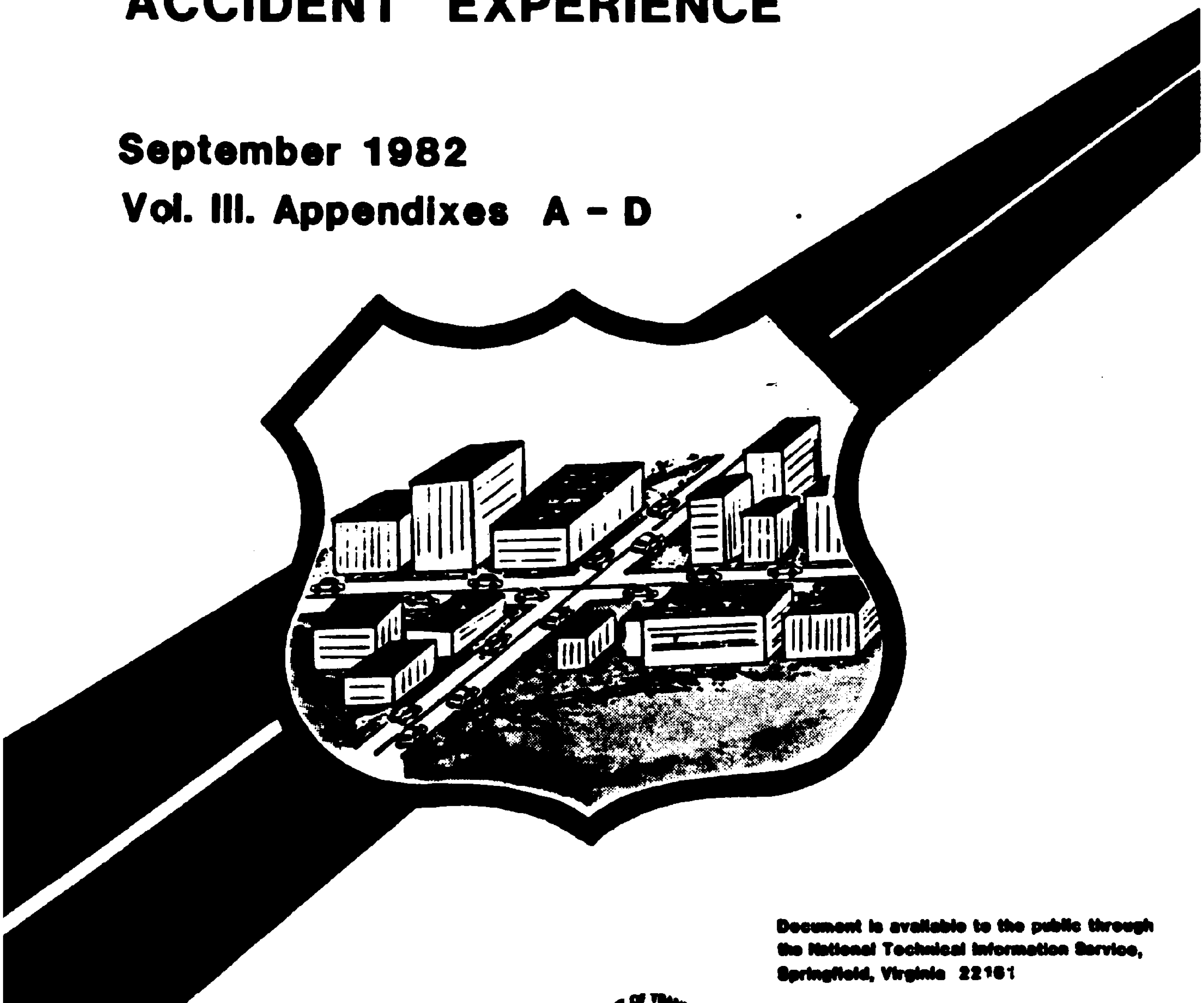
ANALYSIS OF URBAN ARTERIAL ROAD AND STREET ACCIDENT EXPERIENCE

September 1982

Vol. III. Appendixes A - D



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16. Abstract

The purpose of this research study was to examine the specific characteristics of urban arterial traffic accidents, and to identify general causal elements and related countermeasures that can be used to reduce the rate and severity of these accidents. Accident, geometric, traffic control, and volume data were collected and analyzed for 8,678 one-tenth-mile (0.16-km) roadway segments located in 19 metropolitan areas.

The result of the analyses provides further evidence that specific geometric, traffic control, volume, and environmental conditions influence accident frequency and rate on urban roadways. Guidelines that can be used to identify accident problems and to select countermeasures are provided in this report. One important product of this research was the development of a comprehensive computerized accident and roadway data base that can be used to explore in greater detail specific urban arterial accident problems and possible solutions.

This report is the third in a series. The series is comprised of:

FHWA/RD-82/136 - Volume I - Executive Summary
FHWA/RD-82/137 - Volume II - Final Report
FHWA/RD-82/146 - Volume III - Appendixes A-D
FHWA/RD-82/147 - Volume IV - Appendixes E-I

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FOREWORD

The purpose of this study was to examine the specific characteristics of urban arterial traffic accidents, and to identify general causal elements and related countermeasures that can be used to reduce the rate and severity of these accidents. The report will be of interest to state and local highway officials involved in safety and traffic operations on urban roadways.

The results of the study provide further evidence that geometric, traffic control, volume, and environmental conditions influence the accident frequency and rate on urban roadways. Guidelines that can be used to identify accident related problems and to select appropriate countermeasures are provided in the report. One important product of this research was the development of a comprehensive computerized accident and roadway data base that can be used by highway officials and researchers to explore in detail specific urban arterial accident problems and possible solutions. Examples illustrating the use of the data base are given in the Appendixes.

Appreciation is given to the highway safety administrators and police officials who provided the accident data for this study.

Sufficient copies of the research report are being distributed to provide two copies to each regional office, one copy to each division office, and two copies to each State highway agency. Direct distribution is being made to each division office.

Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

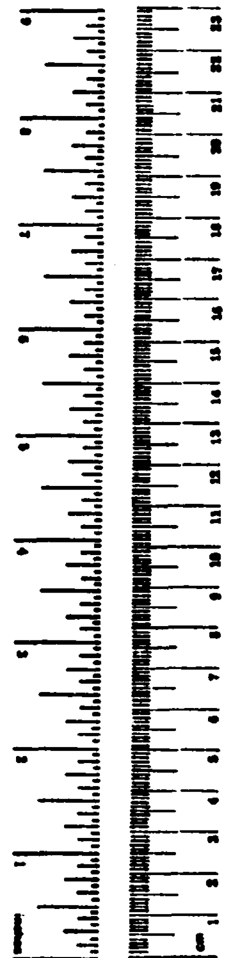
NOTICE

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

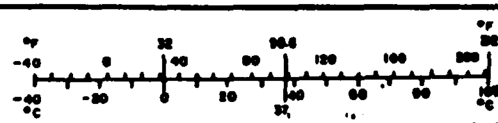
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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APPENDIX A - LITERATURE REVIEW

Introduction

The purpose of the literature review was to summarize the results of past and current studies which were conducted to investigate relationships between traffic accidents and features of nonlimited access urban arterial roadways. Emphasis was placed on identifying research efforts undertaken to:

- establish a relationship between accidents and specific roadway, environmental, and operational features and human factors, and to
- identify countermeasures and evaluate the effect of various countermeasures on accident type and severity.

An extensive search was initiated to identify relevant documents. Library facilities of the University of Notre Dame, Wayne State University, and the University of Michigan as well as other information sources including publications of the Transportation Research Board, National Cooperative Highway Research Program, Institute of Transportation Engineers, and the Federal Highway Administration were utilized.

A large number of studies have been conducted to determine relationships between accidents and specific geometric, environmental, and traffic conditions. The majority of the studies were conducted on rural highways, or include a combination of rural and urban situations. A major problem in determining whether or not a particular document should be included in the review is that there is no standard definition of an urban arterial highway. It is generally accepted that if a roadway lies within urban boundaries, the highway is classified as urban. A more accurate approach to defining an urban arterial would be to categorize the roadway in terms of roadside development characteristics, operating conditions, and other quantifiable factors. Only the studies that were reported to be conducted in urban areas were included in this synthesis but it is conceivable that some of the roadways may be more characteristic of rural conditions.

Another problem encountered in identifying relevant urban arterial materials deals with the definition of the phrase "relationship between accidents and roadway elements." In a statistical context, a relationship is defined as a mathematical degree of association between two or more variables. A less rigid definition of a relationship encompasses an apparent or logical association between two or more factors. For the purpose of this study, the latter definition was used as a guideline for identifying related research documents. Because proven mathematical relationships have been developed for only a few variables, use of the statistical definition would have greatly reduced the number of studies that would be included in the literature review.

Initially, over 200 publications were identified as urban arterial related. Careful screening of the reports by preparation of preliminary abstract cards and a cross-reference index reduced the number of related studies to 74. For each of these documents an abstract was prepared. A comprehensive annotated bibliography including an abstract of each study is given in Appendix B.

A synthesis of the literature is given below. The material is summarized in the following categories.

- Overview of the Urban Arterial Research
- Geometric Factors
- Environmental Factors
- Operational Factors
- Human Factors
- Countermeasures
- Summary of Findings
- Results

Overview of Urban Arterial Safety Research

A tabulation of the studies and relationships identified during the literature review is given in Table 1. Most of the studies were conducted on four-lane divided and multilane facilities, however, two-lane, undivided roadways, and intersections have also received considerable attention. Only five reports included investigations on one-way urban streets.

Over half of the studies have been conducted since 1970. The type of reports included policy documents, guidelines, research results, synthesis, and other types. The policy and guideline reports were listed because they are the key documents used to-date to design and maintain operations and safety on urban arterials. Many of the standards and criteria given in these documents are not based on substantial research investigations; however, the recommendations represent a synopsis of the best information that is available to-date. The synthesis reports contain the results of studies conducted in a specific area. Examples of these documents are reports prepared by Box, 1970 [15]* on intersections and

* The number in the bracket identifies the publication on the reference list provided at the end of this appendix.

Table 1. Summary of urban arterial accident studies.

Reference			Type of Urban Arterial							Type of Report					Analysis Method					Geometrical Relationships																		
No.	Author	Yr.	One-Way	Two-Lane	Four-Lane Undivided	Four-Lane Divided	Multi-Lane	Intersection	Combination or Other	Policy	Guideline	Research	Synthesis	Other	Correlation	Regression	Comparisons	Cost-Effectiveness	Other	Access Control	Driveways	Traffic Signals	Intersections	Two-Way Median	Raised Median	Median Width	Pavement Width	Turn Lanes	Intersection Design	Median Openings	Sight Distance	Fixed Objects	Parking	Vertical Alignment	Horizontal Alignment	Utility Poles	Median Presence	One-Way Streets
01	AASHO	73	●	●	●	●	●	●	●		●																											
02	Auto Safety Foundation	63	●	●	●	●	●	●	●				●																									
03	Avery	60	●	●	●	●						●					●																					
04	Azzeh	75				●	●	●	●		●		●					●		●	●	●																
05	Babcock	78			●	●	●					●					●							●	●												●	
06	Berg	73			●							●				●							●															
07	Billion	58							●			●					●																					
08	Billion	62				●	●					●					●								●	●												
09	Bissell	65	●		●							●					●																					●
10	Blackburn	78		●			●					●				●	●	●																				
11	Bochner	78							●		●								●																			
12	Box	65			●							●					●								●												●	
13	Box	72							●			●					●										●											
14	Box	76					●					●					●																					
15	Box	70							●				●								●																	
16	Box	70						●					●								●							●	●									
17	Burritt	78		●	●							●					●	●						●														
18	Caylor	77							●		●		●											●	●													
19	Chapman	78		●		●	●					●					●						●															
20	Christiff	66							●			●							●																			
21	Clark	65							●			●				●																						
22	Clayton	77						●				●							●																			
23	Coleman	61							●			●					●					●					●											
24	Cribbins	67				●						●			●	●				●		●	●			●				●								
25	Cribbins	67				●						●			●	●				●		●	●			●		●		●								
26	David	75						●				●					●	●				●						●	●		●	●	●	●	●			
27	FHWA - 'MUTCD'	78	●	●	●	●	●	●	●	●																												
28	FHWA - 'Urban Traffic'	N/A						●	●				●																									
29	Fielding	55			●							●					●					●																
30	Fisher	77							●			●					●										●											
31	Foley	67			●							●					●								●												●	
32	Frick	68				●						●					●							●	●													
33	Glauz	80						●				●					●																					
34	Glennon	76							●			●				●			●													●						
35	Gupta	73		●								●				●											●				●			●	●			
36	Hanna	76						●				●					●					●									●			●				

Table 1. Summary of urban arterial accident studies (continued).

Reference			Type of Urban Arterial							Type of Report					Analysis Method					Geometrical Relationships																		
No.	Author	Yr.	One-Way	Two-Lane	Four-Lane Undivided	Four-Lane Divided	Multi-Lane	Intersection	Combination or Other	Policy	Guideline	Research	Synthesis	Other	Correlation	Regression	Comparisons	Cost-Effectiveness	Other	Access Control	Driveways	Traffic Signals	Intersections	Two-Way Median	Raised Median	Median Width	Pavement Width	Turn Lanes	Intersection Design	Median Openings	Sight Distance	Fixed Objects	Parking	Vertical Alignment	Horizontal Alignment	Utility Poles	Median Presence	One-Way Streets
37	Head	59		●		●						●			●	●					●	●	●				●											
38	Heimbach	68							●			●					●																					
39	Hoffman	74				●						●					●							●														
40	Holbrook	76						●				●				●																						
41	Humphreys	79							●			●					●																●					
42	ITE - 'Guidelines'	79							●		●		●																									
43	Jones	78							●			●				●	●															●				●		
44	King	75						●				●					●					●									●			●				
45	Leong	70							●			●					●									●											●	
46	May	59					●					●				●						●	●															
47	May	55		●		●						●					●			●																		
48	Mayer	71	●										●																									●
49	McGee	76						●				●					●																					
50	McQuirk	76	●	●	●							●				●					●	●	●															
51	Moore	75						●			●		●				●														●							
52	Mueller	70							●				●																									
53	Mulinazzi	67		●			●					●				●					●	●	●				●						●					
54	Nemeth	76		●		●						●					●							●														
55	Olson	74							●					●											●													
56	Parker	79			●	●						●				●					●	●	●	●	●					●							●	
57	Parker	75						●				●					●																					
58	Post	77							●		●								●																			
59	Ricci	79							●					●			●																					
60	Roy	78							●				●						●																			
61	Sawhill	68		●		●						●					●							●														
62	Shaw	68						●				●				●												●										
63	Snyder	74							●			●				●																						
64	Stark	73							●			●					●																					
65	Stover	70							●		●								●	●																		
66	Telford	53			●	●						●					●																				●	
67	Terry	68				●						●					●											●										
68	Thomas	66				●						●					●							●														
69	Torres	67							●			●					●					●					●						●					
70	Walton	79				●						●				●	●				●	●		●														
71	Webb	56						●				●					●												●						●			
72	Wooten	64				●						●					●								●													
73	Wright	76		●								●			●	●																			●			
74	Zegeer	75							●			●					●																					

Table 1. Summary of urban arterial accident studies (continued).

No.	Author	Yr.	Environmental Relationships						Operational Relationships																		Human Factor			Accident Countermeasures on Urban Streets														
			Commercial Floor Area	Skid Number	Illumination Level	Roadside Development	Wet Time	Area Population	Speed	Volume	Travel Time	Traffic Signal Control	Yield Signs	Two-Way Stop	Four-Way Stop	Steering Reversals	Brake Applications	Traffic Conflicts	V/C Ratio	Signal Timing	Level of Service	Street Signs	Vehicle Hits	Fuel Economy	Right Turn on Red	Signal Improvements	Sex of Driver	Skin Response	Age	Install Median	Convert to One-Way	Post Proper Speed Limit	Prohibit Parking	Improve Sight Distance	Limit Driveways	Limit Traffic Signals	Provide Two-Way Median	Provide Raised Median	Resurface	Install Illumination	Install Turn Lanes	Widen Pavement	Provide Delineation	Relocate Bus Stops
01	AASHO	73																																										
02	Auto Safety Foundation	63																																										
03	Avery	60							●																																			
04	Azzeh	75								●																				●	●	●	●	●	●	●	●	●						
05	Babcock	78																																			●	●						
06	Berg	73	●								●																																	
07	Billion	58																									●																	
08	Billion	62																												●														
09	Bissell	65								●	●															●		●			●		●											
10	Blackburn	78		●						●																													●					
11	Bochner	78																																	●									
12	Box	65																												●														
13	Box	72			●	●																																		●				
14	Box	76			●																																			●				
15	Box	78																														●	●	●	●		●				●	●		
16	Box	78										●	●	●	●																					●					●			
17	Burritt	78																																			●							
18	Caylor	77																																										
19	Chapman	78				●																																						
20	Christiff	66			●																																			●				
21	Clark	65								●	●					●	●																											
22	Clayton	77																●																										
23	Coleman	61								●	●	●							●	●																								
24	Cribbins	67							●	●											●																							
25	Cribbins	67							●	●																																		
26	David	75								●					●							●	●											●							●		●	●
27	FHWA - 'MUTCD'	78																																										
28	FHWA - 'Urban Traffic'	N/A																																										
29	Fielding	55									●	●														●																		
30	Fisher	77																																								●		
31	Foley	67																																										
32	Frick	68																																				●						
33	Glauz	80																●												●		●	●	●	●	●					●			
34	Glennon	76								●																																		
35	Gupta	73								●																																		
36	Hanna	76																																										

Table 1. Summary of urban arterial accident studies (continued).

Environmental Relationships

No.	Author	Yr.	Commercial Floor Area	Skid Number	Illumination Level	Roadside Development	Wet Time	Area Population
37	Head	59				●		
38	Heimback	68						
39	Hoffman	74						
40	Holbrook	76		●			●	
41	Humphreys	79				●		
42	ITE - 'Guidelines'	79						
43	Jones	70						
44	King	75						
45	Leong	70						
46	May	59						
47	May	55				●		
48	Meyer	71						
49	McGee	76						
50	McQuirt	76						●
51	Moore	75						
52	Mueller	70			●			
53	Mulinazzi	67						
54	Nemeth	76						
55.	Olson	74						
56	Parker	79						●
57	Parker	75						
58.	Post	77						
59	Ricci	79						
60	Roy	70						
61	Smahill	68						
62	Shaw	68						
63	Snyder	74				●		
64	Stark	73			●			
65	Stover	70						
66	Telford	53						
67	Terry	68						
68	Thomas	66						
69	Torres	67						
70	Walton	79						●
71	Webb	55						
72	Wooton	64						
73	Wright	76						●
74	Zegeer	75						●

Operational Relationships

No.	Author	Yr.	Speed	Volume	Travel Time	Traffic Signal Control	Yield Signs	Two-Way Stop	Four-Way Stop	Steering Reversals	Brake Applications	Traffic Conflicts	V/C Ratio	Signal Timing	Level of Service	Street Signs	Vehicle Mix	Fuel Economy	Right Turn on Red	Signal Improvements
37	Head	59	●	●																
38	Heimback	68		●																
39	Hoffman	74																		
40	Holbrook	76																		
41	Humphreys	79																		
42	ITE - 'Guidelines'	79																		
43	Jones	70																		
44	King	75																		
45	Leong	70																		
46	May	59			●													●		
47	May	55	●								●							●		
48	Meyer	71																		
49	McGee	76																	●	
50	McQuirt	76		●																
51	Moore	75																		
52	Mueller	70																		
53	Mulinazzi	67		●																
54	Nemeth	76	●	●	●							●								
55.	Olson	74																		
56	Parker	79		●																
57	Parker	75										●							●	
58.	Post	77																		
59	Ricci	79																		
60	Roy	70																		
61	Smahill	68																		
62	Shaw	68		●																
63	Snyder	74		●																
64	Stark	73																		
65	Stover	70																		
66	Telford	53																		
67	Terry	68																		
68	Thomas	66																		
69	Torres	67			●															
70	Walton	79		●																
71	Webb	55		●																
72	Wooton	64																		
73	Wright	76		●																
74	Zegeer	75																		

Human Factor / **Accident Countermeasures on Urban Streets**

No.	Author	Yr.	Sex of Driver	Skin Response	Age	Install Median	Convert to One-Way	Post Proper Speed Limit	Prohibit Parking	Improve Sight Distance	Limit Driveways	Limit Traffic Signals	Provide Two-Way Median	Provide Raised Median	Resurface	Install Illumination	Install Turn Lanes	Widen Pavement	Provide Delineation	Relocate Bus Stops
37	Head	59																		
38	Heimback	68																		
39	Hoffman	74											●							
40	Holbrook	76																		
41	Humphreys	79							●											
42	ITE - 'Guidelines'	79																		
43	Jones	70																		
44	King	75																		
45	Leong	70																		
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47	May	55																		
48	Meyer	71					●													
49	McGee	76																		
50	McQuirt	76				●					●	●					●			
51	Moore	75								●										
52	Mueller	70			●		●									●				
53	Mulinazzi	67																		
54	Nemeth	76											●							
55.	Olson	74																		
56	Parker	79																		
57	Parker	75																		
58.	Post	77																		
59	Ricci	79																		
60	Roy	70																		
61	Smahill	68											●							
62	Shaw	68															●			
63	Snyder	74			●															
64	Stark	73																		
65	Stover	70																		
66	Telford	53																		
67	Terry	68															●			
68	Thomas	66											●							
69	Torres	67																		
70	Walton	79																		
71	Webb	55																		
72	Wooton	64												●						
73	Wright	76																		
74	Zegeer	75																		

Azzeh, et al., 1975 [4] on access control techniques. Other studies cited pertain to establishing benchmarks for determining the hazardousness of urban roadways. Ricci, 1979 [59] has developed urban crash statistics based on roadway type, time of day, road condition, and other factors. Zegeer, 1975 [74] has established critical accident frequencies for street sections and intersections for various city populations.

The three basic methods which have been used to examine relationships between accidents and urban roadway features are (1) correlation analysis, (2) regression techniques, and (3) comparative analysis. Correlation and regression techniques were often used because they permit the researcher to quantify the relationship between variables and to derive a functional expression of the relationship. The comparative analysis techniques primarily consisted of methods which examined differences between two or more variables. An example of this technique is the study conducted by Frick, 1968 [32] in which the accident rate of a raised median roadway section was compared to the accident rate of an urban section with a continuous two-way, left-turn median lane. A before and after study is another analysis technique used by a number of investigators.

A major problem with much of the research conducted to-date on urban arterial roadways is that there are numerous deficiencies in the experimental design employed, the sample size, and the analysis techniques used. Specific problem areas with each publication are noted in the annotated bibliography, however, as a general rule, most of the studies contain one or more deficiencies. Inadequacies and the inherent problems of obtaining and analyzing accident and exposure data are primary factors responsible for inconsistencies and perhaps erroneous results given in the state-of-the-art. Due to the problems of using accident data to evaluate the effects of roadway features, the results of studies conducted to-date should be interpreted as tentative [75]*. Thus, the reader is cautioned to interpret the findings reported in this literature review as a preliminary indication of the existence or nonexistence of a relationship between accidents and certain roadway features. Further verification of these and other relationships or the absence of a relationship is provided with the urban arterial roadway data collected and analyzed during this study.

In the following sections, a brief summary of the relationship between traffic accidents and each roadway feature identified in the literature is given. Specific details of each study cited are given in the annotated bibliography presented in Appendix B.

Geometric Factors

The roadway geometry consists of all physical elements within and along the highway. Typical geometric factors include medians, intersec-

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* An excellent discussion of the problems of using accident data for safety evaluations is provided by Council, et al., [75].

tions, pavement width, and horizontal alignment. A summary of the geometric factors identified in the literature is given below.

Pavement Width

The effects of pavement width on accidents on urban roadways have been examined by five investigators.

In a study of the effect of geometric design characteristics on accident rates for two-lane, two-way roads in Connecticut, Gupta and Jain, 1973 [35] categorized highways by rural and urban types and by average daily traffic. The results of a multiple linear regression analysis indicate that on two-lane urban streets with less than 12,000 vehicles per day, the roadway width is not significantly related to the accident rate.

Mulinazzi and Michael, 1967 [53] analyzed data from 100 urban arterial highway sections in Indiana. Thirty-two of the sections had a traffic volume ranging from 7,000 to 32,000 vehicles per day. Volume data for the remaining 68 sections were not included in the report. Multiple linear regression techniques failed to show any relationship between street width and accident rate. In fact, regression equations developed for estimating accident rate were not given in the report because the independent variables (i.e., street width, volume, etc.) explained less than 50 percent of the variability in accident rate. Because the correlation was not significant, street width was not included as an independent variable in any of the equations developed to estimate annual number of accidents per mile on a highway section.

In a study of urban two- and four-lane State highways in Oregon, Head, 1959 [37] reported that although pavement width exhibited a positive relationship with accidents, the degree of association varied considerably and was usually fairly low. Pavement width was a variable used in the regression equation that was developed to predict accident rates.

Box, 1972 [13] examined the effects of pavement width on the ratio of night to day accident rate on 105 miles (168 km) of major arterial streets in Syracuse, New York. The results of the study revealed that pavement width had little effect on accident ratio.

Fisher and Camou, 1977 [30], however, conducted a before and after study on 40 sections of arterial streets in Los Angeles and found that street widening had a significant effect on accident frequency. The results of the study indicated that the number of accidents and injuries, as well as intersection and midblock crashes, were reduced as a result of the widening.

The effect of pavement width on travel time has been examined by two researchers. As discussed in the operational factors section of this appendix, a significant relationship has been found between travel time and accidents on urban roadways. Coleman, 1961 [23] investigated the effect of street width on travel time on 15 urban roadways in 5 Pennsylvania cities and found that pavement width had a minor effect on travel time. Torres, 1967 [69] collected data on 158 streets in 7 U.S. cities and found that lane width affects travel time but to a much lesser extent than signal density.

Summary

The results of the research indicate that pavement width may have some effect on accidents but the relationship does not appear to be significant.

Turn Lanes

The effects of providing separate turning lanes to accommodate left-turn movements have been reported in five studies.

In a synthesis of accident studies at intersections conducted prior to 1970, Box, 1970 [16] noted that studies completed in Oregon, California, and Texas on rural and urban roadways indicated that installation of left-turn lanes significantly reduced rear-end and left-turn type collisions.

Shaw, 1968 [62] analyzed data collected at two rural and suburban intersections in Indiana and concluded that installation of a median lane to provide storage space for left-turning vehicles significantly reduced delay time for through vehicles and reduced accident frequency.

Terry and Kassan, 1968 [67] conducted an 18-month before and after study on a 1.14-mile (1.82-km) roadway section in Los Angeles to determine the effectiveness of left-turn lanes and painted medians on accidents. The results of the study revealed that total accidents, injuries, left-turn, and rear-end crashes were significantly reduced after the improvements were completed.

Following an analysis of accident and roadway features data on 92 rural and urban multilane highway sections in North Carolina, Cribbins, et al., 1967 [25] found that the presence of a turn lane has a significant effect on accidents at signalized and unsignalized intersections. It was also concluded that fewer rear-end collisions occurred at median openings with storage lanes than at locations without storage lanes.

A study conducted by David and Norman, 1975 [26] of 558 rural and urban intersections in California revealed that intersections with storage lanes had significantly higher accident frequencies than intersections without storage lanes. This result contradicts the conclusions obtained by the other investigators. Not enough information is given in the study report to determine whether the finding is influenced by the presence or absence of other factors at the study sites. The authors attributed the finding to an increase in the number of nonturning accidents at intersections with storage lanes.

Summary

Considerable evidence presented in the literature suggests that a significant relationship exists between accidents and the presence of a left-turn storage lane at an intersection. The addition of a left-turn lane appears to significantly reduce accidents and injuries at an intersection.

Median Presence

The effects on accidents of installing a median on urban arterial highways were examined in five studies.

Foley, 1967 [31] presented the findings of before and after studies conducted to determine the effectiveness of street improvements on reducing accidents. The major finding of the studies was that the presence of a median reduces accident frequency. The data for two of the study sites indicated that a decrease in total accidents ranging from 23 to 35 percent was observed along with a reduction in injury accidents ranging from 18 to 39 percent.

Box, 1965 [12] conducted a before and after study involving the conversion of a 56-foot (17.4-m) wide undivided highway to a divided highway. The improvement resulted in a 50 percent decrease in the midblock accident rate. The major street improvement in this study consisted of adding a median barrier, installing a RIGHT TURN ONLY sign at driveways, and providing three lanes in each direction.

Leong, 1970 [45] analyzed 3400 accident reports collected on 21 urban highway sections in Sydney and the City of Newcastle, Australia. Data were collected for the periods before, immediately after, and for ten years after the installation of a curbed concrete median strip. During the study period the only geometric change at the sites was the installation of the median strips. The presence of a 3-foot (0.9-m) concrete median influenced a change in accident type (head-on collisions decreased while fixed-object and sideswipe accidents increased) at midblock locations and head-on collisions decreased while rear-end, failure to yield right-of-way, and sideswipe accidents increased at minor intersections. The data indicate that a narrow median may affect the type of collision on an arterial roadway but the median does not appear to affect the short-term or long-term accident rate.

Accident and operational data were collected by Babcock and Foyle, 1978 [5] on 15 urban highway sections in North Carolina. Analysis of the data revealed that four- and six-lane undivided sections had higher accident rates than were found on divided highway sections.

Parker, 1979 [56] collected accident and roadway features data for 50 roadway sections in 31 urban areas in Virginia. The sections included four-lane roadways with raised medians, continuous two-way, left-turn median lanes, and undivided highways. Analysis of the data revealed that there were no statistically significant differences in accident rates between any of the median treatments examined, however, the accident severity rate on undivided sections was significantly higher than the severity rates on the divided sections. A similar result was reported by Telford, 1953 [66].

Summary

The studies indicate that a median is generally beneficial in reducing accidents and accident severity. Although the study results indicate that installation of a median provides a significant reduction in midblock accidents (i.e., injury accidents and total accidents), the specific relationship between median presence and accidents cannot be established from these data.

Median Width

The relationship between median width and accident frequency has been the subject of four studies.

Billion and Parsons, 1962 [8] investigated the influence of roadway features on accidents on 34 urban sections located in Long Island, New York. No correlation was found between the width of median and accident rates on roadways excluding intersections for deterring-type medians (A deterring median is a flush or raised median which discourages but does not physically prevent vehicles from crossing the median). Narrow medians less that 10 feet (3.1 m) wide had high accident rates but low injury accident rates.

A study of 21 urban highway sections was conducted by Leong, 1970 [45] in Australia. It was found that wide medians (10 to 16 feet (3.0 to 4.9 m) in width) had no effect on accident rates at midblocks or at major and minor intersections. This conclusion was based on data collected at two sites.

Cribbins, et al., 1967 [24,25] examined data collected on 92 urban and rural multilane highway sections in North Carolina and found median width had little effect on accidents. Study sites were selected on the basis of homogeneity with respect to roadside development, median width, speed limit, and average daily traffic. The results of the analysis revealed that 9 of 15 correlation coefficients were positive indicating that as the median width increases, the accident rate increases, however, the relationships were not statistically significant.

Summary

An analysis of studies conducted to date suggest that median width may have some effect on accidents, however, the effect is not significant.

Median Openings

Three studies have been conducted to examine the effect of median openings on accidents.

Cribbins, et al., 1967 [24,25] analyzed accident and roadway features data on 92 sections of roadway located in rural and urban areas of North Carolina. The results of the investigation revealed that:

- the number of total and injury accidents per mile (per km) is significantly related to the number of signalized median openings without storage lanes. As the number of openings increases the accident rates increase, and
- the median opening accident rate was influenced by the number of median openings with and without storage lanes.

Regression equations that can be used to predict the accident rate on divided highways were developed during the study. The number of median openings was used as a variable in the equation. Although the number of median openings per mile (per km) was determined to have a significant effect on the accident rate, several of the regression coefficients were negative, indicating that for the accident type being investigated, accident rates decreased as the number of median openings increased.

A study of 50 urban roadway sections located in 31 Virginia cities was conducted by Parker, 1979 [56]. Multiple linear regression analysis of the data revealed that the number of median openings was not significantly related to accident frequency, however, the number of median openings was a significant factor in predicting the midblock left-turn vehicle delay on divided highways.

Summary

The number of median openings on divided highways does not appear to have a significant effect on accidents, however, further research is needed to confirm this observation.

Access Control

The effects of access control on accidents have been examined by five investigators. It should be noted that studies conducted to identify relationships between accidents and the number of driveways, intersections, and other features which are also considered to be measures of access control, are given in another section of this appendix.

May, 1955 [47] collected accident, gasoline consumption, and travel time data for 12 sites on two- and four-lane divided highways in rural and urban areas in 9 states. Accident rates developed during the study along with data obtained for two other studies are shown in Table 2 for urban and rural facilities with various access control types. Generally it was found that urban roadways with no control of access had the highest accident rates.

In another study conducted by May, 1959 [46] accident and roadway features data were collected on 41 sections of straight, level, high volume, multilane urban roadways located in Detroit and Lansing, Michigan. The roadway features were expressed in terms of internal, medial, marginal, and intersectional friction. Internal friction was expressed in terms of traffic volumes, volume/capacity ratios, and density. Medial friction was classified as sections with and without medians. Marginal friction was classified as none, moderate, and heavy depending upon the type of roadside development and the amount of on-street parking. Intersectional friction was subdivided into four groups depending upon the number of intersections and traffic signals within the section. Analysis of the study data indicated that the accident rate increased as the medial, marginal, and intersection friction increased.

Table 2. Relationship between accident rate and access control.

Type of Access Control	Accident Rate* Urban	Rural
Full Access Control		
Twelve Case Studies	247	49
Connecticut Study	261	221
Bureau of Public Road Study	146	210
Partial Access Control		
Twelve Case Studies	---	200
Connecticut Study	180	250
Bureau of Public Roads Study	790	227
No Access Control		
Twelve Case Studies	443	236
Connecticut Study	725	313
Bureau of Public Roads Study	966	407

* Accidents per 100 million vehicle miles (160 million vehicle km) of travel.

Source: May, 1955 [47], pg. 60, Table 13.

Cribbins, 1967 [24] investigated the effects of an access-point index on accident rates on 92 rural and urban divided highways in North Carolina. The access-point index was defined as the total estimated traffic volume at commercial and industrial sites. Analysis of the data revealed that the number of total and injury accidents per mile (per km) were significantly related to the access-point index. The median-opening accident rate was also influenced by the access-point index. The data suggest that as the index increases, the accident frequency increases.

Based on the results of research by others, Stover, et al., 1970 [65] developed guidelines for controlling access to urban arterial highways. Among intersection controls, it was recommended that residential driveways be reduced or eliminated to improve traffic flow and reduce accidents.

Head, 1959 [37] collected accident and roadway features data on 426 sections of two- and four-lane urban highway in Oregon. Analysis of the data revealed that the number of commercial units is significantly related to accident frequency, i.e., as the number of commercial units increases, the accident frequency increases.

Employing the results of research findings developed by others, Azzeh, et al., 1975 [4] developed cost-effective techniques that enhance traffic operations and safety by controlling access on urban arterial highways. Due to the absence of comprehensive accident data, several assumptions regarding accident relationships were made to develop a methodology for selecting and evaluating various access control techniques based on site specific conditions. There is a need to verify these relationships utilizing a large data base.

Summary

The control of access on an urban arterial highway is significantly related to the accident frequency of the roadway, i.e., as access controls are implemented, the accident frequency is reduced.

Driveways

The effects of driveways on accidents have been investigated by five reseachers.

Head, 1959 [37] collected accident and roadway features data on 426 sections of urban highways located in Oregon. Statistical analysis of the data revealed that the number of commercial driveways and residential driveways did not appear to be related to accident frequency. On two-lane roadways carrying 10,000 vehicles per day or more the number of commercial driveways per mile (per km) was found to be significantly related to accident rate.

Box, 1970 [15] prepared a synthesis of the state-of-the-art prior to 1970 concerning the safety effects of driveways. Driveway accidents were reported to range from 6.5 percent in Los Angeles County to 11.2 percent of total accidents in Skokie, Illinois. A study conducted on a suburban route in Lafayette, Indiana revealed that accidents increased as the total number of driveways increased.

A detailed examination of the driveway accident data collected in Skokie, Illinois revealed that 70 percent of the driveway accidents involved vehicles making left-turns. Nearly 42 percent of all driveway accidents were rear-end crashes. The largest single group of accidents was rear-end crashes involving vehicles making a left-turn into a driveway.

Suggested countermeasures to reduce driveway related accidents include constructing a median storage lane to decrease rear-end crashes involving vehicles making a left-turn into a driveway, installation of two-way, left-turn median lanes, limiting the width of driveway openings, increasing sight distance at driveways, reducing speed differentials between through vehicles and those using driveways, providing sufficient spacing between driveways to avoid interference with traffic, and prohibiting on-street parking. A few of these suggested countermeasures have been evaluated under actual field conditions.

While the synthesis reveals that the number of driveways in an urban area has an influence upon the accident frequency, adequate documentation is not available to relate specific driveway designs to particular accident types or driver maneuvers.

A comprehensive study of factors that influence driveway accidents was conducted by McGuirk and Satterly, 1976 [50]. Accident and roadway data were collected for 100 sites. Stepwise multiple regression analysis was used to develop equations to predict driveway accidents for site specific conditions. Analysis of the data revealed the following results.

- Driveway accidents accounted for 13.95 percent of all reported accidents on the study sections.
- Of all driveway accidents, 71.62 percent occurred at commercial entrances and 85.56 percent resulted in property damage only.
- Factors found to be significantly related to driveway accidents were commercial driveways per kilometer, number of through lanes, average daily traffic, and the total number of intersections per kilometer.
- For each commercial driveway added to an arterial street an additional 0.1 to 0.5 driveway related accident per mile per year (0.06 to 0.31 accidents per km per year) can be expected.

Regression equations were developed to predict the number of driveway related accidents per mile (per km) per year.

Walton and Machemehl, 1979 [70] also conducted a study to identify relationships between accidents and roadway features on urban arterial roadways. Use of multiple linear regression techniques revealed that accidents per mile (per km) significantly increased as the number of driveways per mile (per km) on the roadway increased.

A similar finding was revealed by Parker [56] who examined accident data and driveway frequencies on 50 urban highways in 31 Virginia cities. Analysis of the data indicated that as the number of driveways increased, the accident frequency increased on undivided roadways, however, on divided highways the number of driveways was not significantly related to accidents.

Summary

There is considerable evidence that the number of driveways on an urban arterial highway significantly affects accident frequency. The relationship appears to vary considerably depending upon the number of lanes, the type of median treatment, and the traffic volume.

Traffic Signals

Due to their importance in regulating traffic flow and improving safety, seven investigators have examined the effects of traffic signals on accidents on urban roadways.

There is considerable evidence that the number of traffic signals on an urban highway directly influences the accident frequency on the facility. Studies conducted by Mulinazzi and Michael, 1967 [53], Head, 1959 [37], Cribbins, et al., 1967 [24,25], Azzeh et al., 1975 [4], Parker, 1979 [56], and Walton and Machemehl, 1979 [70] revealed that as the number of traffic signals increases, the accident rate increases. Statistically significant relationships were obtained in each study. Regression equations, predicting accident rates in terms of traffic signals and other roadway features were developed by each investigator.

Summary

A synopsis of current literature related to traffic signals and accidents provides substantial evidence that as the number of signalized intersections on a roadway increases, the accident frequency and rate increases.

Intersection Design

The effects of the geometric design on accidents has been examined by three researchers.

The results of a study by Webb, 1955 [71] of 97 signalized intersections in rural, suburban, and urban areas in California revealed that fewer accidents occurred at skewed intersections than at cross-type intersections. Seven of the eight semi-urban skewed approaches had 43 percent fewer accidents than the straight legged approaches.

In a synthesis of intersection accident studies conducted prior to 1970, Box, 1970 [16], reported that investigations at intersections in Los Angeles and Richmond, California revealed that cross-type intersections had significantly higher accident frequencies than tee-type intersections.

The results of an analysis of accident data conducted by David and Norman, 1975 [26] in California are shown in Table 3. For any given traffic volume level, cross-type intersections have higher accident rates than tee-type intersections and signalized cross-type locations have higher rates than stop controlled crosses. Fatal and injury rates (shown in parentheses) are approximately similar for all intersection types.

Table 3. Relationship between accident rate and type of intersection.

	Accident Rate**			
	Tee-Type		Cross-Type	
ADT	Stop	Signal	Stop	Signal
< 5000	1.3 (0.3)	--*	1.3 (0.3)	--
5,000 to 10,000	1.6 (0.4)	--	1.9 (0.4)	4.9 (1.1)
10,000 to 20,000	2.7 (0.7)	--	3.0 (0.7)	6.7 (1.7)
20,000 +	4.2 (1.2)	6.8 (1.8)	8.0 (1.1)	15.9 (3.7)

* Insufficient Data

** Accidents per intersection

Source: David and Norman, 1975 [26], pg. 7, Table 2.

Summary

The results of studies conducted to date indicate that cross-type intersections have higher accident rates than tee-type intersections.

Intersections

The number of signalized and unsignalized intersections on a roadway has been shown to affect traffic operations and safety. Seven investigators have included intersections in their study of urban arterials.

Chapman, 1978 [19] examined over 1,000 personal injury accidents on urban arterial roads in four towns in southern England. His results indicate that accidents along the main traffic routes of a town tend to cluster along relatively short sections of road passing through suburban shopping areas and at a few busy road junctions. Analysis of the data showed that 42 percent of the accidents occurred at these locations, whereas, the sections comprised only 18 percent of the arterial road network studied.

Studies conducted by Head, 1959 [37], Parker, 1979 [56], Mulinazzi and Michael, 1967 [53], and Cribbins, et al., 1967 [24,25], revealed that as the number of intersections per mile (per km) increases, the accident frequency increases. The number of intersections was one of the variables that was used by each of the investigators in the regression equations they developed to predict accidents on urban roadways.

Berg and Anderson, 1973 [6] conducted a study on four-lane undivided roadways in Madison, Wisconsin and found that the number of intersections per mile (per km) significantly affected travel time on the roadways. Research conducted by May, 1959 [46] on 41 sections of multilane urban roadways in Detroit and Lansing, Michigan indicated that intersectional friction, i.e., the number of intersections and number of traffic signals had a greater effect on accident rates and travel time than the other forms of roadway friction.

Summary

There is substantial evidence that the number of intersections on urban roadways significantly affects the accident frequency.

Traversable Median Lanes

With increased emphasis on better utilizing existing transportation facilities, the effects of traversable medians including continuous two-way, left-turn median lanes on accidents has received considerable study.

Sawhill and Neuzil, 1963 [61] conducted a before and after study at three locations in Seattle, Washington and found the following results.

- Only 9.4 percent of the total accidents were related to the use of the median lane.
- The median related accidents were less severe than non-median accidents.
- The number of head-on accidents in the median lane was negligible.
- At one site accidents decreased from 66.75 per year to 49.5 per year, a reduction of 25.8 percent. Most of the decrease was in rear-end accidents.

Thomas, 1966 [68] conducted a one-year before and after study of a four-mile (6.4-km) roadway section in Denver, Colorado where continuous directional left-turn lanes were painted in the median. The results of the investigation revealed the following conclusions.

- Rear-end type accidents decreased by 52 percent at locations which previously had no left-turn lanes.
- There was a 22 percent decrease in injury accidents on the four-mile (6.4 km) study section.
- Total accidents for the entire project were reduced by 20 percent. There were 462 accidents in the before period and 368 in the after period.

Frick, 1968 [32] conducted a comparative analysis of accident data obtained for a raised median roadway and a section with a continuous left-turn median lane located in Springfield, Illinois. The study results revealed that the accident rate on the section with the curbed median was 434 accidents per 100 million vehicle miles (160 million vehicle km) of travel while the section with the two-way, left-turn median lane had a rate of 1143. Frick concluded that curbed medians and intersection channelization should be used for urban arterial street improvements, however, there were a variety of factors including differences in the number of traffic signals, driveways, roadside development, etc. that may explain the difference in the accident rates on the study sections.

Hoffman, 1974 [39] analyzed accident data collected for a one-year before and after period at four sites in Michigan. At each of the study sites the existing four-lane undivided roadway was widened to permit a continuous left-turn median lane. Analysis of data revealed the following results.

- Total accidents decreased by 33 percent.
- Injury accidents decreased by 41 percent.
- Rear-end accidents decreased 62 percent, and head-on left-turn crashes were reduced by 45 percent.

Burritt and Coppola, 1978 [17] recently examined the effects of installing two-way, left-turn lanes on accidents at seven sites in Arizona. An analysis of two-year before and two-year after accident data, is summarized below.

- Total accidents were reduced by 35.9 percent.
- Rear-end accidents declined by 45.4 percent.
- Left-turn accidents decreased by 20.4 percent.
- Other accident types that were reduced included angle, sideswipe, parking, fixed object, and pedestrian/bicycle related crashes.
- A benefit-cost ratio of 8.6 was reported.

Nemeth, 1976 [54] conducted before and after studies at three sites in Ohio to examine the effectiveness of continuous two-way, left-turn lanes. Travel speeds, volumes, and traffic conflict data were collected before and after improvements were made at each site. Accident data were not obtained for this study. At the site where four through lanes were restriped to allow two through lanes and a left-turn median lane, the change resulted in increased travel times, increased weaving, and fewer traffic conflicts. The restriping of a two-lane roadway to provide two through lanes and a median left-turn lane resulted in reduced travel times and delays with some increase in average running speed. Traffic conflicts were reduced by 37 percent in spite of the fact that mainline volumes increased by 2.5 percent; cross traffic volumes increased by 25.0 percent; and left-turns increased by 16 percent. The restriping of a four-lane undivided roadway to allow for four through lanes and a left-turn median lane resulted in a slight increase in running speeds, however, the increase was not statistically significant. Traffic conflicts were reduced.

Although the study did not include an accident analysis, it is one of the few published reports that addresses the operational effectiveness and hazard potential reduction of implementing two-way, left-turn median lanes on urban roadways. The report also provides a comprehensive review of the literature pertaining to median turn lanes, including accident studies, and offers guidelines for traffic engineers to use when they are considering the installation of a median turn lane.

Accident and operational data were collected and analyzed by Babcock and Foyle, 1978 [5] on 14 urban highway sections totalling 32.4 miles (52.1 km) in two North Carolina cities. The roadway sections included four-lane undivided highways, four- and six-lane divided roadways, and five- and seven-lane sections with traversable median lanes. Due to the small sample size, statistical analyses of the data were not performed. A summary of the study results support the following conclusions.

- Accident rates on five- and seven-lane roadways with traversable medians are similar to rates on four- and six-lane divided highways.

- No head-on collisions were reported on the sections with traversable median lanes.

- In all cases the median lane of the five- and seven-lane facilities appeared to handle traffic efficiently.

Azzeh, et al., 1975 [4], developed an excellent methodology for selecting and evaluating alternative access control techniques for arterial highways, including continuous two-way, left-turn median lanes. One major problem with the methodology was the lack of comprehensive updated accident data.

Caylor, 1977 [18] conducted a literature survey and developed general guidelines for using two-way, left-turn median lanes. Very few quantitative criteria were provided to aid in the selection of a median type based on site-specific conditions.

Walton and Machemehl, 1979 [70] collected accident and roadway features data on urban highways in Texas. The results of this investigation indicate that urban arterial accident rates are significantly affected by the number of traffic signals per mile (per km), the number of driveways per mile (per km), the city population, and average daily traffic. A regression equation was developed to predict the annual number of accidents per mile (per km) for site-specific conditions on four-lane highways with two-way, left-turn median lanes.

Accident data were collected by Parker, 1979 [56] for 50 urban roadway sections in 31 urban areas in Virginia. Geometric and operational data were also collected for each study site. Median treatments included in the investigation were raised medians with 6-inch (15-cm) concrete curbs, traversable medians with continuous left-turn lanes, and undivided roadways. All of the study sites had four through lanes. Multiple linear stepwise regression analysis was used to develop equations to estimate the impacts of alternative designs on accidents and left-turn vehicle delay. The results of the analysis are summarized below.

- Mean accident rates are not significantly different for raised and traversable median treatments.
- The type of median treatment influences the type of collision.
- Factors affecting accident frequency on urban roadways with traversable medians are the number of traffic signals, the number of cross streets per mile (per km) and the average daily traffic.
- Factors affecting accident frequency on four-lane undivided urban roadways include the number of traffic signals, cross streets and driveways per mile (per km) and the average daily traffic.
- Midblock left-turn delay was found to be significantly affected by the number of traffic signals per mile (per km), the area population, the mainline hourly volume, and the number of driveways and streets per mile (per km).
- The midblock left-turn delay was not significantly related to the accident frequency for any median treatment.

Regression equations were developed to predict the expected accident frequency for each median treatment, i.e., raised, traversable, and four-lane undivided sections. The equation developed for predicting accidents per mile (per km) for traversable sections was compared to the equation developed by Walton and Machemehl, 1979 [70] using Texas data and the equations appeared to yield similar results. Further verification of these equations should be made to test their validity in other urban areas.

Summary

Installation of a traversable median on an undivided highway to provide storage space for left-turning vehicles appears to significantly reduce accident frequency. Factors which significantly affect accidents on traversable median lanes are traffic volume and the number of driveways, intersections, and traffic signals.

Raised Medians

Raised concrete medians have been extensively used to separate opposing traffic streams on urban arterial streets. The effects of this median treatment have been examined by eight investigators.

One of the most comprehensive studies of the impacts of raised medians was conducted by Wootan, et al., 1964 [72] in three Texas cities. Before and after traffic and accident data were collected and analyzed. The data indicated that after the median was installed there was a significant reduction in rear-end collisions involving vehicles making left-turns. Head-on collisions were eliminated at the study sites. There was an increase in accidents involving drivers making improper lane changes and an increase was reported in fixed-object crashes. In the San Antonio study, total accidents were reduced from 234 to 72 (69 percent) in a one-year before and one-year after period. Personal injury accidents decreased from 40 to 14 (65 percent). The overall effect of the raised median at the study sites was a reduction in traffic accidents.

Studies conducted by Box, 1965 [12], Foley, 1967 [31], Leong, 1970 [45], Frick, 1968 [32], also revealed that the installation of a raised median on an undivided highway significantly reduces accidents.

Billion and Parsons, 1962 [8] examined the effect of median design on accidents. Data were collected on 34 urban roadway sections, which did not have access control. Median types included the flush grass type, raised grass medians with concrete curbs, and raised concrete medians with concrete curbs. The number of intersections varied from three to seven per mile (5 to 11 per km). A summary of the findings is given below.

- For deterring type medians, grass flush medians had the lowest accident rate for roadway sections between intersections and the curbed median had the highest rate.

- Medians with double beam rails had the lowest total accident and injury rates while medians with concrete posts had the highest rates.

- On roadway sections excluding intersections, curbed medians had approximately 2 and 1/2 times the accident ratio of the flush median sections.

- A summary of accidents involving the median revealed that deterring medians had the lowest cross median accident rate (1.8) when compared to roadways with nontraversable medians (4.0). Curbed median sections had the lowest ratio of median accident involvements (1 to 45) compared to earth medians (1 to 24) probably because drivers use the earth median to avoid an accident. On curbed median sections it was speculated that motorists are more confined to the pavement, consequently reducing median related involvements but not total accident involvement.

Parker, 1979 [56] collected accident and roadway features data for 19 raised median sections in urban areas in Virginia. Analysis of the data revealed that factors which significantly affect the accident frequency on urban roadways with raised medians are the number of traffic signals per mile (per km) and the average daily traffic. Regression equations were developed to predict the expected accident frequency for raised median sections based on these site specific conditions.

Olson, et al., 1974 [55] conducted an investigation to examine the effects of vehicle behavior on 4- and 6-inch (10- and 15-cm) concrete curbs, commonly used on divided arterial routes in the U.S. Eighteen full scale crash tests were conducted and simulation impacts were made using the Highway Vehicle Object Simulation Model. The major finding was that concrete curbs 6-inches (15-cm) high or less do not redirect vehicles at speeds above 45 miles per hour (72 kph) with encroachment angles greater than 5 degrees. The results of the crash tests suggest that 6-inch (15-cm) concrete curbs commonly used on urban streets should not be used if traffic speeds are expected to exceed 45 miles per hour (72 kph).

Summary

The installation of a raised median on an undivided highway significantly reduces accidents. Factors which significantly affect accident frequency on roadways with raised medians are the number of traffic signals and the traffic volume.

Horizontal Alinement

The effects of horizontal curvature on accidents for urban arterial roads have been examined by three investigators.

A study of the effects of geometric design characteristics on accident rates on two-lane, two-way roads in Connecticut by Gupta and Jain, 1973 [35] concluded that accident rates on two-lane urban highways carrying 3,000 to 7,900 vehicles per day increased as the degree of curve increases. Although the horizontal curvature rating had a higher correlation with accidents than other variables tested, none of the relationships were statistically significant.

Wright and Mak, 1976 [73] analyzed accident data to determine relationships between single-vehicle, off-road, fixed-object accidents, and traffic, roadway design, and socio-economic variables for urban two-lane roadways. The study utilized data obtained on 45 one-mile (0.6-km) sections of two-lane urban arterial and collector streets in Atlanta, Georgia. Results of the analysis indicate that off-road accident rates were most closely related to average daily traffic, horizontal alinement, and population density. Correlation and factor analysis, simple linear regression, and stepwise multiple linear regression analysis were used to establish relationships between roadway and traffic characteristics, socio-economic factors, and accident rates. No statistically significant relationships were developed as the correlation coefficients for the accident rates and other factors were less than 0.45.

In a study of the relationship between accident involvement and traffic volumes at signalized intersections, Webb, 1955 [71] reported that intersections with curved approaches had higher accident rates than those with straight approaches. In his analysis, Webb stratified data according to semi-urban and rural conditions. Analysis of the data at intersections with curved approaches showed three intersections (two semi-urban and one rural) to have on the average 30 percent more accidents than the 97 straight legged intersections.

Summary

There is some evidence that increases in horizontal curvature may increase accidents. This relationship, however, is not significant as other factors appear to have a greater effect on accidents than horizontal alinement.

Vertical Alinement

The effects of vertical alinement on accidents have been examined by three investigators.

Hanna, et al., 1976 [36] reviewed accident data at 232 intersections in rural municipalities in the State of Virginia. The typical rural municipality had an average population of approximately 15,000 persons. Comparative analysis of two years of accident data at intersections that provided poor driver sight distance on at least one traffic approach or that had an unusually steep grade (greater than 5 percent) as compared with all other intersections provided the following results.

- The accident rate for intersections with severe grades (0.97 per million entering vehicles) was unusually low when compared to the accident rate of 1.13 for all intersections.

- Intersections with extremely severe grades, such as many of those in the small municipalities, experienced unusually low accident rates.

In contrast, King and Goldblatt, 1975 [44] analyzed data from 300 intersections located in urban and rural areas throughout the United States and found a positive correlation between grade and accidents. Differentiation between urban and rural situations was possible because the sites were classified according to: a) central business district, b) fringe areas, and c) rural. The study data indicate that grades significantly affect accidents in almost every case.

Gupta and Jain, 1973 [35] examined the relationships between geometric features and accident rates on rural and urban two-lane highways in Connecticut and established a vertical clearance rating. They however found that the vertical clearance rating was not significantly related to accident rate. The authors hypothesized that the vertical clearance rating was directly proportional to vertical alinement features of a roadway.

Summary

Although there is some evidence that vertical alinement is related to accident frequency, this relationship is not strong.

Sight Distance

Five studies have been conducted on urban arterial streets to examine the effects of sight distance on accidents.

Gupta and Jain, 1973 [35] studied the effects of restricted sight distance on accident rates on two-lane, two-way urban roads in Connecticut. Although no statistically significant relationship was discovered, restricted sight distance appeared to be associated with high accident sections, and in particular, with single-vehicle accidents.

Analysis of accident data conducted by Hanna, et al., 1976 [36] at 232 intersections in rural municipalities in Virginia (cities and towns with a population of approximately 15,000 persons) indicated that intersections with poor sight distance on at least one approach had a higher accident rate (1.33 accidents per million entering vehicles) when compared to the mean accident rate of 1.13 for all intersections. A high percentage of the accidents were angle collisions in which the driver was unable to properly view an approaching vehicle on the cross street.

In a study of 558 highway intersections in California, David and Norman, 1975 [26] found that an increase in sight radius resulted in a decrease in total accident rates, right-angle rates, and right-of-way violation accident rates. Intersections with a traffic volume greater than 15,000 and with obstructions within 20 feet (6.1 m) of the pavement had 5.3 more accidents per year than did intersections with unobstructed distances.

Moore and Humphreys, 1975 [51] examined sight distance obstructions at urban intersections. They reported the results of a before and after study conducted in Concord, California where accidents decreased by 67 percent (from 39 to 13) at five intersections where sight distance obstructions were removed.

King and Goldblatt, 1975 [44] analyzed accident and roadway features data at 300 intersections and found a statistically significant correlation between accidents and sight distance for most of the intersection conditions studied.

Summary

There is some evidence that sight distance obstructions contribute to increasing the accident rate at intersections and on urban roadway sections, however, specific relationships have not been developed.

Fixed-Objects

The relationship between accidents and fixed-objects within the vicinity of roadways in urban areas has received limited study.

Glennon and Wilton, 1976 [34] examined the applicability of the roadside hazard model developed in NCHRP Report 148 to enable the model to predict the effectiveness of roadside safety improvements on all classes of highway including urban arterial streets. Roadside hazards considered in the study consisted of the following obstacles: utility poles, trees, sign posts, light poles, traffic signal poles, railroad signal poles, curbs, guardrails, roadside slopes, ditches, culverts, drainage inlets, bridge abutments, piers, bridge rails, retaining walls, fences, and fireplugs. Accident data obtained from eight cities were used to develop an equation for predicting the roadside accident rate for urban arterial streets. Application of the roadside encroachment parameters developed for the hazard model revealed that little improvement can be expected by implementing roadside safety improvements on urban streets.

Summary

Although there is evidence that roadside obstacles contribute to accident rates on urban highways, the data are limited and specific relationships have not been quantified.

Parking

The relationship between the presence of on-street parking and accidents on urban streets has been examined by three investigators.

In an Indiana study of 100 sections of urban roadways, Mulinazzi and Michael, 1967 [53] found that permitting on-street parking significantly increased the accident frequency on roadways carrying between 1,200 and 5,800 vehicles per day.

Torres, 1967 [69] collected travel time and geometric data on 158 street sections in seven cities. The results of the analysis indicated that parking had an effect on travel time but the effect was not as great as other variables such as signal density. Although accident data were not examined, the results are useful in formulating hypothesis between roadway features, operational conditions, and accidents.

David and Norman, 1975 [26] collected accident data at 558 urban and rural intersections in California. The results of their investigation revealed that there was not a statistically significant relationship between peak-hour parking prohibitions, parking set-back, and accident frequency.

The most comprehensive study undertaken to date concerning the effects of parking on accidents was conducted by Humphreys, et al., 1979 [41]. The purpose of the study was to examine the relationships between accidents reported on urban streets, parking configurations, land use, street width, and street classification. Roadway and accident data were collected for 170 miles (273.5 km) of urban roadway located in 10 U.S. cities.

A summary of the analysis is provided below.

- Parking use has the greatest affect on accident rate, i.e., as the parking use increases, the accident rate increases up to approximately 1.0 million space hours per kilometer per year.

- Accident rates were lowest on roadway sections where parking was prohibited.

- The prohibition of on-street parking where the space use is approximately 300,000 hours per kilometer per year could reduce midblock accident rates by 19 percent. Where space hours usage is 600,000 hours per kilometer per year, midblock accident rates could be reduced by 75 percent.

- For 300,000 space hours of use, total urban accident rates could be reduced by eight percent and for 600,000 hours of use the reduction could be up to 30 percent.

- Parking configuration, i.e., parallel, angle, etc. did not have an effect on accident rate.

- Accident rates generally increased with changes in roadside development i.e., residential, office, and retail land use.

Summary

The available information on parking indicates that parking has a significant effect on accident rates while parking configuration, i.e., parallel vs. angle parking does not affect accident frequency. Prohibiting on-street parking would significantly reduce accidents on urban streets where parking is currently permitted.

Utility Poles

A study of urban utility pole accidents was recently conducted by Jones and Baum, 1978 [43]. In a sample of 6,124 accidents, utility poles were found to be the most frequent (21.1 percent) type of fixed object struck in single-vehicle, run-off-the-road accidents. Approximately 2.2 percent of all accidents in urban areas involved impacts with utility poles and utility pole accidents had the highest percentage (50.5 percent) of injury accidents of all fixed-object crashes. The data suggest that as vehicle speeds increase, the percentage of utility pole accidents increases. Also, the number of utility pole accidents was found to be a function of the relative density of utility poles in an area. As pole spacing increased, the frequency of utility pole accidents was found to decrease. Utility pole accidents were also found to be a function of the distance the pole is located from the roadway. The proportion of utility pole accidents is high at low offsets, i.e., less than 5.5 feet (1.7 m) from the roadway, however, beyond 5.5 feet (1.7 m) the frequency of accidents appears to remain constant (approximately 0.2 utility pole accidents per single-vehicle accident).

Summary

Relationships between utility poles and total accidents have not been fully developed, however, the available data suggest that utility pole accidents may be a small percentage (2.2 percent) of total urban roadway accidents. Based on current study results, it appears that there is a significant relationship between utility pole frequency and pole offset and single vehicle run-off-the-road accidents. Additional research is needed to establish these relationships and to develop cost-effective utility pole countermeasures.

One-Way Streets

A synthesis of the safety effects of converting two-way street systems into one-way operations was conducted by Mayer, 1971 [48]. Generally, research studies indicate that accidents can be reduced from 10 to 50 percent if two-way streets are converted to a one-way operation. Initial operational and safety problems with the conversion are usually resolved within the first six months following implementation. It was also found that accident severity is generally reduced along with rear-end, sideswipe, turning, parking, and pedestrian accidents.

Bissell, 1965 [9] conducted a study to examine changes in traffic flow characteristics as a result of converting two-way streets to a one-way operation. The results of the analysis revealed that the street improvements reduced travel time by 11.5 percent and reduced vehicle stops by 33 percent. The improvements produced significantly less driver tensions on the one-way streets. Driver tension and the travel parameters remained unchanged on the two-way street.

Summary

One-way street systems have generally been shown to improve traffic operations and reduce accidents on urban streets, consequently, this type of change may be regarded as an effective countermeasure. However, additional research is needed to determine the relationships between specific one-way street geometrics and traffic conditions on accidents.

Environmental Factors

For the purpose of this study, environmental factors are defined as measures which are external to the physical features of the roadway. Examples of these measures are climatic conditions, lighting, and roadside development. A summary of the environmental factors identified during the literature review is given below.

Skid Number

Data from numerous studies indicate that a general decrease in accident rate occurs as the coefficient of pavement friction increases on all highway facility types.

Accident statistics, skid number, and related data were collected by Blackburn, et al., 1978 [10] for a one-year before and a one-year period after resurfacing was performed on 428 roadway sections located in 16 states. Eighteen of these sections were urban two-lane roadways and 18 sections were urban multilane facilities with uncontrolled access. The results of the analysis revealed that highway type, average daily traffic, and skid number have a significant effect on wet pavement accident rate. The correlation coefficients for the analyses ranged from 0.26 to 0.42 which indicates that the majority of the variance in the wet-pavement accident rate is not explained by the variables examined.

Although the sample size for urban roadways was small (less than 50 sites), the results indicate weak relationships exist between roadway type, traffic volume level, and skid number and wet pavement accident rates on urban highways.

Holbrook, 1976 [40] conducted a study to develop a model to estimate wet surface accidents at intersections based on skid number, wet time, and seasonal weather effects. Accident, skid number, and weather data were collected from 2,000 rural and urban intersections on State highways in Michigan. The results of the analysis are summarized below.

- Surface wet time and skid number are important factors in wet accident involvement.
- Below a skid value of 30, wet accident involvements increase as the pavement friction decreases.

- Monthly wet time has a significant effect on wet accident occurrences.

- Skid numbers alone will not lead to development of a plan which would optimally reduce wet surface accidents.

The study data indicates that wet pavement accidents are greatly influenced by the amount of time the pavement is wet and the skid number.

Summary

There is considerable evidence that sites (roadways and intersections) with low skid numbers have a significantly higher proportion of wet pavement accidents than sites with high skid numbers.

Illumination Level

Several investigators have examined the effects of illumination level on accident frequency.

A study was conducted by Christie, 1966 [20] to examine the effects of lighting improvements on traffic accidents on urban streets. Before and after data were collected at 64 locations in England. The measure of effectiveness used to determine the effect of the lighting was the r ratio defined as follows:

$$r = \frac{\dfrac{\text{Darkness Accidents After Improvement}}{\text{Darkness Accidents Before Improvement}}}{\dfrac{\text{Daylight Accidents After Improvement}}{\text{Daylight Accidents Before Improvement}}}$$

When $r = 1$, the lighting has no effect

If $r < 1$, darkness accidents have decreased
If $r > 1$, darkness accidents have increased

The following r ratios were obtained at the study locations.

Accident Type	r Ratio
Fatal	0.50
Serious injury	0.67
Slight injury	0.73
Total	0.90

With the exception of fatal accidents, the ratios were statistically significant at the $\alpha = 0.05$ level.

A study of 97 miles (156 km) of street relighting in Kansas City, Missouri conducted by Stark, 1973 [64] revealed that property damage accidents were reduced by four percent, injury accidents by 18 percent and fatal crashes by 28 percent. Based on the study findings, it was suggested that a serious night accident problem exists when the ratio of night-day accidents is more than 1.5 times the average ratio for similar locations or sections on the same system of roads and streets. The study data tend to support the hypothesis that low illumination levels are associated with high accident ocurrences.

An investigation was conducted by Box, 1976 [14] to determine the effect of illumination on accident frequency. One-year before and one-year after accident data were collected on a 2.5-mile (4.0-km) urban street located in Clearwater, Florida. The study section consists of a six-lane divided facility with a median barrier carrying between 33,000 and 45,000 vehicles per day. In November 1974, alternate luminaires were turned off. This change reduced the level of illumination from 1.8 to 0.9 horizontal foot-candles (19.4 to 9.7 lumen/sq. m) which was below the recommended level of 1.4 horizontal foot-candles (15.1 lumen/sq. m). The effect of lighting reduction on accidents and accident severity revealed that overall night accidents increased 39.5 percent and night injury accidents increased 33 percent.

Box, 1972 [13] also investigated the effects of illumination on highway accidents in the City of Syracuse, New York. Accident data for the year 1967 were analyzed for 105 miles (169 km) of major arterial and collector routes located in the city. The independent variables that were examined included road type, pavement width, illumination level, and abutting land characteristics. The dependent variables were the ratio of night accidents to day accidents and the night-day ratio of accident costs.

The results of the study are summarized below.

- Streets with little or no illumination had higher night-day accident ratios and costs than the average street in their category.

- Streets with extremely high illumination levels had higher night-day accident ratios and costs than the average street in their category.

- The most favorable illumination level ranged from 0.8 to 1.8 horizontal foot-candles (8.6 to 19.4 lumen/sq. m).

Summary

The results of studies conducted to-date suggest that there is a relationship between roadway illumination level and accidents on urban streets. Sections with a low level (or no lighting) and a high level of illumination appear to have higher accident rates than sections with illumination levels between 0.8 and 1.8 foot-candles (8.6 to 19.4 lumen/sq. m). Although additional data are needed to identify the reasons streets with high illumination levels were found to have high accident ratios, one hypothesis is that these sites previously had high accident ratios before the level of illumination was increased and increasing the lighting level did not result in a further reduction in accidents.

Commercial Floor Area

Berg and Anderson, 1973 [6] conducted a study to examine the relationships between traffic service and level of land access on four-lane undivided urban arterial highways in Madison, Wisconsin. Average travel time, roadway and land use characteristics were recorded for 0.2-mile (0.32-km) sections for each direction of travel. Data were collected on three roadways carrying between 9,680 and 20,170 vehicles per day. The results of the analysis reveal that the commercial floor area per mile (per km) and the number of intersections per mile (per km) significantly affect the travel time on arterial roadways. Consequently, commercial floor area is suggested as a measure of the level of land access on an urban facility.

Although the authors did not examine the relationship between accidents and roadside development, they did establish a link between the quality of flow, i.e., travel time, and independent variables such as intersections per mile (per km) which have been shown to be related to accident frequency.

Summary

There is no evidence that the amount of commercial floor area adjacent to urban roadways is related to accident occurrence, however, an increase in commercial floor area has been shown to significantly increase travel time on major urban roadways.

Pavement Wet Time

Holbrook, 1976 [40] analyzed approximately 40,000 accidents reported at over 2,000 intersections in urban and rural areas in Michigan to develop a wet surface accident model which incorporates skid number, wet time, and seasonal weather effects. Surface wet time was developed as a means of converting precipitation data into the percent wet time. Holbrook concluded that precipitation data, as reported by weather bureaus, is not suitable for predicting wet accident experience. A long steady rain may produce wet pavement over several hours, yet only produce an inch of rainfall. On the other hand, a heavy downpour may produce more rainfall, yet last only a few hours during hot summer months. Thus, the amount of precipitation does not correlate with the amount of time a pavement surface is wet, and as such, should not be used directly to predict wet accident experience.

The results of the study indicated that:

- surface wet time and skid numbers are important factors in wet accident involvement, and
- monthly wet time has a significant effect on wet accident occurrence.

The study findings suggest that wet pavement accidents are greatly influenced by the amount of time the pavement is wet and the skid number.

Summary

There is some evidence to suggest that the length of time the pavement is wet has a significant effect on wet pavement accidents.

Area Population

Three investigators have examined the effects of area population on urban roadway accident occurrence.

Wright and Mak, 1976 [73] collected accident, geometric features, and socio-economic data including population density (persons per square mile or per square km) for 45 sections of two-lane roadways in Atlanta, Georgia. The results of the study indicate that single-vehicle, fixed-object accidents are significantly related to average daily traffic, horizontal curvature, and population density. However, the equations developed do not account for a majority of the variance in accidents.

Walton and Machemehl, 1979 [70] also included area population as an independent variable in their study of continuous left-turn median lanes in urban areas in Texas. Analysis of the data revealed that the number of accidents per mile (per km) on four-lane roadways with two-way, left-turn median lanes was significantly affected by the population of an area, i.e., as population increased, the number of accidents increased.

In a study of four-lane urban roadways with raised medians and two-way, left-turn median lanes, Parker, 1979 [56] also examined the effects of area population on traffic accidents. Analysis of data collected at 50 sites in Virginia revealed that area population was not significantly related to accident frequency, however, midblock left-turn delay was significantly affected by area population.

Summary

There is some evidence that area population affects traffic accidents on urban roadways, however, the relationship is not significant.

Roadside Development

The effects of roadside development on accidents have been studied by four researchers.

In a study of 426 urban roadway sections, Head, 1959 [37] defined roadside development in terms of the number of residential and commercial units on a section. Analysis of the data revealed that the number of residential and commercial units are not related to accident frequency.

Chapman, 1978 [19] examined relationships between injury accident rates and environmental features on arterial roads in four towns in southern England. Roadside development was measured in terms of residential, open, industrial, and shopping space. The study results indicated that sections with shopping area development had significantly higher injury accident rates than sections with other types of land use.

Humphreys, et.al., 1979 [41] analyzed accident data collected on 170 miles (273.5 km) of urban roadway and found that accident rates generally increased with changes in roadside development. Roadside development was classified as residential, office, and retail land use.

In a study of 135 roadway segments in Oakland County, Michigan, Snyder, 1974 [63] concluded that the intensity of road frontage development was one of the variables that best predicted accident rates on the study sections.

Summary

Although roadside development has been defined in different ways by each investigator, the results of the studies suggest that changes in roadside development influences accident frequency on urban roadways.

Operational Factors

Operational factors include measures of the performance of the traffic stream and traffic controls which influence traffic flow. A summary of these measures is given below.

Speed Limit

Cribbins, et al., 1967 [24,25] examined the relationship between posted speed limit and accidents on 92 rural and urban roadways in North Carolina. A significant relationship between speed limit and injury accidents per mile (per km) was found, however, the speed limit had little effect on the median opening accident rate.

Although the sample size was small Avery, 1960 [3] examined the effects of raising speed limits from 30 to 35 miles per hour (48 to 56 kph) on 11 sections of highway in St. Paul, Minnesota. A review of the speed data revealed that the changes in the posted speed limit did not affect vehicle speeds and the accident frequency within the study sections was not significantly affected by the change.

Head, 1959 [37] also included speed limit as an independent variable in his study of urban roadways in Oregon. Generally for the study sections it was found that roadways with higher posted speeds had lower accident frequencies.

Summary

Based on available research, speed limits may have an effect on accidents, however, this result may be confused by the fact that lower speed limits are usually posted in heavily developed areas.

Acceleration Noise

Heimbach and Vick, 1968 [38] investigated the relationship between acceleration noise (change of speed per unit time) and accident rates at six sites. While no statistical analysis was employed, sites with high acceleration noise levels had high accident rates.

Summary

Acceleration noise may be significantly related to accident rates, however, additional research is needed to verify this hypothesis.

Traffic Volume

Numerous authors have concluded that traffic volumes are more closely related to accident experience than any other nonaccident factor or combination of nonaccident factors. Further, most studies normally utilize ranges of volume in explaining the effects of other elements on accident experience. Although numerous relationships have been reported, the conclusions have not always been consistent. The absence of a consistent relationship between accidents and traffic volume may be due to the effect other variables have on accidents.

The effects of traffic volumes on intersection accidents have been reported by David and Norman, 1975 [26]. Analysis of data collected at 558 intersections in California revealed that accident rates increased with increases in traffic volumes. Fatal and injury rates also followed a similar pattern.

Shaw and Michael, 1968 [62] collected delay time and accident data at 11 intersections in Indiana and found that:

- delay caused by left-turning vehicles was significantly related to total hourly volume and the number of left-turn vehicles per hour, and

- traffic volumes significantly affect accident rates at intersections.

The results of a number of studies conducted on urban roadway sections indicate that increases in traffic volumes lead to significant increases in accident frequency. Evidence supporting this statement can be found in reports prepared by Azzeh, 1975 [4], Cribbins, et al., 1967 [24,25], Head, 1959 [37], Mulinazzi, 1967 [53], Parker, 1979 [56] and Walton, 1979 [70]. Increases in volume have also been shown to be positively correlated with skidding accidents (Blackburn, 1978 [10]), traffic events (Clark, 1968, [21]), and travel time (Coleman, 1961, [23]).

In a study of single-vehicle accidents on two-lane roadways in Atlanta, Georgia, Wright and Mak, 1976 [73] found that an increase in traffic volume would decrease the rate of run-off-road accidents.

Summary

There is considerable evidence that increases in the traffic volumes will lead to increases in accidents on urban roadways.

Travel Time

Based on the results of a study conducted by May, 1959 [46] on 41 sections of multilane highway in Detroit and Lansing, Michigan, a statistically significant relationship was found between accident rates and travel time.

Coleman, 1961 [23] analyzed data collected in Pennsylvania and provided the following conclusions.

- Volume/capacity ratio can be used to estimate travel time on urban highways.
- Traffic volume and signal timing have major effects on travel time.
- Street width, percentage of heavy commercial vehicles, direction of flow, and area type have minor affects on travel time.
- Travel time along an urban highway section is directly proportional to the average number of traffic signals per mile (per km) on the section.

Torres, 1967 [69] collected data on 158 street sections in seven U.S. cities and concluded that signal density has a highly significant (statistical) effect on travel time. Lane width, percent of green time, and parking also effect travel time but to a much lesser extent than signal density.

Summary

There is some evidence that a relationship exists between travel time and accidents, however, much more data are available indicating that a relationship exists between travel time and accident-related roadway features such as signals per mile (per km).

Signal Improvements

Fielding and Young, 1955 [29] conducted a study to evaluate the effects of traffic signal modifications on accident frequency, traffic volume, capacity, delay, and speeds on a 3.85 mile (6.16 km) section of four-lane urban arterial highway in Cincinnati. As a result of traffic signal modifications including the installation of a new signal, increasing the cycle length, synchronizing the controls, and other changes such as restriping, installing parking signs, etc., the total number of accidents on the section decreased 3.5 percent (from 749 accidents in 1952 to 723 accidents in 1953). Accidents at signalized intersections decreased 21 percent, however, accidents at locations other than at traffic signals increased 22.6 percent. During the study period traffic volumes increased from 10 to 15 percent, however, average trip times decreased 7.5 percent and speed increases ranged from 0.4 to 2.1 miles per hour (0.64 to 3.36 kph) i.e., 19.5 to 21.1 miles per hour (31.20 to 33.76 kph). This is one of the few studies where accident and operational data were collected at the same time following physical changes on an urban roadway. Unfortunately no correlations or statistical inferences can be made from data collected at one site but the analysis indicates that reducing delay at signalized intersections can reduce intersection crashes.

Summary

Based on one sample, there is evidence that traffic signal modifications can lead to reduced traffic accidents and increased vehicle speeds.

Yield Signs

Based on a synthesis of the literature prepared by Box, 1970 [16], yield sign controls have been found to be effective in reducing accidents at low volume, previously uncontrolled urban intersections. Accident reductions ranged from 23 to 52 percent.

Summary

The use of yield signs erected in compliance with MUTCD, 1978 [27] warrants have been found to be effective in reducing accidents at intersections which previously had no control.

Two-Way Stop Control

A synthesis of completed studies on two-way stop control intersections conducted by Box, 1970 [16]. Analysis of accident data at 400 cross-type intersections, where cross street volumes ranged up to 4,000 vehicles per day and through street volumes up to 32,000 vehicles per day, showed that for two-way stop control:

- as cross street volumes increased, the accident rate increased, and
- as through street volume increased, the accident rate decreased.

Summary

There is some evidence that accident frequency at two-way stop controls is related to the cross-street traffic volume.

Four-Way Stop Control

Based on a synthesis of completed studies concerning the impacts of four-way stop control, Box, 1970 [16] concluded that:

"Generally four-way stop controls have been found to be effective in reducing accidents provided that traffic signal warrants were not met and the volumes on the intersection approaches were reasonably balanced. Analysis of before and after accident rates at 38 intersections in St. Paul, Minnesota with volume ranging from 3,500 to 18,900 revealed a 56 percent reduction in accidents as a result of implementing four-way stop instead of two-way stops. A 20 percent increase in rear-end accident rates was reported, however, there was a 75 percent reduction in right-angle crashes, a 67 percent reduction in head-on accidents, and a 50 percent reduction in fixed-object crashes."

Summary

There is some evidence that accidents can be reduced with the use of four-way stops if traffic volumes on the approaches are nearly balanced and traffic signal warrants are not met at the intersections.

Traffic Signal Control

The results of a synthesis conducted by Box, 1970 [16] relative to the effects of traffic signals on accidents is summarized below.

- A study of the effect of signalization on accidents at 599 intersections in 24 cities revealed that traffic signals reduced accidents an average of 20 percent, however, accidents increased at one-third of the intersections. There was an increase in rear-end accidents, a decrease in right-angle crashes, and increases in accidents at intersections where the accident frequency was three or fewer accidents before signalization.

- A study of 39 urban and rural intersections in Michigan indicated that accidents increased 23 percent but injuries and fatal accidents decreased by 20 and 50 percent respectively. After the signals were installed rear-end accidents increased 200 percent, head-on accidents increased 157 percent, and side-swipe crashes increased 74 percent. Angle accidents decreased by 51 percent. It was further concluded that signalization tends to increase accident rates at simple intersection designs, but decreases rates at complex locations.

- Another study of 52 urban and suburban intersections in Michigan showed an increase in accidents of 33 percent. The data revealed that rear-end accidents increased by 98 percent and left-turn accidents increased by 66 percent while right-angle accidents decreased by 45 percent.

- Factors which appear favorable to reducing accidents through traffic signalization are high traffic volumes, high accident frequency, and complex intersection layouts.

Studies of the effects of type of intersection control on accidents conducted by King and Goldblatt, 1975 [44] revealed that:

- installation of traffic signals influences a reduction in right-angle accidents and an increase in rear-end collisions, however,

- no evidence was found to suggest that the installation of signals reduces the adverse effects of accidents.

Summary

Based on a review of the literature it appears that traffic signals influence accident patterns but signals do not necessarily reduce the accident frequency at intersections.

Steering Wheel Reversals

In a study conducted on arterial streets in Raleigh, North Carolina, Clark and Cribbins, 1968 [21] found that a combination of steering wheel reversals and brake applications can be used to estimate traffic volumes on the facility. Although no direct correlation was made between accidents and steering wheel reversals, there may be some relationship because volumes have been found to have a significant relationship with accidents.

Summary

No direct relationship between steering wheel reversals and accidents has been reported, however, there is some indirect evidence that implies that such a relationship may exist.

Brake Applications

Based on the results of data collected on urban roadways in Raleigh, North Carolina, Clark and Cribbins, 1968 [21] concluded that steering wheel reversals and brake applications can be used to predict traffic volumes on the roadway. May, 1955 [47] also collected data on roadways in nine states and found the duration of brake application per mile (per km) of travel (expressed in seconds) was 5.74 seconds on urban routes without access control compared with zero seconds on urban roads with full control of access. Brake application duration averaged 0.21 seconds on rural highways with access control.

Summary

Because traffic volumes and access control measures have been reported to have a direct relationship with accidents, brake applications may also be related to accidents.

Traffic Conflicts

Traffic conflicts have been used by Clayton and Deen, 1977 [22] to identify traffic hazards at intersections and by Parker, 1975 [57] to evaluate the effects of implementing right-turn-on-red regulations at signalized intersections. Glauz and Migletz, 1980 [33] have suggested that a relationship between traffic conflicts and accidents exists, however, substantial evidence of this relationship has not be developed.

Summary

There is some evidence that a relationship between traffic conflicts and accidents exist, however, additional studies are needed to establish this relationship.

Volume/Capacity Ratio

Coleman, 1961 [23] collected operational and roadway features data in five cities in eastern Pennsylvania and concluded that volume/capacity ratio can be used to estimate travel time on urban streets. Further studies reporting relationships between volume/capacity ratio and other measures were not found in the literature.

Summary

There is some evidence that volume/capacity ratio is related to travel time, however, there is no information suggesting that it is related to traffic accidents.

Signal Timing

Coleman, 1961 [23] analyzed operational and roadway data in five cities in eastern Pennsylvania and concluded that signal timing has a major effect on travel time. Further studies regarding relationships between signal timing and other measures were not identified during the literature review.

Summary

There is some evidence that signal timing has an influence on travel time, however, there is no information suggesting that signal timing is related to urban arterial accident frequency.

Level of Service

The relationship between level of service and accidents was examined by Cribbins, et al., 1967 [24] in a study of 92 sections of rural and urban divided roadways in North Carolina. Level of service was defined as the travel time for a site divided by the site length. The results of the analysis indicated that level of service is significantly related to the number of injury accidents per mile (per km), i.e., as the level of service increases, the accident frequency increases.

Summary

There is some evidence that level of service, defined as the travel time divided by the segment length is related to accident frequency.

Street Signs

David and Norman, 1975 [26] analyzed roadway and accident data at 558 urban and rural intersections in California and found that high volume intersections with street signs with white letters on a dark background have an average of 5.1 more accidents per year than at intersections having dark lettering on a white background.

Summary

There is some evidence that intersections with street signs with white letters on a dark background have a higher accident rate than intersections with signs with dark letters on a white background.

Vehicle Mix

While a number of researchers have examined the effects of large vehicles on the traffic stream, no studies were found that examined the effects of large vehicles on accidents on urban arterial streets. In their study of 558 intersections in California, David and Norman, 1975 [76] found that high volume intersections along bus routes have significantly higher accident rates than intersections without bus routes.

Summary

There is very limited information indicating that vehicle mix influences accident frequency on urban streets.

Fuel Consumption

Some evidence of a relationship between fuel consumption, travel time, and accident rate is provided in studies conducted by May, 1959 and 1955 [46,47] who found that the number of intersections and traffic signals along a roadway appear to have a greater influence on accident rates, travel time, and fuel consumption than any other forms of roadway friction. It was also found that gasoline consumption was higher on urban sections with no access control due to greater roadside friction when compared to urban roads with full access control.

Summary

There is some evidence that fuel consumption is influenced by roadside friction which has a significant effect on accident rates.

Right-Turn-On-Red

McGee, et al., 1976 [49] and Parker, et al., 1975 [57] conducted studies to determine the effect on accidents of permitting motorists to make right turns on red lights at intersections. The results of the studies revealed that right-turn-on-red manuevers did not appear to significantly influence accident frequencies at intersections.

Summary

There is considerable evidence that right-turn-on-red does not influence accident frequencies at intersections.

Human Factors

For the purpose of this study, human factors are defined as measures of driver performance. Typical illustrations of human factors measures are eye movements, reaction times, information processing ability, and problem recognition. Most human factors measurements have been made under laboratory conditions. The literature revealed only a few cases where mention is made of any human factors measure in relation to accidents on urban arterial streets. These measures are discussed below.

Sex of Driver

During 1955 Billion, 1958 [7] conducted a study of 810 drivers in Schenectady, New York. The drivers were interviewed to obtain their personal, social, health and driving characteristics. Accident records for these drivers were also obtained for the period January 1953 through June 1955. In addition, 428 male and 122 female drivers were followed while driving in the city and rated relative to their speed, headway, passing, traffic signals, stop signs, turning movements, yielding and attentiveness characteristics. The results of the analysis indicated that; 1) more male drivers are involved in urban accidents than female drivers, 2) there was no significant difference between frequency of accidents and type of accident, and 3) there was no significant difference between the driving characteristics of drivers who were involved in accidents and drivers who were not involved in accidents.

Summary

Although more male drivers are involved in accidents than female drivers there is some evidence that there is no relationship between sex of driver, driving characteristics, and accident frequency.

Galvanic Skin Response

Bissell, 1965 [9] used galvanic skin response measurements to examine differences in driver tension as a result of converting a two-way street to one-way operation. The tests were conducted on several streets in Washington, D.C. Analysis of the data revealed that after the roadway improvements there was significantly less driver tension. Operational conditions, i.e., travel times, number of stops, etc. were also improved in the after period.

Summary

No direct evidence of a relationship between driver tensions and accidents was found, however, there is some evidence that driver tensions are related to travel times, delay, and other operational measures which have been found to influence accident frequencies on urban roadways.

Driver Age

Snyder, 1974 [63] collected accident data on 135 sections of roadway in Oakland County, Michigan and found that accident rates on the sections were best predicted from type of road, intensity of road frontage development and percentage of population between 16 and 24 years old.

Summary

There is some evidence that younger drivers are involved in a high proportion of accidents on urban roadways than other age groups.

Countermeasures

The literature review revealed that numerous studies have been conducted to evaluate the effectiveness of roadway and traffic control devices to reduce accidents and accident severity. While a discussion of the warrants and effectiveness of each countermeasure is beyond the scope of this report, a summary of the countermeasures identified during the review of studies conducted in urban areas is given in Table 1. Some of the most frequently used countermeasures in urban areas are listed below.

- Install median to separate opposing traffic streams
- Convert from two-way to one-way operation
- Prohibit on-street parking
- Improve intersection sight distance
- Limit number of driveways through access control policies
- Construct continuous two-way, left-turn median lane
- Construct raised median
- Resurface to improve skid resistance
- Provide illumination
- Install left- and right-turn lanes
- Widen pavement or provide additional lanes
- Provide delineation
- Relocate bus stops

Summary of Findings

The purpose of the literature review was to identify studies which examined the relationships between accidents and urban roadway features. Although a number of investigators have identified accident relationships for urban arterial roadways, each study was conducted to accomplish specific objectives and differed in scope, method, and purpose. Due to the differences in study techniques, it is not possible to quantify specific relationships between roadway features and accidents. Nevertheless, the literature can be used to identify elements which appear to be related to accidents on urban roadways. Each of the roadway elements identified in the literature was placed in one of the following categories.

Definite Relationship

A roadway feature was placed in this category when a large number of studies revealed that a statistically significant relationship existed between the variable and accidents. Further examination of this relationship would probably not produce new results.

Probable Relationship

A roadway feature was placed in this category when several studies identified a relationship between the variable and accidents. Further research to establish the relationship is needed.

Possible Relationship

A variable was placed in this category when some evidence was available to suggest a link between the variable and accidents. Additional research is needed to establish the relationship.

Results

Based on these definitions, each variable was subjectively rated and placed into the appropriate category. A summary of the results is given in Table 4. It should be noted that the significance of the relationship noted in Table 4 is based on a subjective evaluation of the literature results. In many cases not enough data were available to conclusively determine if there were statistically significant differences and/or relationships between the variables and accidents.

Table 4. Summary of accident relationships on urban arterial streets.

Roadway Features	Type of Relationship		
	Definite	Probable	Possible
Geometric Factors			
Pavement width		NS	
Turn lanes	S		
Median presence		S	
Median width		NS	
Median openings		NS	
Access control	S		
Driveways		S	
Traffic signals	S		
Intersection design		S	
Intersections		S	
Traversable median lanes	S		
Raised medians	S		
Horizontal alinement		S	
Vertical alinement		S	
Sight distance		S	
Fixed-objects		S	
Parking	S		
Utility poles		S	
One-Way streets	S		
Environmental Factors			
Skid number	S		
Illumination level	S		
Commercial floor area			X
Pavement wet time			S
Area population			NS
Roadside development		S	

Legend

S = Significant relationship
NS = Not significant
X = Relationship Unknown

Table 4. Summary of accident relationships on urban arterial streets (continued).

Roadway Features	Type of Relationship		
	Definite	Probable	Possible
<u>Operational Factors</u>			
Speed limit		NS	
Acceleration noise			S
Traffic volume	S		
Travel time			S
Signal improvements			S
Yield signs		S	
Two-Way stop control		S	
Four-Way stop control		S	
Traffic signal control		NS	
Steering wheel reversals			X
Brake applications			X
Traffic conflicts			S
Volume/capacity ratio			X
Signal timing			X
Level of service			S
Street signs			S
Vehicle mix			X
Fuel consumption			X
Right-Turn-On-Red		NS	
<u>Human Factors</u>			
Sex of driver			NS
Galvanic skin response			X
Driver's age			S

Legend

S = Significant relationship
NS = Not significant
X = Relationship Unknown

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APPENDIX B - ANNOTATED BIBLIOGRAPHY

Introduction

An extensive review was conducted of past and current literature in which relationships between accident experience and roadway, environmental, human, and traffic operational features were reported for nonlimited access urban arterial highways. The survey also encompassed documents identifying the effects of accident countermeasures implemented on urban roadways.

Reports which are of greatest applicability to the current research effort are listed below. The annotations are in alphabetical order by author or agency. Each annotation begins with a brief statement of the purpose and scope of the study followed by a synopsis of the results. In some cases, data which support findings directly applicable to the objectives of the current study are reported in detail. The conclusion of each annotation includes a critical review of the report and its applicability to the current research effort.

Annotations

1. **American Association of State Highway Officials, "A Policy on Design of Urban Highways and Arterial Streets," Washington, D.C., 1973.**

    This policy presents a synthesis of current knowledge and practice regarding the design of urban arterial roadways. Specific design features are based on the state-of-the-art practices and are felt applicable for national use. The authors recommend satisfying minimum design criteria and applying a generous factor of safety in determining all geometric features.

    Although the AASHO design policy represents a consensus of the current knowledge on urban roadway design, the relationships between many geometric features and accidents have not been quantified. Further research identifying relationships between specific geometric features, operating conditions, behavioral characteristics, environmental impacts, and accidents is needed. This information would greatly add to current knowledge and could be used to formulate future urban highway design policies.

2. **Automotive Safety Foundation, "Traffic Control & Roadway Elements - Their Relationship to Highway Safety," prepared in cooperation with the U.S. Bureau of Public Roads, Washington, D.C., 1963.**

This report provides a comprehensive summary of studies conducted prior to 1962 to examine the relationships between traffic accidents and roadway design features and traffic control devices. The synthesis includes studies conducted in rural, suburban, and urban areas. A complete revision of the report was undertaken by the Highway Users Federation for Safety and Mobility in 1970 and related studies conducted in urban areas are discussed in other sections of this bibliography.

3. **Avery, Eugene V., "Effect of Raising Speed Limits on Urban Arterial Streets," <u>Highway Research Bulletin 244</u>, Highway Research Board, Washington, D.C., 1960.**

This study was conducted to examine the effects of raising the speed limits from 30 to 35 miles per hour (48 to 56 kph) on 11 sections of arterial highway in St. Paul, Minnesota. Before and after spot speed data were collected on the sections which carried from 4,000 to 26,000 vehicles per day. Analysis of the speed data indicated that small changes in the posted speed limit did not effect changes in vehicle speeds. A review of the annual number of accidents reported within the study sections did not reveal any change in the accident frequency.

The study data indicate that making small changes in the posted speed limit appears to have no effect on operating speeds or on accident frequency. In urban areas many factors have been found to be associated with accident occurrence, however, this study suggests that minor changes in speed limits as an accident countermeasure probably would not have any significant affect on vehicle speeds or accidents.

4. **Azzeh, J.A., B.A. Thorson, J.J. Valenta, J.C. Glennon, and C.J. Wilton, "Evaluation of Techniques for the Control of Direct Access to Arterial Highways," Final Report, <u>FHWA-RD-76-85</u> prepared for Federal Highway Administration, Washington, D.C., August 1975.**

This research was conducted to develop cost-effective techniques that enhance traffic operations and safety by controlling access on urban and suburban arterial highways. Estimates of accident experience for the 68 techniques identified in the report are based on the findings of other investigators. Some modifications of the safety relationships were made by the authors. The techniques identified included 27 highway design and operations measures, 21 driveway location measures, and 20 driveway design and operations techniques. A benefit-cost methodology is presented for selecting and evaluating various access control techniques based on site specific conditions, i.e., average daily traffic, number of driveways per mile (per km), width of the right-of-way, etc.

Although the authors provide an excellent methodology for selecting and evaluating alternative access control techniques for arterial highways, one major problem encountered during the study was the lack of accident data needed to evaluate the effectiveness of the countermeasure. To overcome this deficiency for arterial roadway sections the authors utilized accident predictive equations based on data collected on urban arterials in Indiana during the mid 1960's. The equations were modified to fit specific countermeasures based on certain assumptions and findings offered by other investigators. To improve the evaluation process a large data base consisting of up-to-date accident data collected on a nationwide basis should be used in lieu of the current base. This task would be an important step toward evaluating a variety of countermeasures for reducing accidents on urban arterial highways.

5. **Babcock, W.F. and Robert Foyle, "Urban Street Design For Traffic and Land Service," Highway Research Program, North Carolina State University, Raleigh, North Carolina, March 1978.**

Accident and operational data were collected and analyzed on 15 urban highway sections totalling 32.4 miles (52.1 km) in two North Carolina cities. The roadway sections included four-lane undivided highways, four- and six-lane divided roadways, and five- and seven-lane sections with traversable median lanes. Accident data were collected for the years 1975 and 1976. Due to the small sample size, statistical analyses of the data were not performed. A summary of the study results is outlined below.

- Accident rates on five and seven lane roadways with traversable medians are similar to rates on four- and six-lane divided highways.

- No head-on collisions were reported on the sections with traversable median lanes.

- In all cases the median lane of the five- and seven-lane facilities appeared to handle traffic efficiently.

- Four- and six-lane undivided roadways had higher accident rates than sections with medians.

Although the sample size is small, comparison of the accident rates between sections with divided roadways and sections with a continuous two-way, left-turn median lane appears to indicate that median type does not influence accident rates. The data also lend support to the hypothesis that two-way, left-turn lanes do not create situations which contribute to head-on collisions.

6. **Berg, W.D. and J.C. Anderson, "Analysis of the Trade-Off Between Level of Land Access and Quality of Traffic Service Along Urban Arterials," Highway Research Record 453, Highway Research Board, Washington, D.C., 1973.**

This study was conducted to examine the relationships between traffic service and level of land access on four-lane undivided urban arterial highways in Madison, Wisconsin. Average travel time, roadway and land use characteristics were recorded for 0.2-mile (0.32-km) sections for each direction of travel. Data were collected on three roadways carrying between 9,680 and 20,170 vehicles per day. Multiple linear stepwise regression analysis was used to examine the relationship between travel time, the dependent variable, and the independent variables. The results of the analysis reveal that the commercial floor area per mile (per km) and the number of intersections per mile (per km) significantly affect the travel time on arterial roadways. Consequently, commercial floor area is suggested as a measure of the level of land access on an urban facility.

Although the authors did not examine the relationship between accidents and roadside development, they did establish a link between the quality of flow, i.e., travel time, and independent variables such as intersections per mile (per km) which have been shown to be related to accident frequency. While the travel time model that was developed to evaluate alternative roadside development schemes would be a useful tool for transportation engineers and planners, further refinement or use of the model has not been reported in the literature.

7. **Billion, C.E., "Community Study of the Characteristics of Drivers and Driver Behavior Related to Accident Experience," Highway Research Bulletin 172, Highway Research Board, Washington, D.C., 1958.**

During 1955, a study of 810 drivers was conducted in Schenectady, New York. The drivers wre interviewed to obtain their personal, social, health, and driving characteristics. Accident records for these drivers were also obtained for the period January 1953 through June 1955. In addition, 428 male and 122 female drivers were followed while driving in the city and rated relative to their speed, headway, passing, traffic signals, stop signs, turning movements, yielding, and attentiveness characteristics. The results of the analysis indicated that; a) more male drivers are involved in urban accidents than female drivers, b) there was no significant difference between frequency of accidents and type of accident, and c) there were no significant differences between the driving characteristics of drivers who were involved in accidents and drivers who were not involved in accidents. Also, the percentage of drivers involved in unsafe actions was found to be highest at stop signs, i.e., 67 percent of the drivers committed unsafe actions at stop signs. Other specific driver behavior and unsafe action percentages are given in Table 5.

The results of the study did not identify specific relationships between urban street geometrics and human factors, however, the findings are beneficial in adding to the knowledge of urban accident experience by describing characteristics of drivers utilizing urban roadways.

Table 5. Percentage of unsafe drivers for different types of driver actions.

Driver Action	Percent Of Unsafe Drivers
Stop Sign	67
Yielding	36
Turning Movement	35
Passing	19
Speed	17
Attentiveness	13
Lane Markings	8
Headway	6

Source: HRB 172, pg. 57.

8. **Billion, C.E. and N.C. Parsons, "Median Accident Study - Long Island, New York," Highway Research Bulletin 308, Highway Research Board, Washington, D.C., 1962.**

This investigation was conducted to examine the effect of median design on accident rates for urban divided highways. The study encompassed the collection of 8,180 accident reports for the years 1955 through 1959 on 34 urban sections without access control. The sections ranged from 0.5 to 9.3 miles (0.8 to 14.9 km) in length and a total of 82 miles (131.9 km) of urban roadway was included in the study. The roadways consisted of four- and six-lane divided highways. Median types included flush grass, raised grass with concrete curbs, and raised paved with concrete curbs. The number of intersections varied from 3 to 7 per mile (5 to 11 per km). A summary of the data obtained for the study sites is given in Table 6.

The results of the study are outlined below.

- No correlation was found between width of median and accident rates on roadways excluding intersections for deterring type medians (a deterring median is a flush or raised median which discourages but does not physically prevent vehicles from crossing the median). As shown in the Figure 1, narrow medians less than 10 feet (3.1 m) wide had high accident rates but low injury accident rates.

- For deterring type medians, grass flush medians had the lowest accident rate for roadway sections between intersections and the curbed median had the highest rate.

- Medians with double beam rails had the lowest total accident and injury rates while medians with concrete posts had the highest rates.

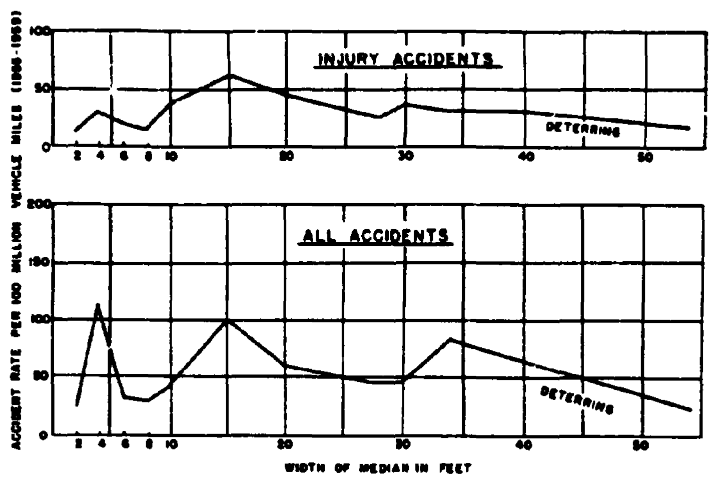
- On roadway sections excluding intersections, curbed medians had approximately 2 and 1/2 times the accident ratio of the flush median sections.

- A summary of accidents involving a median (shown in Table 7) revealed that deterring medians had the lowest cross median accident rate (1.8) when compared to the sections with nontraversable medians (4.0). Curbed median sections

Table 6. Summary of accident data by median type.

Functional Type of Median	No. of Sections	Total Length (mi)	No. of Reported Accidents: Study Period	No. of Reported Accidents: Between Intersections	No. of Reported Accidents: At Intersections	Travel MVM for Period of Study
Deterring						
Earth: grass or soft surface, slopes 1 on 4 or flatter.	10	45.8	1955-60	408	1,325	893.1
Curbed: with standard curbs 6 in. or less in height (vertical and mountable)	19	26.3	1955-60	860	4,607	780.7
Miscellaneous Features: median with intermittent shrubbery, curbed and flush	2	3.6	1955-60	58	208	87.9
Sub-total	31	75.7		1,326	6,140	1,761.7
Non-Traversable						
Median, 12 ft wide and curbed with double type steel guide railing and steel posts	1	4.3	1960	35	1	127.1
Median, with concrete posts to prevent crossings	1	3.3	1955-60	104	436	132.6
Median, with NYSDPW single-beam-type guide railing and concrete posts	1	2.2	1959	5	9	7.8
Median, with concrete posts and railing and some large trees. Deep ditch slope 1 and 2	1	0.7	1958-60	4	49	9.8
Subtotal	4	10.5		[illegible]	[illegible]	[illegible]
Total	35	86.2		1,582	6,626	2,038.8

Source: HRB 308, Table 1, pg. 68.



Source: HRB 308, Figure 4, pg. 71

Figure 1. Effect of median width on accident occurrence.

Table 7. Summary of median related accidents.

Type of Median	MVM	All Cross Median Accidents No.	All Cross Median Accidents Rate/100 MVM	All Median Accidents No.	All Median Accidents Rate/100 MVM	All Accidents between Interchanges No.	All Accidents between Interchanges Rate/100 MVM	Ratio Median Accidents to Accidents between Interchanges	Ratio Cross Median Accidents to All Median Accidents
Traversable									
Earth	[illegible]	14	1.6	17	1.9	[illegible]	46	1 to 26	4 to 5
Curbed	[illegible]	12	1.5	[illegible]	2.4	[illegible]	[illegible]	1 to 45	3 to 5
Miscellaneous features	97.[illegible]	6	[illegible]	6	[illegible]	[illegible]	[illegible]	1 to 10	1 to 1
Subtotal	1,[illegible]	32[a]	1.8	[illegible]	[illegible]	1,[illegible]	[illegible]	1 to [illegible]	[illegible]
Non-Traversable									
Double guide rail	127.1	2	1.6	2	1.6	[illegible]	[illegible]	1 to 17	1 to 1
Concrete posts	138.4	6	4.3	8	[illegible]	104	[illegible]	1 to [illegible]	3 to 4
Single guide rail	7.8	1	12.8	1	12.8	5	[illegible]	1 to 5	1 to 1
Guide rail and ditch	[illegible]	2	[illegible]	2	[illegible]	4	41	1 to 2	1 to 1
Subtotal	277.1	11[b]	[illegible]	13	4.7	[illegible]	[illegible]	1 to [illegible]	[illegible]
Total	2,[illegible]	43	[illegible]	[illegible]	2.7	1,[illegible]	[illegible]	1 to [illegible]	[illegible]

[a] [illegible] of 14, 3 of 12 and [illegible] of 6 for the 3 groups, respectively, were head-on collisions.
[b] All head-on collisions.

Source: HRB 308, Table 5, pg. 76.

had the lowest ratio of median accident involvements (1 to 45) compared to earth medians (1 to 24) probably because drivers use an earth median to avoid an accident. On curbed median sections it was speculated that motorists are more confined to the pavement, consequently reducing median related involvements but not total accident involvement.

The results of the study indicate that median characteristics influence accident types and rates in urban areas. Perhaps the most significant finding is that roadways with raised curbed medians have higher accident rates than do roadways with flush grass medians. This finding should be further explored using a larger accident data base. The results of the study could have a significant impact upon future urban design standards.

9. **Bissell, Howard H., "Analysis of a Three-Street Traffic System," Highway Research Record 72, Highway Research Board, Washington, D.C., 1965.**

During 1961 and 1962 this study was conducted to examine changes in traffic flow characteristics created where three parallel streets in Washington, D.C. were changed from three two-way streets to a one-way street system on each side of a curbed two-lane roadway. In addition to the conversion from two-way to one-way operation, some on-street parking changes and signal coordination measures were made at the study sites. Data collected before and after the changes included volumes, travel times, number of vehicle stops, speed changes per mile (per km), and the driver's galvanic skin response. The results of the analysis revealed that the street improvements reduced travel time by 11.5 percent and reduced vehicle stops by 33 percent. The improvements produced significantly less driver tensions on the one-way streets. Drivers tensions and the travel parameters remained unchanged on the two-way street. There was a small change in traffic volumes following the street improvements.

Although the research did not include a before and after accident analysis, it was one of the few studies where human factors (galvanic skin response) data were taken in an urban area along with traffic flow data. The study results indicate that converting from two-way to one-way operations may reduce travel time, increase speeds, and reduce driver tensions.

10. **Blackburn, R.R., D.W. Harwood, A.D. St. John, and M.C. Sharp, "Effectiveness of Alternative Skid Reduction Measures, Volume 1, Evaluation of Accident Rate - Skid Number Relationships," Report No. FHWA-RD-79-22, prepared for the Federal Highway Administration, Washington, D.C., November 1978.**

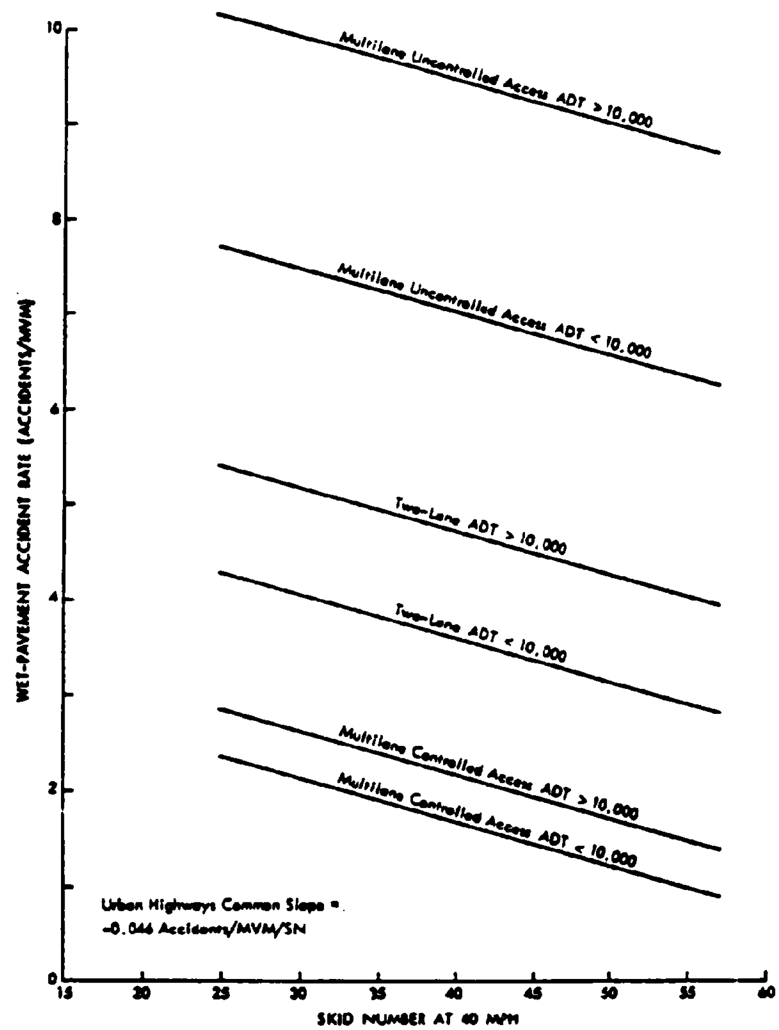
Accident statistics, skid number, and related data were collected for a one-year before and a one-year period after resurfacing 428 roadway sections located in 16 states. Eighteen of the sections were urban two-lane roadways and 18 sections were urban multilane facilities with uncontrolled access. The before data were collected prior to July 1, 1973 and the after data were obtained after June 30, 1974. Statistical analyses of these data included matched-pair comparisons, regression analysis, and analysis of covariance. The results of the analysis revealed that highway type, average daily traffic, and skid number have a significant effect on wet pavement accident rate. The correlation coefficients for the analyses ranged from 0.26 to 0.42 which indicates that the majority of the variance in the wet pavement accident rate is not explained by the variables examined. The relationships for urban arterial highways are given in Figure 2.

Although the sample size for urban roadways was small (less than 50 sites) the results indicate a weak relationship exists between roadway type, average daily traffic level, and skid number and wet-pavement accident rates on urban highways. Figure 2 can be used to estimate the effectiveness of improving skid resistance on the wet-pavement accident rate. A benefit-cost methodology is also given in the report to examine the cost effectiveness of accident countermeasures.

11. **Bochner, Brian S., "Regulation of Driveway Access To Arterial Streets," Compendium of Technical Papers, 48th Annual Meeting of Institute of Transportation Engineers, Atlanta, Georgia, August 1978.**

Based on the effects of driveways on arterial roadway safety and capacity as reported by other researchers, a driveway access control policy is presented. Subdivision, zoning, and driveway ordinances which should incorporate driveway access provisions are summarized.

The policies presented contain some general guidelines for controlling driveway access to arterial streets, however, the effects of specific countermeasures are not presented.



Source: Blackburn, et. al., 1978 [10], Figure 6, pg. 79.

Figure 2. Relationship between wet-pavement accident rate and skid number for urban highways.

12. **Box, Paul C., "Access Control and Accident Reductions," Municipal Signal Engineer, May-June 1965.**

The objective of this article was to describe the effects on accidents of converting a 56-foot (17.1-m) wide undivided urban highway into a divided roadway. In addition to the median barrier, RIGHT TURN ONLY signs were installed and three lanes were provided for each direction of travel. The improvements resulted in a 50 percent decrease in the midblock accident rate.

The results of a study at one site does not provide sufficient evidence of an accident and design relationship, however, the results of this study plus other research investigations indicate that providing medians on urban roadways may lead to a reduction in traffic accidents.

13. **Box, Paul C., "Comparison of Accidents and Illumination," Highway Research Record 416, Highway Research Board, Washington, D.C., 1972.**

The purpose of this study was to investigate the effects of illumination on highway accidents in the City of Syracuse, New York. Accident data for the year 1967 were analyzed for 105 miles (169 km) of major arterial and collector routes located in the City of Syracuse. The independent variables that were examined included road type, pavement width, illumination level, and abutting land characteristics. The dependent variables were the ratio of night accidents to day accidents and the night-day ratio of accident costs.

The results of the study are summarized below.

- Streets with little or no illumination had higher night-day accident ratios and costs than the average street in their category.
- Streets with extremely high illumination levels had higher night-day accident ratios and costs than the average street in their category.
- The most favorable illumination level (based on minimizing accidents and costs) ranged from 0.8 to 1.8 horizontal foot-candles (8.6 to 19.4 lumen/sq. m).

The study data tend to suggest that either a low or high level of illumination led to higher accident ratios on urban arterial streets. Because the accident data were based only on one year of information and the study was limited to one city, the investigation should be repeated in other cities using a larger data collection period. Although the data could not be examined, it is possible that the sites with high illumination levels also had high accident ratios prior to increasing the level of illumination, and increasing the illumination level did not result in a further reduction in accidents.

14. **Box, Paul C., "Effect of Lighting Reduction on an Urban Major Route," No. 10, Vol. 46, Traffic Engineering, Institute of Transportation Engineers, Arlington, Virginia, October 1976.**

This investigation was conducted to determine the effect of illumination on accident frequency. One-year before and one-year after accident data were collected on a 2.5-mile (4.0-km) urban street located in Clearwater, Florida. The study section consisted of a six-lane divided facility with a median barrier carrying between 33,000 and 45,000 vehicles per day. In November 1974 alternate luminaires were turned off. This change reduced level of illumination from 1.8 to 0.9 horizontal foot-candles (19.4 to 9.7 lumen/sq. m) which was below the recommended level of 1.4 horizontal foot-candles (1.51 lumen/sq. m). The effect of the lighting reduction on accidents and accident severity is shown in Table 8 and 9. Overall night accidents increased 39.5 percent and night injury accidents increased 33 percent.

Although it is not possible to draw general conclusions based on one sample, the study results indicate that level of illumination has an effect on accident occurrence. Further investigation is needed to verify this hypothesis.

15. **Box, Paul C. and Associates, "Driveways," Chapter 5, Traffic Control & Roadway Elements, Highway Users Federation for Safety and Mobility, Washington, D.C., 1970.**

The purpose of this document was to synthesize the current state-of-the-art concerning the safety effects of driveways. Driveway accidents were reported to range from 6.5 percent of the accidents in Los Angeles County to 11.2 percent of the total accidents in Skokie, Illinois. A study conducted on a suburban route in Lafayette, Indiana revealed that accidents increased as the total number of driveways increased.

A detailed examination of the driveway accident data collected in Skokie, Illinois revealed that 70 percent of the driveway accidents involved vehicles making left-turns. Nearly 42 percent of all driveway accidents were rear-end crashes. The

Table 8. Accident comparison by intersection/midblock.

	Number of Accidents		
	Day	Night	Total
Before (1973)			
Intersection	187	44	231
Midblock	81	24	105
	268	68	336
After (1975)			
Intersection	182	52	234
Midblock	96	43	139
	278	95	373
Net Change			
Intersection	− 5	+ 8	+ 3
Midblock	+15	+19	+34
	+10	+27	+37
Change	+ 3.7%	+39.5%	+11%

Source: Box 1976, [14], Table 1, pg. 27.

Table 9. Accident comparison by severity.

	Number of Accidents		
	Day	Night	Total
Before (1973)			
Property Damage	192	47	239
Injury	76	21	97
	268	68	326
After (1975)			
Property Damage	209	67	276
Injury	69	28	97
	278	95	373
Change			
Property Damage	+ 9%	+42%	—
Injury	− 9%	+33%	—

Source: Box 1976, [14]. Table 2, pg. 27.

largest single group of accidents were rear-end crashes involving vehicles making a left-turn into a driveway.

Suggested countermeasures to reduce driveway related accidents include constructing a median storage lane to decrease rear-end crashes involving vehicles making a left-turn into a driveway, installation of two-way, left-turn median lanes; limiting the width of driveway openings, increasing sight distance at driveways, reducing speed differentials between through vehicles and those using driveways, providing sufficient spacing between driveways to avoid interference with traffic, and prohibiting on-street parking. Only a few of these suggested countermeasures have been evaluated under actual field conditions.

While the synthesis reveals that the number of driveways in an urban area has an influence upon the accident frequency, adequate documentation is not available to relate specific driveway designs to particular accident types or driver maneuvers. These data would be beneficial in optimizing driveway width, turning radii, and spacing to reduce accidents and increase operational efficiency.

16. Box, Paul C. and Associates, "Intersections," Chapter 4, Traffic Control & Roadway Elements, Highway Users Federation for Safety and Mobility, Washington, D.C., 1970.

This report provides a comprehensive summary of the studies conducted to examine the effects of intersection design and traffic control devices on accidents in rural and urban areas. Because intersection accidents in urban areas constitute approximately 41 percent of the total accidents and 39 percent of the fatal crashes, special attention was given to examining the effects of intersections on urban roadway accidents. A summary of accident relationships for specific geometric and traffic control features for intersections is given below.

Intersection Design

Studies conducted at intersections in Los Angeles and Richmond, California revealed that cross-type intersections had significantly higher accident frequencies than tee-type intersections.

Left-Turn Lanes

Studies conducted in Oregon, California, and Texas on rural and urban locations indicated that installation of left-turn lanes significantly reduced rear-end and left-turn type collisions.

Yield Signs

Generally, yield sign control has been found to be effective in reducing accidents at low volume, previously uncontrolled urban intersections. Accident reductions ranged from 23 to 52 percent.

Two-Way Stop Control

Analysis of accident data at 400 cross-type intersections in Los Angeles County with minor street volumes of 4,000 vehicles per day and major street volumes ranging up to 32,000 vehicles per day revealed that:

- accident rate increased as cross street volume increased, and
- accident rate decreased as major streets volume increased.

Only right-angle, left-turn, and rear-end type accidents were examined in this study.

Four-Way Stop Control

Generally four-way stop controls have been found to be effective in reducing accidents provided that traffic signal warrants were not met and the volumes on the intersection approaches were reasonably balanced. Analysis of before and after accident rates at 38 intersections in St. Paul, Minnesota with volumes ranging from 3,500 to 18,900 revealed a 56 percent reduction in accidents as a result of implement ing four-way stops instead of two-way stops. A 20 percent increase in the rear-end accident rates were reported, however, there was a 75 percent reduction in right-angle crashes, and a 67 percent reduction in fixed-object crashes. Accident reductions were found to be greater at intersections with unrestricted sight distances.

Traffic Signals

- A study of the effect of signalization on accidents at 599 intersections in 24 cities revealed that traffic signals reduced accidents an average of 20 percent, however, accidents increased at one-third of the intersections. There was an increase in rear-end accidents, a decrease in right-angle crashes, and increases in accidents at intersections where the accident frequency was 3 or fewer accidents before signalization.

- A study of 39 urban and rural intersections in Michigan indicated that accidents increased 23 percent but injuries and fatal accidents decreased by 20 and 50 percent, respectively. After the signals were installed rear-end accidents increased 200 percent, head-on accidents increased 157 percent, and sideswipe crashes increased 74 percent. Angle accidents decreased by 51 percent. It was further concluded, that signalization tends to increase accident rates at simple intersection designs, but decreases rates at complex locations.

- Another study of 52 urban and suburban intersections in Michigan showed an increase in accidents of 33 percent after signalization. The data revealed that rear-end accidents increased by 98 percent and left-turn accidents increased by 66 percent while right-angle accidents decreased by 45 percent.

- Factors which appear favorable to reducing accidents through traffic signalization are high traffic volumes, high accident frequency, and complex intersection layouts.

17. **Burritt, Benjamin E., and Eugene E. Coppola, "Accident Reductions Associated With Continuous Two-Way Left-Turn Channelization," Arizona Department of Transportation, Phoenix, Arizona, July 31, 1978.**

This investigation was conducted to examine the effect of two-way, left-turn median lanes on accidents. Seven projects ranging in length from 0.46 to 2.93 miles (0.74 to 4.71 km) were selected for study. Traffic volumes on the three- and five-lane sections varied between 8,500 and 23,000 vehicles per day. The study sections were located in urban areas in Arizona. An analysis of two-year before and two-year after accident data is summarized below.

- Total accidents were reduced by 35.9 percent.

- Rear-end accidents declined by 45.4 percent.

- Left-turn accidents decreased by 20.4 percent.

- Other accident types that were reduced included angle, sideswipe, parking, fixed-object, and pedestrian/bicycle related crashes.

- A benefit-cost ratio of 8.6 was reported.

The study supports the conclusion reached by other investigators that two-way, left-turn median lanes reduce traffic accidents, however, the effects of other variables on accidents such as driveways, signals, etc. were not included in the evaluation.

18. Caylor, Lamar N.C., "Two-Way, Left-Turn Lanes Versus Medians Study," Office of Materials and Research, Georgia Department of Transportation, Atlanta, Georgia, July 1977.

The objectives of this study were to develop criteria for selecting between a two-way, left-turn median lane and a nontraversable median and to determine the appropriate width of a two-way, left-turn median lane. The study findings were based on a literature survey and input from traffic engineers.

Guidelines developed for this report are substantiated by an analysis of data, including accident data, conducted by other researchers. The guidelines appear to be practical but rely upon the knowledge and experience of the user. Few quantitative criteria are given; consequently, considerable latitude exists in interpreting the criteria for any site specific situation. At least one guideline is in conflict with findings reported by others. The maximum width of a two-way, left-turn median lane should not be 16 feet (4.9 m) as suggested in the report. Median lanes wider than 14 feet (4.3 m) tend to encourage unsafe driving acts as motorists use the single lane as two lanes. Also the guidelines do not address specific geometric design features and their relationship to accidents.

19. Chapman, R.G., "Accidents on Urban Arterial Roads", <u>TRRL Laboratory Report 838</u>, Transport and Road Research Laboratory, <u>Crowthorne, Berkshire</u>, United Kingdom, 1978.

The relationships between roadway and environmental features and accident rates were examined on urban arterial roadways in four towns in southern England. The study included an examination of 1,015 personal injury accidents that were reported during 1972 on 101.8 km (63.3 miles) of two-lane and four- and six-lane dual roadways. The network was divided into 160 sections ranging in length from 200 to 1,000 meters (0.12 to 0.62 miles). Roadway features and traffic flow conditions were constant on each section. Traffic volumes ranged from 6,000 to 54,000 vehicles per day. The results of the study are summarized below.

- Pedestrians were involved in 25 percent of all accidents on arterial roads.
- Fifty-nine percent of the accidents were intersection related.
- Roadway sections in shopping areas had the highest accident rate (2.90 accidents/vehicle-km = 1.80 accidents/vehicle-mile).
- The accident rate on dual roadways (0.83 accidents/vehicle-km = 0.52 accidents/vehicle-mile) was one-half the rate for single roadways (1.55 accidents/vehicle-km = 0.96 accidents/vehicle-mile).
- Forty-two percent of all accidents occurred on just 18 percent of the arterial roadways.

It was concluded that a substantial reduction in accidents on arterial roads could be achieved by applying safety measures on a small part of the network.

Although the results of the study indicate that the type of roadside development may be related to accident injury rates, the relationship was not quantified. In fact, the data were not used to identify relationships between specific roadway elements and accidents. Also, the study revealed that most of the accidents occurred on a small part of the roadway network, however, neither site specific accident problems nor the roadway features associated with the high accident rates were identified. Several countermeasures were discussed to reduce accidents, however, an evaluation of these measures was not conducted.

20. Christie, A.W., "Street Lighting and Road Safety", <u>Traffic Engineering & Control</u>, Vol. 8, No.4, Printerhall Limited, <u>London, England, August, 1966</u>.

The purpose of this study was to examine the effects of lighting improvements on urban streets on traffic accidents. Before and after data were collected at 64 locations in England. The measure of effectiveness used to determine the effect of the lighting was the r ratio defined as shown below.

$$r = \frac{\dfrac{\text{darkness accidents after improvement}}{\text{darkness accidents before improvement}}}{\dfrac{\text{daylight accidents after improvement}}{\text{daylight accidents before improvement}}}$$

When $r = 1$, the lighting has no effect
If $r < 1$, darkness accidents have decreased
If $r > 1$, darkness accidents have increased

The following r ratios are based on data collected at the study sites.

Accident Type	r Ratio
Fatal	0.50
Serious injuries	0.67
Slight injuries	0.73
Total	0.70

With the exception of fatal accidents, the ratios were statistically significant at the $\alpha = 0.05$ level.

The study data reveal that there is a relationship between street illumination and accidents which is in agreement with the findings of other researchers, however, the author does not identify the level of lighting that is needed to favorably reduce accidents.

21. Clark, J.E. and P.D. Cribbins, "Traffic Volume Measurements Using Drivometer Events," Highway Research Record 230, Highway Research Board, Washington, D.C., 1968.

The purpose of the study was to determine if correlations exist between traffic events and volumes on urban arterial streets in Raleigh, North Carolina. The traffic events were measured every 0.1 mile (0.16 km) using a drivometer. The events recorded included travel time, change in speed, running time, steering wheel reversals, brake applications, accelerator applications, and direction of travel. Regression analysis was used to examine the relationship of these events to the traffic volume. The results of the study revealed the following points.

- The frequency of traffic events increased with increases in traffic volume.

- The combination of steering wheel reversals and brake applications can be used to estimate traffic volumes on an urban facility.

It should be noted that accident data were not collected for this investigation, thus no correlations between accident frequency and traffic events were reported. The results of the experiment are relevant to the current study because relationships between volume and brake applications, (two parameters which have been directly associated with accident occurrence) were established on an urban facility. The prediction equation developed as a result of the research is of little practical value because the number of steering reversals and brake applications are not easy to record except for a research investigation.

22. **Clayton, Mike E. and Robert C. Deen, "Evaluation of Urban Intersections Using Traffic Conflicts Measures," Division of Research, Kentucky Department of Transportation, Lexington, Kentucky, August, 1977.**

This study was conducted to analyze traffic hazards at two urban intersections using traffic conflicts and erratic maneuvers data. Conflicts and traffic volume data were collected for 11 hour periods at two intersections in Lexington, Kentucky. Analysis of the conflict data revealed that improvements including installation of left-turn lanes, three phase signals, and signs were necessary to reduce conflicts and improve traffic safety.

The authors provide an excellent overview of the procedure for using traffic conflicts to identify hazards at urban intersections. Unfortunately, the relationships between accidents and conflicts have not been developed, thus, it is not possible at the present time to use traffic conflicts to identify relationships between roadway features and accidents.

23. **Coleman, Robert R., "A Study of Urban Travel Times in Pennsylvania Cities," Highway Research Bulletin 303, Highway Research Board, Washington, D.C., 1961.**

The purpose of the study was to investigate methods that can be used to predict traffic congestion or vehicular delay at a given location based on site specific information. Travel time was selected as a measure of relative traffic congestion. Independent variables collected include volume, traffic control, street classification, percentage of heavy vehicles, street width, and area type. Data were collected on 15 urban roadway sections varying in length from 0.3 to 1.5 miles (0.48 to 2.40 km) in five cities in eastern Pennsylvania. Analysis of the study data lead to the following conclusions.

- Volume/capacity ratio can be used to estimate travel time on urban highways.
- Traffic volume and signal timing have major effects on travel time.
- Street width, percentage of heavy commercial vehicles, direction of flow, and area type have minor effects on travel time.
- Travel time along an urban highway section is directly proportional to the average number of traffic signals per mile on the section.

The analysis does not establish relationships between accident occurrence and traffic operational measures, however, it does provide links between several traffic parameters which have been shown by others to be related to accident frequency, i.e., traffic volume and signal density. Relating these measures to travel time suggests that travel time may also be an important variable in identifying accident problems on urban arterial highways.

24. Cribbins, P.D., J.M. Arey, and J.K. Donaldson, "Effects of Selected Roadway and Operational Characteristics on Accidents on Multilane Highways," Highway Research Record 188, Highway Research Board, Washington, D.C., 1967.

This study was conducted to determine the relationships between accidents and roadway features on rural and urban divided highways. Accident data covering the period January 1, 1963 to September 30, 1964 were collected on 92 sections consisting of 388 miles (624.3 km) of roadway in North Carolina. Sites with lengths less than one-half mile (0.80 km) were excluded from the study. The independent variables selected for the study are listed below.

- Access-point index
- Intersection openings per mile (per km)

- Signalized openings per mile (per km)
- Median openings per mile (per km)
- Median width
- Speed limit
- Volume
- Level of service

The access-point index was defined as the total estimated traffic volume at commercial and industrial sites. The level of service was defined as the travel time for a site divided by the site length. The dependent variables included total accidents and injury accidents. Multiple linear regression was used to examine the relationships between accident frequency and the site variables.

The major findings of the study are outlined below.

- A statistically significant correlation between total accidents and injury accidents was established.

- The number of injury accidents per mile (per km) was found to be significantly related to the following factors.

  a. access-point index, X1
  b. signalized openings per mile, X3
  c. speed limit, X6
  d. volume, X7
  e. level of service, X8

The regression equation developed is shown below.

$$Y = -28.34 + 0.00011(X1) + 3.28(X3) + 0.34(X6) + 0.0005(X7) + 7.35(X8)$$

The R^2 (explained variance) value was 0.685.

- The median opening accident rate was influenced by the following factors.

  a. access-point index,
  b. the number of intersections
  c. the number of signalized intersections
  d. the number of median openings

- Median width and speed limit had the least effect on median opening accident rate.

- It was estimated that 37 percent of the accidents were median related.

The study data indicate that accidents per mile (per km) on divided highways are influenced by the traffic volume at commercial and industrial establishments, traffic signals per mile (per km) and the speed limit. Unfortunately, urban and rural sites were combined in the data base, thus it is not possible to isolate specific factors related only to urban arterial highways.

25. **Cribbins, P.D., J.W. Horn, F.V. Beeson, and R.D. Taylor, "Median Openings on Divided Highways: Their Effect on Accident Rates and Level of Service," Highway Research Record 188, Highway Research Board, Washington, D.C., 1967.**

The purpose of this study was to investigate the relationship between median opening spacing on multilane divided highways and accidents. Roadside features and accident data were collected for the years 1963 and 1964 on 92 sections consisting of 388 miles (624.3 km) of roadway in North Carolina. The sites included rural and urban roadway sections.

The following regression equation was developed to predict the number of accidents per mile (per km) on divided highways.

$$Y_t = -0.479 + 0.006(X2) + 0.0099(X3) + 0.054(X4) + 0.166(X5) + 0.236(X6) + 0.027(X8) + 0.0688(X9) + 0.071(X10)$$

Where Y_t = log 10 of total accidents per mile (per km)

X_2 = width of median, in feet (m)

X_3 = posted speed limit, mph (kph)

X_4 = average daily traffic, in 1000's

X_5 = number of signalized intersections with left-turn storage facilities per mile (per km)

X_6 = number of signalized intersections without left-turn storage facilities per mile (per km)

X_8 = number of median openings without storage facilities per mile (per km), excluding intersections

X_9 = number of intersections with left-turn storage facilities per mile (per km)

X_{10} = number of intersections without storage facilities per mile (per km)

The R^2 (explained variance) value was 0.68 indicating that the independent variables explain 68 percent of the variance in the dependent variable, i.e., the number of accidents per mile (per km). The general findings indicate that traffic volume, roadside access, and frequency of median openings can be used to predict accident frequency.

Other significant findings of the study are outlined below.

- Rear-end collisions amounted to 33 percent of all accidents on four-lane divided highways.
- Fewer rear-end collisions occurred at median openings with storage lanes than at locations without storage lanes.
- As traffic volumes increase, median accidents increase.

Because the analysis contained both rural and urban sections, it is not possible to isolate specific roadway and accident relationships for urban arterial highways. The general findings, however, appear to be applicable to urban roads as evidenced by the results reported by other researchers. Application of the regression equations to estimate the differences in alternative highway designs does not appear to be practical due to the difficulty encountered in estimating assumed values of the independent variables.

26. **David, N.A., and J.R. Norman, "Motor Vehicle Accidents in Relation to Geometric and Traffic Features of Highway Intersections: Volume I - Executive Summary and Volume II - Research Report," prepared for Federal Highway Administration and the National Highway Traffic Safety Administration, Washington, D.C., June, 1975.**

The purpose of this investigation was to examine relationships between accidents and geometric intersection features and to identify countermeasures to reduce accidents or their severity. Accident data were collected at 558 urban and rural intersections in California for the three year period, January 1972 to 1974. The dependent variables investigated were the number of accidents and number of fatal and injury accidents per year per intersection. Intersections were grouped by similar geometry for analysis. The differences between mean accident rates for groups with and without certain design features were tested for significance. The results of the analyses are summarized below.

- As shown in Table 10, for any given traffic volume level, cross-type intersections have higher accident rates than tee type intersections and signalized cross-type locations have higher rates than stop controlled cross intersections. Fatal and injury rates (shown in parenthesis) are approximately similar for all intersection types.

- A summary of the study results is given in Table 11. Significant relationships between accidents and the following variables were found.

  a. turn lanes
  b. sight obstructions and alinement
  c. signlization
  d. street name signs
  e. delineation
  f. buses

Table 10. Average yearly accident rates.

ADT	Accident Rate**			
	Tee-Type		Cross-Type	
	Stop	Signal	Stop	Signal
< 5,000	1.3 (0.3)	--*	1.3 (0.3)	--
5,000 to 10,000	1.6 (0.4)	--	1.9 (0.4)	4.9 (1.1)
10,000 to 20,000	2.7 (0.7)	--	3.0 (0.7)	6.7 (1.7)
20,000 +	4.2 (1.2)	6.8 (1.8)	8.0 (1.1)	15.9 (3.7)

* Insufficient data.
** Accidents per intersection.

Source: David and Norman, 1975 [26], Table 2, pg.7.

Table 11. Relationship between accidents and geometric intersection features and traffic control.

Study Element	Conclusive Results	No Statistically Significant Results	Insufficient Sample for Analysis	Inconclusive Results
Intersection Geometry				
Throughwidth				X
Turning lanes	X			
Shoulders			X	
Dividers and curbs			X	
Obstructions and alignment	X			
Hazards				
Fixed objects		X		
Accesses		X		
Intersection Traffic Controls				
Signalization	X			
Signs and markings				
Street name signs	X			
Stop signs and pavement markings		X		
Pedestrian signs		X		
Delineation	X			
Parking				
Parking set-back		X		
Peak-hour prohibition		X		
Intersection Traffic				
Buses	X			
Routes				
Loading zones				
Trucks			X	
Bicycles		X		

Source: David and Norman, 1975 [26], Table 3, pg. 9.

- As illustrated in Table 12, the significant study findings are summarized below.

  a. Intersections with a traffic volume level greater than 15,000 and with obstructions within 20 feet (6.1 m) of the stop line have 5.3 more accidents per year than do intersections with unobstructed distances.

  b. High volume intersections with street signs with white letters on a dark background have an average of 5.1 more accidents per year than intersections having dark lettering on a white background.

  c. High volume intersections with storage lanes have higher average accident rates than intersections without storage lanes.

  d. Intersections without ceramic markers have higher accident rates than do intersections with the markers.

  e. High volume intersections without loading zone stops have lower accident rates than intersections with those stops.

  f. High volume intersections along bus routes have higher accident rates than intersections without bus routes.

  g. Intersections without left-turn only signalization have higher accident rates than intersections with the left-turn phase.

The potential effectiveness of several accident countermeasures were determined and are provided in Table 13.

The study provides evidence of relationships between accidents and specific geometric factors. However, not all of the findings appear to be explained by the data and additional study should be undertaken in some cases. For example, the color arrangement of the street sign does not appear in a practical sense to be a critical factor influencing the accident frequency. Also, using white letters on a dark background is not sanctioned by the Manual on Uniform Traffic Control Devices. Another example is the finding that intersections without left-turn storage lanes have lower accident rates than do intersections with left-turn lanes. This difference may be caused by a heavier left-turn volume and should not be interpreted to imply that removal of left-turn lanes will improve the accident frequency.

Table 12. Analysis results of relationships between accidents and intersection features and traffic control.

Study Element	ADT	Average Yearly Accidents/Intersection: Obstructed	Clear	Difference	Statistical Confidence (%)	Basis of Analysis
Sight-distance visibility	≤20 ft	1.5	1.3	0.2	99	All types of study intersections
	<5,000	2.3	1.9	1.0		
	5,000 to 10,000	4.1	3.2	0.9		
	10,000 to 15,000	11.4	6.2	5.3		
	>15,000	1.4	1.38	0.02		
	≤50 ft	2.2	1.9	0.3		
	<5,000	4.3	2.9	1.4		
	5,000 to 10,000	8.2	6.0	2.2		
	10,000 to 15,000					
	>15,000	1.4	1.3	0.1		
	≤100 ft	2.1	1.9	0.2		
	<5,000	4.0	2.8	1.2		
	5,000 to 10,000	8.7	4.8	3.9		
	10,000 to 15,000					
	>15,000					
		White Lettering on Dark Background (Reflectorized)	Dark Lettering on White Background (Non-reflectorized)			
Street-sign lettering and background	<5,000	1.3	1.4	<0.1>	99	All types of study intersections
	5,000 to 10,000	2.3	1.7	0.6		
	10,000 to 20,000	4.0	3.1	0.9		
	>20,000	10.4	5.3	5.1		

Source: David and Norman, 1975 [26], Table 4, pg. 10.

Table 12. Analysis results of relationships between accidents and intersection features and traffic control (continued).

Study Element	ADT	Accidents/Intersection/Year: With Storage Lanes	Without Storage Lanes	Difference	Statistical Confidence (%)	Basis of Analysis
Intersection geometry Left-turn storage lanes (exclusive of multiphase signals)	10,000 to 15,000 15,000 to 20,000 >20,000	5.9 7.8 16.2	3.5 5.4 10.1	2.4 2.4 6.1	99	Cross, two-phased signalized or stop-controlled intersections with one storage lane in each direction on one street
		With	Without			
Ceramic markers and retroreflectors	5,000 to 10,000 10,000 to 20,000	2.1 3.6	2.3 5.7	0.2 2.1	95	Cross-type (signalized or stop-controlled) intersections using some form of lane delineation
		With	Without			
Bus stops and routes Loading zones (stops)	< 5,000 5,000 to 10,000 10,000 to 15,000 15,000 to 25,000	1.4 2.4 4.4 8.3	1.4 2.0 3.5 4.3	0 0.4 0.9 4.0	95	Cross and Tee (signalized or stop-controlled) intersection on designated bus routes
		Along Bus Routes	No Bus Route			
Routes	< 5,000 5,000 to 10,000 10,000 to 15,000 15,000 to 25,000	1.4 2.4 4.3 7.0	1.3 1.9 2.7 3.8	0.1 0.5 1.6 3.2	95	All types of study intersections
		With	Without			
Signalization* Left-turn-only signal phase	< 15,000 >15,000	0.3 1.8	1.1 3.0	0.8 1.2	90	Cross- and Tee-type signalized intersections

*Figures relate to fatal injury accidents only.

Source: David and Norman, 1975 [26], Table 4, pg. 11.

Table 13. Effectiveness of accident countermeasures at intersections.

Measure	Application	Potential Accident Savings: ADT Range	Accidents Reduced/ Year	Confidence (%)	Annual* Savings in Injury Severity
Sight distance clear for:	All study-		0.2		$ 700
radius, 20 ft	intersection	<5,000	0	99%	--
radius, 50 ft	types		0.1		400
radius, 100 ft			1.0		3,700
		5,000 to 10,000	0.3	99	1,100
			0.2		700
			0.9		3,300
		10,000 to 15,000	1.4	99	5,100
			1.2		4,400
			5.3		19,400
		>15,000	2.2	99	8,100
			3.9		14,300
Street-name sign (white letters on dark background)	All study-intersection types	<5,000	0.1	99	--
		5,000 to 10,000	0.6		2,200
		10,000 to 20,000	0.9		3,300
		>20,000	5.1		18,700
Left-turn-only storage lane	Cross--two-phase signal or stop sign	10,000 to 15,000	2.4	99	8,800
		15,000 to 20,000	2.4		8,800
		>20,000	6.1		22,400
Ceramic markers and retro-reflectors	Cross--signal or stop sign	5,000 to 10,000	0.2	95	700
		10,000 to 20,000	2.1		7,800
Bus stops (relocate)	Cross and Tee--signal or stop sign, at near (approach) corner location	< 5,000	0.0	95	--
		5,000 to 10,000	0.4		1,500
		10,000 to 15,000	0.9		3,300
		15,000 to 25,000	4.0		14,700
Bus routes (abandon or relocate)	All study-intersection types	< 5,000	0.1	95	400
		5,000 to 10,000	0.5		1,800
		10,000 to 15,000	1.6		5,900
		15,000 to 25,000	3.2		11,700
Phase addition†--clear left turn	Cross and Tee--two-phase signal, actuated or fixed time	< 15,000	0.8	90	12,600
		>15,000	1.2		$18,900

†Fatal and injury accidents only.

Source: David and Norman, 1975 [26], Table 34, pg. 190.

27. **Federal Highway Administration, "Manual on Uniform Traffic Control Devices For Streets and Highways," prepared in cooperation with the National Advisory Committee on Uniform Traffic Control Devices, U.S. Government Printing Office, Washington, D.C., 1978.**

The purpose of this manual is to provide uniform standards for all signs, signals, markings and other devices placed on roadways to regulate, warn, or guide motorists.

Standards promogulated in the manual have been subjected to considerable review by professionals and are felt to have desirable effects on traffic efficiency and safety based on the best information available. The standards have and will continue to be revised as new research findings are developed. Many of the warrants are currently being re-evaluated.

28. **Federal Highway Administration, "Design of Urban Streets," Technology Sharing Report 80-204, prepared by JHK & Associates, Washington, D.C., January, 1980.**

The purpose of the textbook is to present a comprehensive review of urban street design. A large number of arterial street design features are discussed including intersection design, traffic signals, illumination, traffic signs and markings, and pedestrian facilities. Design criteria and some of the advantages and disadvantages of specific design elements are identified. One major objective of the course is to review existing facilities and to determine impacts on design standards and practices.

The textbook provides a clear concise review of current urban street design features, and suggests methods for evaluating the effectiveness of alternative designs. Use of the standards may be expected to improve operations and enhance safety.

29. **Fielding, Roy H. and Thomas E. Young, "Analysis of Flow on an Urban Thoroughfare", Highway Research Bulletin 107, Highway Research Board, Washington, D.C., 1955.**

The purpose of this study was to evaluate the effects of traffic signal modifications on accident frequency, traffic

volume, capacity, delay, and speeds on a 3.85-mile (6.19-km) section of four-lane urban arterial highway in Cincinnati. The study covered the period 1952 to 1954. As a result of traffic signal modifications including the installation of a new signal, increasing the cycle length, synchronizing the controls, and other changes such as restriping, installing parking signs, etc., the total number of accidents on the section decreased 3.5 percent (from 749 in 1952 to 723 in 1953). Accidents at signalized intersections decreased 21 percent, however, accidents at locations other than at traffic signals increased 22.6 percent. Dur-During the study period, traffic volumes increased from 10 to 15 percent, however, average trip times decreased 7.5 percent and speed increases ranged from 0.4 to 2.1 miles per hour (0.64 to 3.38 kph) i.e., average speeds increased from 19.5 to 21.1 miles per hour (31.3 to 34.0 kph).

This is one of the few studies where accident and operational data were collected at the same time following physical changes on an urban roadway. Unfortunately, no correlations or statistical inferences can be made from data collected at one site but the analysis indicates that reducing delay at signalized intersections can reduce accidents at the intersection. However, perhaps due to an increase in overall traffic speeds, accidents between intersections increased. Further testing is needed to examine this hypothesis.

30. **Fisher, John E. and Robert E. Camou, "The Safety Benefit of Arterial Street Widening," No. 10, Vol. 47, Transportation Engineering, Institute of Transportation Engineers, Arlington, Virginia, October 1977.**

This study consisted of collecting and analyzing geometric, accident, and volume data on 40 sections of urban arterial streets located in Los Angeles. Data were collected for a total of 31.5 miles (50.7 km) of roadway for a two-year before and two-year after period. The projects involved only street widening. The effects of the widening on accidents are shown in Table 14. The effect of roadway widening on accidents for each major category of street is also given in Table 15. The results of the analysis are outlined below.

- Street widening has a significant affect on accident frequency. The number of accidents as well as the number of injury accidents stratified by crash type was reduced an average of 21 percent following widening. Intersection

Table 14. Summary of arterial widening projects.

Stratification Category	Total Reported Accidents Before	After Actual	After Adjusted	Percent Change	Statistically Significant ?
A. Accident Location					
1. Signalized I/S	1,020	906	807	−21	Yes
2. Unsignalized I/S	269	238	215	−20	Yes
3. Midblock	849	753	665	−22	Yes
Total	2,138	1,897	1,687	−21	Yes
B. Accident Type					
1. Right-Angle	513	482	433	−16	Yes
2. Left-Turn	445	432	382	−21	Yes
3. Rear-End	503	387	341	−32	Yes
4. Fixed-Object	67	46	42	−37	Yes
5. Vehicle-Pedestrian	77	50	45	−42	Yes
6. Sideswipe	146	123	109	−25	Yes
7. Head-On	44	24	22	−50	Yes
8. Ran-Off-Road	102	70	64	−37	Yes
9. Parked-Vehicle	145	150	132	−09	No
10. Other	96	133	117	+22	Yes
Total	2,138	1,897	1,687	−21	Yes
C. Injury Accidents					
1. Percent (Injury & Fatal)	60	59	—	—	—
2. Rate (Inj.Acc./MVM)	3.08	2.41	—	−22	Yes
D. ADT Average	17,950	20,150	—	+12	—

Source: Fisher and Camou, 1977 [30], Table 1, pg. 25.

Table 15. Results of arterial street widening projects.

Project Category	Reported Accidents* (Injury Accident Rate) Before	After Actual	After Adjusted	Percent Change	Statistically Significant ?
Major Street (≥80 feet)	484 (2.27)	397 (1.74)	367 —	−24 (−23)	Yes (Yes)
Divided Major Street (≥80 feet)	300 (2.67)	258 (1.99)	217 —	−28 (−25)	Yes (Yes)
Secondary Street (66 feet)	256 (4.04)	200 (2.60)	178 —	−30 (−36)	Yes (Yes)
Secondary Street—Substandard Width (<66 feet)	206 (3.81)	245 (4.45)	244 —	+18 (+17)	Yes (No)
Jut-Out Elimination	892 (3.41)	797 (2.59)	681 —	−24 (−24)	Yes (Yes)
Total	2,138 (3.08)	1,897 (2.41)	1,687 —	−21 (−22)	Yes (Yes)

*Upper numbers refer to total reported accidents. Parenthesised lower numbers refer to the Injury Accident Rate (injury plus fatal accidents per million vehicle-miles).

Source: Fisher and Camou, 1977 [30], Table 2, pg. 26.

and midblock accidents were also reduced as a result of the widening.

- Significant reductions in accident frequency were found for projects where major streets were widened or divided and on secondary streets which were widened to 66 feet 20.1 m). An accident increase was reported on sections which were widened to a standard that did not permit two lanes of traffic in each direction.

The study results demonstrate that widening urban arterial streets can produce significant decreases in accident occurrence. The percentage reduction figures shown in Table 15 for each project can be used to estimate expected benefits for similar urban roadways, however, the results do not identify specific roadway features which may affect accident frequency.

31. **Foley, J.L., Jr., "Major Route Improvements", Special Report 93, Highway Research Board, Washington, D.C., 1967.**

The purpose of this article is to present the findings of before and after studies conducted to determine the effectiveness of street improvements. The major finding of the studies was that the presence of a median reduces accident frequency. The data for two of the study sites are given in Tables 16 and 17. A decrease in total accidents ranging from 23 to 35 percent was observed along with a reduction in injury accidents ranging from 18 to 39 percent.

The sample size (i.e., number of sites) is too small to warrant development of generalized conclusions. Furthermore, the effects of other factors, such as average daily traffic, number of driveways, etc. were not considered in the analysis.

32. **Frick, Warren A., "The Effect of Major Physical Improvements on Capacity and Safety", Traffic Engineering, Institute of Traffic Engineers, Arlington, Virginia, December 1968.**

This article documents the results of a comparative evaluation of two urban arterial projects implemented in the City of

Table 16. Street improvement for Druid Park Lake Drive.

Item	Before	After	Change (%)
Width*	40 ft.	Two 32-ft. (9.9 m) roadways plus 4-ft. (1.2 m) median	--
Average daily traffic	28,900	28,200	-2
Injury accidents	11	9	-18
Total accidents	39	30	-23

*Length of reconstruction, 1/2 mile (0.8 km).

Source: Foley, 1967 [31], Table 1, pg. 166.

Table 17. Street improvement for Skokie Boulevard.

Item	Before	After	Change (%)
Width*	56 ft. (17.4 km)	Two 36-ft. (9.9 m) roadways plus median	--
Total accidents	151	98	-35
Injury accidents	62	38	-39
Intersection accidents	59	75	+27
Midblock accidents	92	23	-75

*Length of widening, 1/2 mile (0.8 km).

Source: Foley, 1967 [31], Table 5, pg. 168.

Springfield, Illinois. In one case, a 1.9-mile (3.06 km) section of a two-lane roadway was widened to provide for four through lanes separated by a raised curbed median. In the other case, a 1.5-mile (2.41 km) section of two-lane highway was widened to provide for four through lanes separated by a continuous two-way, left-turn median lane. Accident data for the years 1966 and 1967 were collected and analyzed for the two sections. The study results revealed that the accident rate on the section with the curbed median was 434 accidents per 100 million vehicle-miles (per 160 million vehicle-km) of travel while the section with the two-way, left-turn median lane had a rate of 1,143. The author concluded that curbed medians and intersection channelization should be used for urban arterial street improvements.

There are a variety of factors including differences in the number of traffic signals, driveways, roadside development, etc. that may explain the difference in the accident rates on the study sections. Also the sample size (two sites) is too small to permit generalized conclusions, regarding the effectiveness of raised medians and continuous two-way, left-turn median lanes.

33. **Glauz, William D. and Donald J. Migletz, "Application of Traffic Conflict Analysis at Intersections", National Cooperative Highway Research Program Report 219, Transportation Research Board, Washington, D.C., February, 1980.**

The objective of this study was to develop a standard procedure for collecting traffic conflicts data at intersections. The scope of the study included a comprehensive state-of-the-art review, field testing at rural and urban intersections, and the development of a user's manual. The traffic conflict technique was recommended as a tool for diagnosing safety problems at intersections and for evaluating the effectiveness of countermeasures. A suggested list of countermeasures for reducing conflicts at intersections is given in Tables 18, 19 and 20.

There is some evidence given in the report and in the literature review, that a relationship exists between traffic conflicts and accidents. While the effects of specific urban roadway features on conflicts have been examined, it is not possible to relate specific roadway features to accidents using conflicts because the conflict-accident relationship has not been fully developed.

Table 18. Suggested improvements to reduce conflicts for signalized, 4-leg, 4-lane intersections.

Improvement	Same Direction (Rear-End): Left-Turn	Same Direction (Rear-End): Right-Turn	Same Direction (Rear-End): Slow Vehicle	Same Direction (Rear-End): Lane Change	Same Direction (Rear-End): Total Rear-End	Opposing Left-Turn	Right Turn Cross Traffic: From Left	Right Turn Cross Traffic: From Right	Left Turn Cross Traffic: From Left	Left Turn Cross Traffic: From Right	Thru Cross Traffic: From Left	Thru Cross Traffic: From Right	Pedestrian	Opposing RTOR
Left-Turn Bay	X			X		X								
Left-Turn Phase	X			X		X								
Left-Turn Restriction	X			X		X								
Right-Turn Bay		X		X										
Right-Turn Radius or Roadway		X		X			X	X						
Signal Cycle or Phase Length	X		X	X	X	X							X	
Actuated Signals								X	X	X	X	X		
Longer Amber or all Red Clearance					X			X	X	X	X	X		
RTOR Restrictions							X	X						X
Pedestrian Barriers													X	
Pedestrian Phase													X	
Add Lanes	X	X	X		X		X							
Parking Restrictions	X	X												
Install Median							X							
Improve Corner Sight Distance								X					X	
Speed Zone	X	X	X		X			X						
Advance Warning or Sight Distance Control	X	X	X	X	X			X						
Advance Street Name Sign	X	X	X	X	X									
Enforcement								X	X	X	X	X		

Source: NCHRP 219, Table 10, pg. 17.

Table 19. Suggested improvements to reduce conflicts for unsignalized, 4-leg, 2-lane intersections.

Improvement	Same Direction (Rear-End): Left-Turn	Same Direction (Rear-End): Right-Turn	Same Direction (Rear-End): Slow Vehicle	Same Direction (Rear-End): Lane Change	Same Direction (Rear-End): Total Rear-End	Opposing Left-Turn	Right Turn Cross Traffic: From Left	Right Turn Cross Traffic: From Right	Left Turn Cross Traffic: From Left	Left Turn Cross Traffic: From Right	Thru Cross Traffic: From Left	Thru Cross Traffic: From Right	Pedestrian
Add Signal	X	X			X				X	X	X	X	X
Left-Turn Bay	X					X							
Right-Turn Bay		X											
Right-Turn Radius or Roadway		X					X	X					
Pedestrian Barriers													X
Add Lanes	X	X	X		X		X						
Parking Restrictions	X	X											X
Improve Corner Sight Distance								X	X	X	X	X	X
Speed Zone	X	X	X		X			X	X	X	X	X	
Advance Warning or Sight Distance to Traffic Control	X	X	X		X			X					• -
Advance Street Name Sign	X	X	X		X								
Enforcement								X	X	X	X	X	

Source: NCHRP 219, Table 11, pg. 17.

Table 20. Suggested improvements to reduce conflicts for unsignalized, 3-leg, 2-lane intersections.

Improvement	Same Direction (Rear-End): Right Turn	Same Direction (Rear-End): Slow Vehicle	Same Direction (Rear-End): Lane Change	Same Direction (Rear-End): Total Rear-End	Right Turn Cross Traffic: From Right	Left Turn Cross Traffic: From Right	Pedestrian
Add Signal	X			X		X	X
Right-Turn Bay	X						
Right Turn Radius or Roadway	X				X		
Pedestrian Barriers							X
Add Lanes	X	X		X			
Parking Restrictions	X						X
Improve Corner Sight Distance					X	X	X
Speed Zone	X	X		X	X	X	
Advance Warning or Sight Distance to Traffic Control	X	X		X	X		
Advance Street Name Sign	X	X		X			
Enforcement					X	X	
RTOR Restrictions					X		

a/ Viewed from leg allowing thru and right-turn movements.

Source: NCHRP 219, Table 12, pg. 18.

34. **Glennon, John C. and Cathy J. Wilton, "Roadside Encroachment Parameters for Non-Freeway Facilities", Transportation Research Record 601, Transportation Research Board, Washington, D.C., 1976.**

The purpose of this study was to enlarge the applicability of the roadside hazard model developed in NCHRP Report 148 to enable the model to predict the effectiveness of roadside safety improvements on all classes of highway including urban arterial streets. Roadside hazards considered in the study consisted of the following obstacles; utility poles, trees, sign posts, light poles, traffic signal poles, railroad signal poles, curbs, guardrails, roadside slopes, ditches, culverts, drainage inlets, bridge abutments, piers, bridge rails, retaining walls, fences, and fireplugs. Speed limits on the streets ranged from 48 to 72 kph (30 to 45 mph). Accident data obtained from eight cities were used to develop the following equation for predicting the roadside accident rate for urban arterial streets.

$$Y = 0.474 + 0.000254\ (ADT)$$

For these data, the correlation coefficient r, was 0.608 and the standard error of the estimate was 2.570. Application of the developed roadside encroachment parameters in the hazard model revealed that little improvement can be expected by implementing roadside safety improvements on urban arterial streets.

Although the study findings suggest that roadside obstacles contribute to accident rates on urban highways, the sample size was small and the data were not developed to identify site specific situations, e.g., highway curves, sections with low skid resistance, etc. Further research is needed to develop hazard models for urban roadways that are sensitive to site specific parameters.

35. **Gupta, R.C. and R. Jain, "Effect of Certain Geometric Design Characteristics of Highways on Accident Rates for Two-Lane, Two-Way Roads in Connecticut", University of Connecticut, Storrs, Connecticut, August, 1973.**

This study was conducted to examine the relationships between geometric features and accident rates on rural and urban highways in Connecticut. Relationships were identified between accident rates and sufficiency rating variables which were considered proportional to roadway features. Multiple linear regression analysis was used to analyze the data. The analyses revealed the following results.

- On two-lane roadways with less than 12,000 vehicles per day, there is no significant relationship between roadway width and accident rate.
- The vertical clearance rating is not significantly related to accident rates.
- Urban roads carrying between 3,000 and 7,900 vehicles per day were found to have an increasing accident rate as the degree of horizontal curvature increases.
- Two-lane urban roads with restricted sight distances were found to have higher accident rates than sections with no sight distance deficiencies.

One of the limitations of the study is that roadway features ratings were used in the correlations instead of specific roadway variables. Whether or not it is appropriate to substitute ratings for geometric conditions is a point of debate. Consequently, the study findings should be accepted only with a considerable degree of caution and not as proof that certain relationships do or do not exist.

36. Hanna, John T., Thomas E. Flynn, and Webb L. Tyler, "Characteristics of Intersection Accidents in Rural Municipalities", Transportation Research Record 601, Transportation Research Board, Washington, D.C., 1976.

Accident and geometric data were collected and analyzed for 300 intersections in 42 towns in Virginia which had an average population of 15,000 persons. Accident data were collected at each site for a 24-month period during the study years 1969 through 1973. The following pertinent results were obtained from the analysis.

- As shown in Table 21, intersections with traffic signals had higher accident rates than intersections with stop and yield sign control.
- Intersections with poor driver sight distance had a higher than normal accident rate, particularly with regard to angle collisions as noted in Table 22.

Table 21. Summary of accidents by intersection geometrics.

Intersection Type[b]	Number	Rear End Number	Rear End Percent	Angle Number	Angle Percent	Sideswipe Number	Sideswipe Percent	Other Number	Other Percent	Total	Average Accident Rate[a]
Four-way											
Signalized	52	379	40	384	40	105	11	79	9	947	1.47
STOP or YIELD sign control	66	125	22	340	59	55	10	50	9	570	1.27
Total	118	504	33	724	48	160	11	129	8	1517	1.35
T-type											
Signalized	12	68	58	30	25	13	11	7	6	118	0.82
STOP or YIELD sign control	48	72	28	109	43	30	12	44	17	255	0.79
Total	60	140	38	139	37	43	11	51	14	373	0.80
Offset											
Signalized	3	3	42	0	0	2	29	2	29	7	0.40
STOP or YIELD sign control	9	16	34	14	30	6	13	11	23	47	0.76
Total	12	19	35	14	26	8	15	13	24	54	0.58
Y-type											
Signalized	1	10	42	7	29	6	25	1	4	24	1.40
STOP or YIELD sign control	14	68	66	24	23	4	4	7	7	103	1.04
Total	15	78	61	31	25	10	8	8	6	127	1.22

[a] Accidents per million entering vehicles. [b] Accidents for miscellaneous intersection geometrics not summarized.

Source: TRR 601, Table 2, pg. 80.

Table 22. Summary of accidents at intersections with severe grades and poor sight distance.

Intersection Condition	Number	Rear End Number	Rear End Percent	Angle Number	Angle Percent	Sideswipe Number	Sideswipe Percent	Other Number	Other Percent	Total	Average Accident Rate[a]
Severe grades	35	106	39	104	38	24	9	37	14	271	0.97
Poor sight distance	41	73	20	207	56	32	9	54	15	366	1.33

[a] Accidents per million entering vehicles.

Source: TRR 601, Table 5, pg. 81.

- The frequency of night accidents did not appear to be a function of traffic control or intersection geometrics.

- Intersections with severe grades appear to operate safely in spite of potential hazards as shown in Table 22.

The study data revealed that the type of intersection control and poor sight distance affect accident rates at intersections located on urban highways in small cities. The researchers, however, did not attempt to quantify these relationships so that the results could be used to estimate the effectiveness of specific countermeasures.

37. Head, J.A., "Predicting Traffic Accidents from Roadway Elements on Urban Extensions of State Highways", Highway Research Bulletin 208, Highway Research Board, Washington, D.C., 1959.

The purpose of the study was to develop equations that could be used to predict accidents on urban highways using, as independent variables, site specific data such as average daily traffic, number of driveways, intersections, signalized intersections, posted speed limit, pavement width and number of lanes. Accident and roadway features data were collected on two- and four-lane urban highways in Oregon. Accident data for the years 1954 and 1955 were used in the analysis. Data were collected for 426 sections; a total of 186.4 miles (299.9 km) of highway. Section lengths ranged from 0.1 mile to 2.1 miles (0.16 km to 3.38 km) with an average length of 0.4 mile (0.64 km). The following variables were collected during the field investigations.

- Commercial units (CU)
- Commercial driveways (CDW)
- Residential units (RU)
- Residential driveways (RDW)
- Intersections (INT)
- Traffic signals (SIG)
- Channelized intersections (CI)
- Indicated speed (SP)
- Pavement width (PA)
- Shoulder width (SH)
- Number of lanes
- Median width
- Effective lane width (ELA)

The study sections, aggregated by average daily traffic range, area type, and number of lanes are summarized in Table 23.

Table 23. Distribution of study sections by number of lanes, average daily traffic ranges and culture type.

ADT Range	Area of Culture	Number of Sections	Total Length of Sections (mi)	Average Length of Sections (mi)
		2 Lanes		
Under 5,000	Urban	130	45.2	0.3
	Suburban	35	17.6	0.5
	Corporate	95	27.6	0.3
	Business	30	-	-
	Residential	46	-	-
	Mixed	54	-	-
5,000 - 9,999	Urban	140	54.8	0.4
	Suburban	33	18.8	0.6
	Corporate	107	36.0	0.3
	Business	52	-	-
	Residential	33	-	-
	Mixed	55	-	-
10,000 and over	Urban	26	18.6	0.7
	Suburban	2	1.1	0.5
	Corporate	24	17.5	0.7
	Business	11	-	-
	Residential	5	-	-
	Mixed	10	-	-
All	Corporate Portland	22	15.8	0.7
	Corporate Non-Portland	204	66.0	0.3
		4 Lanes		
Under 9,000	Urban	54	16.4	0.3
	Suburban	9	3.7	0.4
	Corporate	45	12.7	0.3
	Business	35	-	-
	Residential	8	-	-
	Mixed	11	-	-
9,000 - 17,999	Urban	50	31.2	0.6
	Suburban	17	12.2	0.7
	Corporate	33	19.0	0.6
	Business	29	-	-
	Residential	3	-	-
	Mixed	18	-	-
18,000 and over	Urban	26	20.0	0.8
	Suburban	5	2.8	0.6
	Corporate	21	17.2	0.8
	Business	20	-	-
	Residential	3	-	-
	Mixed	3	-	-
All	Corporate Portland	32	25.6	0.8
	Corporate Non-Portland	67	22.6	0.3

Source: HRB 208, Table 1, pg. 48.

Correlation coefficients, computed for the accident rates for each of the independent variables are given in Table 24.

The authors recognized that study sections with various lengths could bias the results by giving disproportionate consideration to short lengths and little consideration to long sections. The sections were normalized to account for length variations and the correlations for these data are given in Table 25.

The authors found that "In general, very little benefit was realized by adjusting the study sections to compensate for the varying length of the sections".

Finally, multiple correlation coefficients were computed between roadway features data and accident rates and these coefficients are given in Table 26.

Equations that can be used to predict accident rates on two- and four-lane urban roadways for site specific conditions are given below.

- <u>Two-Lane, 5,000 - 9,999 ADT</u>

  A = -7.54 + 0.09 ADT + 0.12 CU + 0.36 INT + 0.94 SIG + 0.06 SP - 0.01 PA

- <u>Two-Lane, 10,000 or over ADT</u>

  A = -18.21 + 0.09 ADT + 0.25 CU + 0.07 CDW + 0.41 INT + 3.87 SIG - 0.16 SP

- <u>Four-Lane, Under 9,000 ADT</u>

  A = 4.60 + 0.07 CU + 6.78 SIG

- <u>Four-Lane, 9,000 - 17,999 ADT</u>

  A = 7.93 + 0.04 CU + 0.03 INT + 2.70 SIG - 0.10 SP + 0.05 PA

- <u>Four-Lane, 18,000 or over ADT</u>

  A = 1.79 + 0.18 ADT + 0.04 CU + 0.23 INT + 0.80 SIG - 0.70 SP - 0.09 PA

The following symbols were used in the equations.

A = Accidents per million vehicle miles (per million vehicle km).

Table 24. Zero order correlations between accident rates and roadway elements.

Study Group	ADT	CU	CDW	RU	RDW	D/T	SG	SP	PA	ELA
	Accident Rate - Roadway Elements Correlations									
2 Lane, Under 5,000 ADT										
Urban	0.03	0.26	0.12	-0.06	-0.14	0.04	0.06	-0.08	0.37	0.22
Suburban	0.06	-0.10	-0.06	-0.11	-0.10	-0.06	[1]	0.32	0.13	0.30
Corporate	0.03	0.33	0.20	-0.08	-0.15	0.01	0.04	-0.08	0.37	0.20
Business	-0.03	0.20	0.10	-0.27	-0.25	-0.06	-0.02	-0.10	0.40	0.27
Residential	0.04	0.19	0.06	0.30	-0.01	-0.03	0.03	-0.13	0.32	0.28
Mixed	0.07	-0.03	-0.08	-0.03	-0.18	0.16	0.28	0.11	0.21	0.00
2 Lane, 5,000 - 9,999 ADT										
Urban	0.33	0.66	0.26	-0.15	-0.18	0.45	0.40	-0.32	0.30	0.10
Suburban[2]										
Corporate	0.32	0.71	0.24	[3]	[3]	0.42	0.40	-0.35	0.30	0.16
2 Lane, 10,000 and over, ADT										
Urban	0.43	0.67	0.44	-0.07	-0.11	0.53	0.89	-0.44	0.37	0.02
Suburban[2]										
Corporate	0.44	0.67	0.46	[3]	[3]	0.51	0.89	-0.41	0.37	0.02
2 Lane, 5,000 and over ADT										
Suburban	0.10	0.15	0.41	0.04	0.06	0.52	[1]	-0.02	0.16	0.28
Business	0.47	0.67	0.13	0.07	0.06	0.55	0.78	-0.38	0.42	0.12
Residential	0.45	0.02	-0.00	0.32	0.15	0.77	0.01	0.06	0.10	-0.02
Mixed	0.40	0.46	0.23	0.35	0.22	0.64	0.27	-0.20	0.42	0.00
2 Lane, All ADT's										
Corporate Portland	0.54	0.60	0.60	[3]	[3]	0.53	0.87	-0.30	0.35	-0.17
Corporate Non-Portland	0.10	0.47	0.21	-0.08	-0.16	0.18	0.27	-0.20	0.27	0.22
4 Lane, Under 9,000 ADT										
Urban	0.06	0.30	0.20	-0.13	0.04	0.13	0.79	-0.11	0.07	-0.18
Suburban[2]										
Corporate	0.14	0.42	0.20	-0.17	0.03	0.11	0.80	-0.06	-0.08	-0.21
Business	0.03	0.36	0.12	0.12	0.20	0.12	0.81	-0.00	0.03	-0.23
Residential & Mixed	0.07	-0.11	0.01	-0.20	0.26	-0.04	0.56	0.20	0.20	-0.06
4 Lane, 9,000 - 17,999 ADT										
Urban	0.27	0.62	0.30	0.00	-0.02	-0.28	0.78	-0.45	0.35	0.06
Suburban[2]										
Corporate	0.24	0.30	0.18	[3]	[3]	0.17	0.78	-0.41	0.26	0.04
4 Lane 18,000 & over ADT										
Urban	0.60	0.66	0.20	0.27	0.18	0.51	0.71	-0.72	0.57	0.40
Suburban[2]										
Corporate	0.64	0.60	0.30	[3]	[3]	0.33	0.72	[illegible]	0.40	0.50
4 Lane, 9,000 & over ADT										
Business	0.40	0.66	0.14	0.11	-0.10	0.30	0.78	-0.54	0.36	0.14
Residential & Mixed	0.67	0.40	0.24	0.37	0.19	0.51	0.74	-0.38	0.66	0.07
4 Lane, All ADT's										
Suburban	-0.02	0.35	0.00	0.27	0.32	0.60	0.62	-0.26	0.52	0.17
Corporate Portland	0.64	0.58	0.20	[3]	[3]	0.27	0.78	-0.40	0.40	0.44
Corporate Non-Portland	0.19	0.47	0.23	-0.17	-0.01	0.12	0.71	-0.17	-0.07	-0.18

Note: Roadway elements considered for regression equations are underlined.

[1] Insufficient sample to compute simple correlation.
[2] Insufficient sample sections for computation of reliable regression equations. Data combine with other ADT ranges.
[3] Preliminary analyses indicated low correlations, therefore, computations were not completed.

Source: HRB 208, Table 2, pg. 49.

Table 25. Zero order correlations between accident rates and roadway elements normalized to account for segment length variations.

Study Group	Accidents - Roadway Elements Correlations									
	ADT	CU	CDW	RU	ADW	DFT	SIG	SP	PA	SLA
2 Lane, Under 5,000 ADT										
Suburban	0.01	-0.20	-0.22	-0.24	-0.19	-0.01	[1]	0.41	0.43	0.60
Corporate	-0.14	0.18	0.15	[1]	[1]	0.07	0.04	-0.08	0.27	0.03
2 Lane, 5,000 - 9,999 ADT										
Corporate	0.35	0.77	0.34	[2]	[2]	0.44	0.50	-0.32	0.46	0.22
2 Lane, 10,000 & over ADT										
Corporate	0.32	0.76	0.50	[2]	[2]	0.66	0.80	-0.64	0.62	0.17
2 Lane, 5,000 & over ADT										
Suburban	0.08	0.26	0.41	0.00	0.06	0.66	0.34	-0.07	0.22	0.38
2 Lane, All ADT's										
Corporate Portland	0.29	0.68	0.42	[2]	[2]	0.60	0.66	-0.56	0.30	-0.20
Corporate Non-Portland	0.09	0.46	0.26	[2]	[2]	0.24	0.36	-0.24	0.20	0.19
4 Lane, Under 9,000 ADT										
Corporate	0.05	0.63	0.20	-0.13	0.06	0.12	0.70	-0.34	-0.12	-0.36
4 Lane, 9,000 - 17,999 ADT										
Corporate	0.34	0.71	0.30	[2]	[2]	0.47	0.82	-0.58	0.32	0.03
4 Lane, 18,000 & over ADT										
Corporate	0.54	0.71	0.53	[2]	[2]	0.52	0.79	-0.73	0.52	0.30
4 Lane, All ADT's										
Suburban	-0.08	0.37	0.07	0.62	0.52	0.67	0.48	-0.48	0.64	0.19
Corporate Portland	0.48	0.71	0.54	[1]	[1]	0.54	0.81	-0.83	0.54	0.30
Corporate Non-Portland	-0.20	0.31	0.18	[2]	[2]	0.06	0.34	-0.18	-0.13	-0.38

Note: Roadway elements considered for regression equations are underlined.
[1] Insufficient sample to compute simple correlation.
[2] Insufficient sample sections for computation of reliable regression equations. Data combine with other ADT ranges.

Source: HRB 208, Table 3, pg. 50.

Table 26. Multiple correlations between roadway elements and accident rates.

Study Group	Best Predictors	Coefficient of Multiple Correlation: Un-Weighted	Coefficient of Multiple Correlation: Weighted	Standard Error of Estimate: Un-Weighted	Standard Error of Estimate: Weighted	Ratio of Standard Error of Estimate to the Mean: Un-Weighted	Ratio of Standard Error of Estimate to the Mean: Weighted
2 Lane, Under 5,000 ADT							
Urban	[1]	[1]	[2]	[1]	[2]	[1]	[2]
Suburban	(RU), (SP), (ELA)	0.37	0.52	5.28	8.85	1.57	1.34
Corporate	CU, PA	0.30	[2]	17.43	[2]	1.74	[2]
Business	[1]	[1]	[2]	[1]	[2]	[1]	[2]
Residential	RU, PA	0.55	[2]	6.78	[2]	1.11	[2]
Mixed	[1]	[1]	[2]	[1]	[2]	[1]	[2]
2 Lane, 5,000 - 9,999 ADT							
Urban	ADT, CU, INT, SIG, SP, PA	0.74	[2]	6.44	[2]	0.60	[2]
Suburban[3]							
Corporate	(ADT), (CU), (CDW), (INT), (SIG), (SP), (PA)	0.75	0.82	6.82	6.11	0.68	0.62
2 Lane 10,000 & over ADT							
Urban	ADT, CU, CDW, INT, SIG, SP	0.80	[2]	8.07	[2]	0.42	[2]
Suburban[3]							
Corporate	(ADT), CU, (CDW), (INT), (SIG), (SP), (PA)	0.80	0.93	7.98	5.44	0.30	0.36
3 Lane, 5,000 & over ADT							
Suburban	(CDW), (INT), (SIG), (ELA)	0.64	0.75	3.58	2.95	0.58	0.44
Business	ADT, CU, INT, SIG, SP, PA	0.86	[2]	8.25	[2]	0.53	[2]
Residential	ADT, RU	0.49	[2]	4.58	[2]	0.64	[2]
Mixed	ADT, CU, RU, INT, PA	0.89	[2]	5.25	[2]	0.62	[2]
3 Lane, All ADT's							
Corporate Portland	(ADT), (CU), (CDW), (INT), (SIG), (SP), (PA)	0.92	0.91	7.08	5.48	0.37	0.36
Corporate Non-Portland	(CU), PA	0.48	0.46	13.29	14.28	1.20	1.38
4 Lane, Under 9,000 ADT							
Urban	CU, SIG	0.84	[2]	7.75	[2]	0.50	[2]
Suburban[3]							
Corporate	(CU), (SIG), (SP), (ELA)	0.86	0.80	7.87	6.17	0.57	0.40
Business	CU, SIG	0.90	[2]	8.60	[2]	0.56	[2]
Residential & Mixed	[1]	[1]	[2]	[1]	[2]	[1]	[2]
4 Lane, 9,000 - 17,999 ADT							
Urban	CU, INT, SIG, SP, PA	0.81	[2]	5.95	[2]	0.42	[2]
Suburban[3]							
Corporate	(ADT), (CU), (CDW), (INT), (SIG), (SP)	0.78	0.88	8.60	4.55	0.60	0.28
4 Lane, 18,000 & over ADT							
Urban	ADT, CU, INT, SIG, SP, PA	0.80	[2]	6.30	[2]	0.30	[2]
Suburban[3]							
Corporate	(ADT), (CU), (CDW), (INT), (SIG), (SP), (PA)	0.88	0.92	6.80	5.33	0.25	0.25
4 Lane, 9,000 & over ADT							
Business	ADT, CU, INT, SIG, SP, PA	0.87	[2]	6.30	[2]	0.32	[2]
Residential & Mixed	ADT, CU, INT, SIG, PA	0.88	[2]	4.78	[2]	0.35	[2]
4 Lane, All ADT's							
Suburban	(CU), RU, (RDW), (INT), (SIG), (SP), (PA)	0.90	0.88	3.58	3.40	0.34	0.33
Corporate Portland	(ADT), (CU), (CDW), (INT), (SIG), (SP), (PA)	0.84	0.90	7.37	5.28	0.38	0.28
Corporate Non-Portland	(ADT), (CU), (SIG), (ELA)	0.74	0.58	9.33	31.92	0.63	1.40

Note: Best predictors underlined for unweighted, parenthesis for weighted.
[1] No prediction equations computed because the zero order correlations indicated insignificant correlations.
[2] No prediction equations computed.
[3] Insufficient sample sections for computation of reliable regression equations.

Source: HRB 208, Table 4, pg. 51.

ADT = The average daily traffic divided by 100.
CU = The number of commercial units per mile (per km).
CDW = The number of commercial driveways per mile (per km).
INT = The number of intersections per mile (per km).
SIG = The number of traffic signals per mile (per km).
SP = The indicated speed in mph (kph).
PA = The pavement width in feet (m).

The number of commercial units and the number of traffic signals were found to be significantly related to accident rate. Also, the following factors were related to accident rates: number of intersections, the indicated speed, average daily traffic, and pavement width.

The following roadway elements do not appear to be related to accidents: number of commercial driveways, residential units, residential driveways, and effective lane width.

Accident rates were found to increase when:

- The number of commercial units increase.
- The number of traffic signals increase.
- The number of intersections increase.
- Indicated speed decreases.
- Average daily traffic increases.
- Pavement width increases.

The findings presented in this paper clearly illustrate that there are relationships between geometric and traffic variables and accident rates on urban roadways. The coefficients of determination for the equations ranged from 0.55 to 0.79 which indicates that from 45 to 21 percent of the variance in the accident rates is not explained by the independent variables. These values were within limits achieved by other researchers and may be the maximum correlations that can be obtained using accident data. An advantage to using the equations is that the independent variables are easy to measure.

38. **Heimbach, Clinton, L., and Harold D. Vick, "Relating Change of Highway Speed Per Unit of Time to Motor Vehicle Accident Rates", Highway Research Record 225, Highway Research Board, Washington, D.C. 1968.**

The purpose of this study was to investigate the relationship between acceleration noise (change of speed per unit time) and accident rates on rural and urban highways. Two of the six study sites were located in Raleigh, North Carolina. Each site was homogeneous in traffic and geometric characteristics. Accident rates were computed for the years 1963 to 1965. Acceleration noise measurements were made by having five drivers operate a test car over the study sites under a variety of traffic conditions. The results of a rank-order pairing of acceleration noise and accident rates for the sites are shown in Table 27. While no statistical analysis was employed there was a consistent relationship between acceleration noise and accident rate, i.e., sites with higher values of acceleration noise also had higher accident rates.

Acceleration noise has been described as a traffic parameter that is directly related to road conditions, congestion, and the hazards encountered when driving on a highway. The significance of this research is that it provides some empirical evidence that acceleration noise may be directly related to accident rates. While the study data suggest a link between acceleration noise and accidents, additional research is needed to quantify this relationship for urban roadways.

39. **Hoffman, Max R., "Two-Way, Left-Turn Lanes Work!", <u>Traffic Engineering</u>, Vol. 44, No. 11, Institute of Traffic Engineers, Arlington, Virginia, August 1974.**

This study was conducted to determine the effectiveness of two-way, left-turn median lanes. A one-year before and one-year after analysis of accident data collected at four projects in Michigan was conducted. At each of the study sites, the existing four-lane undivided roadways were widened to permit a center lane for left-turns. The total length of the four projects was 6.58 miles (10.59 km). Traffic volumes on the sections ranged from 15,000 to 30,000 vehicles per day. Analysis of the accident data lead to the following results.

- Total accidents decreased by 33 percent.
- Injury accidents decreased by 41 percent.
- Rear-end accidents decreased 62 percent, and head-on left-turn crashes were reduced by 45 percent.

Although the author examined the overall effect of two-way, left-turn median lanes on accidents, injuries, and collision type, the study period was limited to a one-year before and after study and other factors such as driveways, traffic signals, etc. were not considered in the analysis. The data, however, suggest that two-way median lanes may have a beneficial effect on reducing accidents on urban arterial roadways.

Table 27. Comparison of acceleration noise vs. mean absolute change of speed by highway facility.

Facility	Average Daily Traffic	Accident Rate per MVM	Absolute 2-mph Speed Change Distribution		Acceleration Noise σ	
			Mean $\bar{a}$	Std. Dev. s	2-mph Speed Changes per 60 sec	ft/sec^2
Hillsborough St.	15,000	12.64	28.21	13.58	31.48	1.54
Western Blvd.	17,000	5.96	20.27	14.14	24.84	1.31
NC 54	3,000	2.90	13.04	6.62	14.64	0.72
US 70	12,000	1.45	9.18	4.22	10.12	0.40
SR 1002	1,500	3.20	8.42	5.56	10.10	0.40
Beltline	10,000	0.73	5.88	2.94	6.58	0.33

Source: HRR 225, Table 12, pg. 56.

40. **Holbrook, L.F., "Prediction of Wet Surface Intersection Accidents From Weather and Skid Test Data", <u>Transportation Research Record 623</u>, Transportation Research Board, Washington, D.C., 1976.**

The purpose of this study was to develop a model to estimate wet pavement accidents at intersections based on skid number, wet time, and seasonal weather effects. Accident, skid, and weather data were collected for 2,000 rural and urban intersections on state highways in Michigan. The data were analyzed by employing a nonlinear least squares computer program. The results of the analysis produced the following conclusions.

- Surface wet time and skid number are important factors in wet pavement accident involvement.
- Below a skid value of 30, wet pavement accident involvements increase as the pavement friction decreases.
- The amount of time the pavement is wet during the month has a significant effect on wet pavement accident occurrence.
- Skid numbers alone will not lead to development of a plan which would optimally reduce wet surface accidents.

The study data indicate that wet pavement accidents are greatly influenced by the amount of time the pavement is wet and the skid number. Although the data were collected for rural and urban intersections, no distinction was made in the analysis between the effects of rural versus urban conditions. Consequently, it has not been determined whether the results apply to urban locations.

41. **Humphreys, Jack B., Donald J. Wheeler, Paul C. Box, and T. Darcy Sullivan, "Safety Considerations in the Use of On-Street Parking", <u>Transportation Research Record 722</u>, Transportation Research Board, Washington, D.C., 1979.**

The purpose of this study was to examine the relationships between accidents reported on urban streets and parking configurations, land use, street width, and street classification. Roadway and accident data were collected for 170 miles (273.5 km) of urban roadways located in 10 U.S. Cities. The accident data covered a period of two years. The analysis of variance statistical technique was used to examine differences in mean accident rates based on the independent variables selected for testing. The findings of the study are listed below.

- Parking use (turnover) has the greatest effect on accident rate, i.e., as the parking use increases, the accident rate increases up to approximately 1.0 million space hours per kilometer per year as shown in Figure 3.

- Accident rates were lowest on roadway sections where parking was prohibited.

- The prohibition of on-street parking where the space use is approximately 300,000 hours per kilometer per hour could reduce midblock accident rates by 19 percent. Where space usage is 600,000 hours per kilometer per year midblock accident rates could be reduced by 75 percent.

- For 300,000 space hours of use, total urban accident rates could be reduced by 8 percent and for 600,000 hours of use the reduction could be up to 30 percent.

- Parking configuration, i.e., parallel, angle, etc. did not have an effect on accident rate.

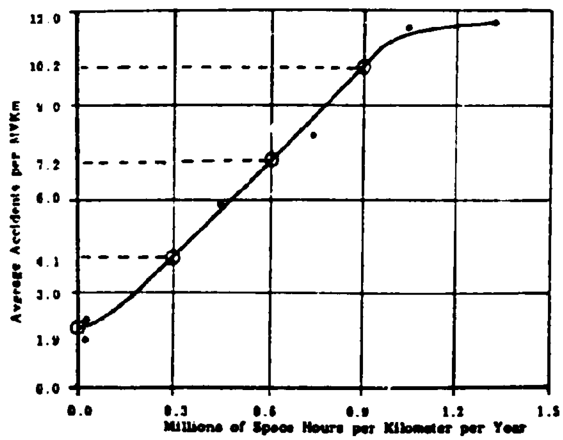
- Accident rates generally increased with changes in roadside development, i.e., residential, office, and retail land use.

- Parking related accidents at midblock locations accounted for 49 percent of all accidents on major urban streets, 68 percent on collector streets, and 72 percent on local streets.

This study presents the results of the most comprehensive investigation of accidents and parking characteristics undertaken to-date. Parking turnover and land use have a significant effect on urban roadway accidents while parking configuration did not affect accident experience. Based on turnover rates, i.e., space hours of use, accident reduction factors that can be used to estimate the impact of removing parking on arterial streets have been developed and should receive widespread use by traffic and safety officials.

42. ITE Technical Council Committee 5-S, "Guidelines For Urban Major Street Design: Tentative Recommended Practice - A Summary", ITE Journal, Vol. 48, No. 9, Institute of Transportation Engineers, Arlington, Virginia, September, 1979.

The guidelines were prepared to supplement design standards given in the 1973 AASHO Policy on Design of Urban Highways and



Source: TRR 722, Figure 3, pg. 32.

Figure 3. Accident rate vs. parking use on major streets for all land uses.

Arterial Streets. Both a minimum design value, the least value felt necessary to produce a safe and functional street, and a desirable design value, the condition worth obtaining if there are no severe constraints, are given in the guidelines. The values were determined through a consensus of professional opinion of operations, design, and planning engineers. The geometric design standards pertain only to major urban arterial steets, excluding freeways, expressways, and local urban streets.

The guidelines appear to present a practical state-of-the-art synthesis of design criteria for major arterial streets, however, many of the dimensions suggested are based on little or partial research findings. Further research identifying relationships between accidents and specific geometric design features is needed to supplement or modify the guidelines for future use.

43. **Jones, Ian S. and A. Stephen Baum, "Analysis of the Problem of Urban Utility-Pole Accidents," Transportation Research Record 681, Transportation Research Board, Washington, D.C., 1978.**

A study of urban utility pole accidents was undertaken using 1975 accident data on roadways in 20 urban areas. In a sample of 6,124 accidents, utility poles were found to be the most frequent (21.1 percent) type of fixed object struck in single-vehicle, run-off-the-road accidents. Approximately 2.2 percent of all accidents in urban areas involved impacts with utility poles and utility pole accidents had the highest percentage (50.5 percent) of injury accidents of all fixed object crashes. The data suggest that as vehicle speeds increase, the percentage of utility pole accidents increases. Also the number of utility pole accidents were also found to be a function of the relative density of utility poles in an area. As pole spacing increased, the frequency of utility pole accidents was found to decrease. Utility pole accidents were also found to be a function of the distance the pole is located from the roadway. The proportion of utility pole accidents is high at low offsets, i.e., less than 5.5 feet (1.68 m) from the roadway, however, beyond 5.5 feet (1.68 m) the frequency of accidents appears to remain constant (approximately 0.2 utility pole accidents per single-vehicle accident). The distribution of run-off-the-road accidents by type of fixed object for total accidents and injury accidents is given in Tables 28 and 29. The relationships involving utility pole accidents and pole spacing and offset are given in Figures 4 and 5.

Table 28. Distribution of run-off-the-road accidents by type of fixed-object.

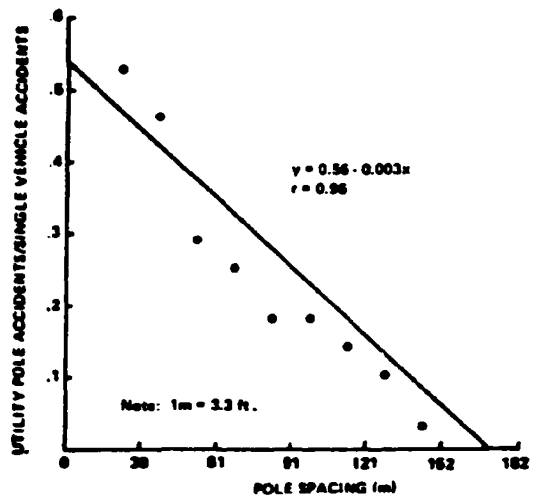
First Object Struck	Number of Accidents	Percentage of Total
Utility pole	1291	21.1
Fence, guardrail	825	13.5
Sign, mailbox, parking meter, guy wire	728	11.9
Culvert, ditch, embankment	714	11.7
Tree	682	11.1
Light, signal pole	466	7.6
Fire hydrant	223	3.6
Building	215	3.5
Ground (generally rollover)	187	3.1
Wall	175	2.9
Shrubbery	120	2.0
Bridge	116	1.9
None	79	1.3
Other	303	4.9
Total	6124	100.0

Source: TRR 681, pg. 89.

Table 29. Distribution of run-off-the-road injury accidents by type of fixed-object.

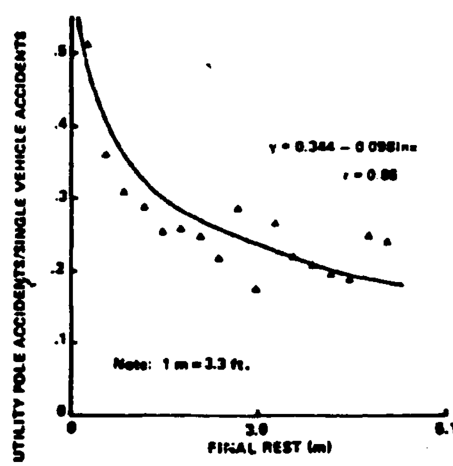
Object	Total Accidents	Injury Accidents		Percentage of Total Injury Accidents
		Number	Percent	
Utility pole	1166	589	50.5	31.4
Fence, guardrail	740	171	23.1	9.1
Sign, parking meter, mail-box, guy wire	668	133	19.9	7.1
Culvert, ditch, em-bankment	674	300	44.5	16 0
Tree	598	257	43.0	13.7
Light, signal pole	365	77	21.1	4.1
Fire hydrant	179	32	17.9	1.7
Building	163	33	21.2	1.8
Ground (generally rollover)	175	92	52.6	4.9
Wall	147	53	36.1	2.8
Shrubbery	100	7	7.0	0.4
Bridge	115	47	40.9	2.5

Source: TRR 681, pg. 89.



Source: TRR 681, Figure 3, pg. 91.

Figure 4. Proportion of single-vehicle accidents involving utility poles vs. pole spacing.



Source: TRR 681, Figure 4, pg. 91.

Figure 5. Proportion of single-vehicle accidents involving utility poles vs. final rest position of pole.

The study data provide evidence that utility pole density and offset from the roadway significantly contribute to the proportion of utility pole accidents per single-vehicle, run-off-the-road accident. The data also suggest that utility pole accidents are also related to a high percentage of injury accidents. The relationship between utility pole accidents and total accidents cannot be developed from the available data. The authors suggest that utility pole accidents may be a small percentage (2.2 percent) of the total urban roadway accident experience. The effectiveness of accident countermeasures such as increasing the pole spacing or increasing the pole offset for existing utility poles is illustrated in Figures 4 and 5. Because utility pole accidents are a small part of the total accident frequency, it is probable that some utility pole countermeasures would not be cost-effective. Further data to verify the study results plus an examination of the cost-effectiveness of utility pole accident countermeasures would greatly enhance the existing knowledge of urban roadway accident experience.

44. King, G.F. and R.B. Goldblatt, "Relationship of Accident Patterns to Type of Intersection Control", Transportation Research Record 540, Transportation Research Board, Washington, D.C., 1975.

An evaluation of the distribution of accidents by type and severity was made for various intersection control techniques. Data were collected at 300 intersections located in urban and rural areas throughout the United States. Values of the measures of accident effectiveness for the urban intersection data are given in Table 30. The results of the study are summarized below.

- Installation of traffic signals influences a reduction in right-angle accidents and an increase in rear-end collisions.
- No evidence was found to suggest that the installation of signals reduces the adverse effects of accidents.
- Right-angle ratio (the ratio of right-angle collisions to total accidents) appears to be a good indicator of detecting improvements in accidents as a result of signalization.
- Statistically significant correlations were found between accidents and sight distance and grade for most of the conditions studied.

Table 30. Summary of accident statistics for signal and stop sign control.

Measure of Effectiveness	Signal Control[a]			Stop-Sign Control[b]			Significance of Difference	
	$\bar{x}$	s	$\bar{x}/s$	$\bar{x}$	s	$\bar{x}/s$	$\bar{x}$	s^2
Accident evaluation index	1.399	0.324	4.3	1.570	0.434	3.6	—	0.05
Injury and fatality ratio	0.316	0.256	1.2	0.296	0.244	1.2	—[c]	—[c]
Rear-end ratio	0.321	0.212	1.5	0.175	0.124	1.4	—	0.01
Severity index	2.37	4.84	0.49	5.230	7.682	0.68	—	0.05
Right-angle ratio	0.240	0.191	1.3	0.456	0.198	2.3	0.01	—[c]
Normalized accident total	11.56	7.045	1.6	4.747	2.572	1.8	—	0.01
Volume accident rate	5.28	3.422	1.5	3.786	2.380	1.6	—	0.05
Accident disutility	7.247	4.549	1.6	5.639	3.408	1.7	0.10	0.10
Right-angle accidents	2.765	8.883	0.31	2.119	1.290	1.6	—	0.01
Right-angle accident rate	1.306	1.319	0.99	1.811	1.426	1.3	0.10	—[c]

[a]118 in sample. [b]24 in sample. [c]Not significant.

Source: TRR 540, Table 8, pg. 9.

An assessment of the study data indicates that traffic signals installed at urban intersections may have higher accident rates than nonsignalized intersections. Also signalization may reduce right-angle collisions but rear-end crashes will most likely increase. The data do not permit examination of the specific geometric, volume, environmental, and human factor elements that also tend to influence accident frequency.

45. **Leong, H.J.W., "Effect of Kerbed Median Strips on Accident Rates on Urban Roads", Proceedings of the Fifth Conference, Volume 5, Part 3, Australian Road Research Board, Victoria, Australia, 1970.**

This study consisted of analyzing 3,400 accident reports collected on 21 urban highway sections in Sydney and the City of Newcastle. Data were collected for the periods before, immediately after, and four to ten years after the installation of a curbed concrete median strip. The results of the analysis are summarized below.

- Wide Medians - 10 to 16 Feet (3.0 to 4.9 m)

It was found that wide medians had no effect on accident rates at midblocks or at major or minor intersections. However, this conclusion is only based on data collected at two sites.

- Narrow Medians - 3 Feet (0.9 m)

a. At midblock locations, a significant decrease in head-on collisions was found, however, there was a significant increase in fixed-object and sideswipe crashes.

b. At minor intersections there was a significant decrease in head-on collisions and increase in total accidents. Accident types that increased included rear-end, failure to yield right-of-way, and sideswipe accidents.

c. At major intersections, there was a short-term reduction in total accidents, however, there were no differences in the long-term rates.

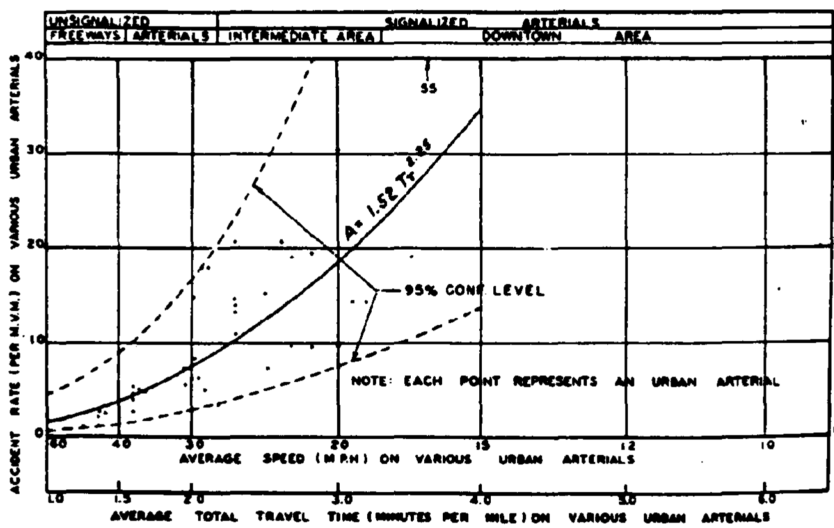
d. In general, there was no difference between the immediate short-term and permanent long-term effects of narrow medians on accident rates on urban arterial roads.

During the study period, the only geometric change at the sites was the installation of the median strips. The presence of a 3-foot (0.9-m) concrete median effected a change in accident type (head-on collisions decreased while fixed-object and side-swipe accidents increased) at midblock locations and head-on collisions decreased while rear-end, failure to yield right-of-way, and sideswipe accidents increased at minor intersections. The data indicate that a narrow median may affect the type of collision on an arterial roadway but the median does not influence a difference between the short-term and long-term accident rates.

46. May, Adolf D., Jr., "A Friction Concept of Traffic Flow", Vol. 38 Proceedings, 38th Annual Meeting, Highway Research Board, Washington, D.C., 1959.

The purpose of this investigation was to determine the relationships between roadway features, operating characteristics, and accident experience. Data were collected on 41 sections of straight, level, high volume, multilane urban roadways located in Detroit and Lansing, Michigan. The length of the test sections ranged from 0.75 to 1.25 miles (1.20 and 2.00 km). Accident data for the test sections were collected for the years 1956 and 1957. The operating characteristics were obtained by driving a specially equipped research vehicle over the test sections. These characteristics included average and running speeds, travel time, spot speeds, fuel economy, number of brake applications, and brake time. The roadway features were expressed in terms of internal, medial, marginal, and intersectional friction. Internal friction was expressed in terms of traffic volumes, volume/capacity ratios, and density. Medial friction was classified as sections with and without medians. Marginal friction was classified as none, moderate, and heavy depending upon the type of roadside development and the amount of on-street parking. Intersectional friction was subdivided into four groups depending upon the number of intersections and traffic signals within the section.

Analysis of the study data indicated that the accident rate increases as the medial, marginal, and intersection friction increases. Intersectional friction, i.e., the number of intersections and the number of traffic signals appeared to have a greater influence on accident rates, travel time, and fuel economy than the other forms of roadway friction. Travel time and fuel economy were also adversely affected by increased marginal friction. A statistically significant relationship was found between accident rate and travel time as given in the following equation and in Figure 6.



Source: HRB Proceedings, Figure 12, pg. 508.

Figure 6. Accident rates related to average total travel time for various urban arterials.

$$A = 1.52\ (T_t)^{2.25}$$

where:

A = accident rate, expressed as the number of accidents per million vehicle miles (per 1.6 million vehicle km).

T = average travel time, expressed in minutes per mile (per km).

The limits of the data for travel time ranged from 1.2 to 3.0 minutes per mile (1.93 to 4.83 minutes per km). A summary of the interrelationships of the variables studied, as shown in Table 31, indicates that each of the variables are related to roadway characteristics.

The results of the study suggest that travel time, fuel economy, and accident rate are interrelated and an equation for estimating the accident rate based on travel time is provided. While the friction concept is one method of examining relationships, the definitions of the categories of friction are too general to permit identifying relationships between accidents and site specific geometric variables.

47. May, A.D., Jr., "Economics of Operation on Limited-Access Highways", Highway Research Bulletin 107, Highway Research Board, Washington, D.C., 1955.

The purpose of the study was to compare the benefits, including accident reduction potential between limited access and roadway sections without access control. Accident, gasoline consumption, and travel time data were collected for 12 case studies on two- and four-lane divided highways in rural and urban areas in nine states during 1954.

While no statistical correlations were developed between accident experience and the operational data, the study findings revealed the following results.

- Average speeds were lower on urban study sites with no control of access (26.4 mph or 42.5 kph) when compared to average vehicle speeds on controlled access roads (47.2 mph or 76.0 kph).

Table 31. Summary of interrelationships of urban arterial and operating characteristics.

Characteristic	Unsignalized		Signalized			
	Freeways	Arterials	Interm. Area		Downtown Area	
Travel time, avg. (min/mi)	1.2	1.5	2.0	3.0	4.0	6.0
Speed, avg. (mph)	50	40	30	20	15	10
Time in motion, avg. (min/mi)	1.2	1.5	1.9	2.6	3.1	3.8
Running speed, avg. (mph)	50	40	32	23	19	16
Stopped time, avg. (min/mi)	0.0	0.0	0.1	0.4	0.9	2.2
Speed distribution (% time):						
Stopped	0	0	4	16	25	38
1-10 mph	0	0	3	7	10	15
11-20 mph	2	2	4	13	21	35
21-30 mph	1	1	12	51	44	12
31-40 mph	3	37	74	13	0	0
41-50 mph	5	60	3	0	0	0
51-60 mph	89	0	0	0	0	0
Fuel economy, avg. (mi/gal)	18	20	18	14	12	10
Accident rate (no./veh-mi)	2	3	18	17	24	41

Source: HRB Proceedings, Table 1, pg. 509.

- Gasoline consumption was higher on urban sections with no access control (17.2 miles per gallon or 7.3 km per l) due to greater roadside friction and congestion when compared to consumption rates on urban roads with full access control (18.8 miles per gallon or 8.0 km per l).

- The length of brake application per mile (per km) of travel (expressed in seconds) was 5.74 seconds on urban routes without access control compared with zero seconds on urban roads with full control of access. Brake application duration averaged 0.21 seconds on rural highways with access control.

- Accident rates developed during this study and obtained for two other studies are shown in Table 32 for urban and rural facilities with various access control types. Generally, it was found that urban roadways with no control of access had the highest accident rates.

The results of the study suggest that differences in accident rates can be associated with degree of access control in urban areas. More importantly, because accident and operational data were collected and analyzed for the same roadway sections, the data suggest a link between accidents and average speed, gasoline consumption, and brake application duration (a human factors measure).

48. Mayer, Peter A., "One-Way Streets", Chapter 10, Traffic Control and Roadway Elements, Highway Users Federation for Safety and Mobility, Washington, D.C., 1971.

This report presents an excellent summary of studies conducted to examine the safety effects of converting two-way streets into one-way streets. Generally, the research studies indicate that accidents can be reduced from 10 to 50 percent if one-way streets are converted with adequate publicity, signing, and enforcement. Initial operational and safety problems with the conversion are usually resolved within the first six months following implementation. It was also found that accident severity is generally reduced along with rear-end, sideswipe, turning, parking, and pedestrian accidents. Research findings showing the effects of one-way street conversion on accidents in New York City, Washington, D.C., Oregon, and Michigan are given in Tables 33 through 36.

One-way street systems have generally been shown to improve traffic operations and reduce accidents on urban streets, conse-

Table 32. Comparison of accident rates as related to access control.

Type of Access Control	Urban	Rural
Full Access Control		
Twelve Case Studies	247	49
Connecticut Study	261	221
Bureau of Public Roads Study	146	210
Partial Access Control		
Twelve Case Studies	-	209
Connecticut Study	180	250
Bureau of Public Roads Study	790	227
No Access Control		
Twelve Case Studies	443	236
Connecticut Study	725	313
Bureau of Public Roads Study	966	407

The values in the table represent the number of accidents per 100 million vehicle-miles of travel.

Source: HRB 107, Table 13, pg. 60.

Table 33. The effects of one-way street conversion on accidents in New York City.

Street and Length Made One-Way	Period	Number of Accidents					Total Accidents	Total Injured	Accident Rate [1]
		Angle	Rear End	Turning	Other	Pedestrian			
Madison Avenue 23rd St. to 135th St. 5.7 miles	Before	23	49	53	67	54	246	167	16.7
	After	23	34	24	45	32	158	101	9.3
	Percent Change	0%	−31%	−49%	−33%	−41%	−36%	−40%	−44%
Fifth Avenue Washington Sq. to 38th Street 6.5 miles	Before	40	65	68	84	63	326	190	20.4
	After	38	53	52	73	45	261	156	13.7
	Percent Change	− 5%	−18%	−23%	−13%	−29%	−18%	−18%	−32%
Both Streets	Before	63	114	121	151	117	572	357	18.6
	After	61	87	76	118	77	419	257	11.6
	Percent Change	− 3%	−24%	−37%	−22%	−34%	−27%	−28%	−38%

[1] Accidents per million vehicle miles

SOURCE DATA FROM: "One-Way Major Arterial Streets," by John A. Bruce, Highway Research Board Special Report 93, 1967 (1).

Source: Mayer, 1971 [48], Table 4, pg. 4.

Table 34. The effects of one-way street conversion on accidents in Washington, D.C.

	Time Period (Years)	Intersection		Mid-Block	
		Injury	Total	Injury	Total
Two-Way	2	64	212	10	70
One-Way	2	50	175	12	70
Percent different from two-way		−22%	− 17%	+20%	0

SOURCE: "The Frequency and Severity of Traffic Accidents in Washington, D.C." by C. Thomas Van Vechten, D.C. Department of Highways and Traffic, 1967, Appendix B, (13).

Source: Mayer, 1971 [48], Table 5, pg. 4.

Table 35. The effects of one-way street conversion on accidents in six Oregon cities.

	Time Period (Years)	Number of Accidents	Accident Rate [1]	Percent Reduction in Rate
Intersectional				
Before One-Way	3	969	18.36	
After One-Way	3	1024	13.52	26.4
Non-Intersectional				
Before One-Way	3	1069	20.27	
After One-Way	3	833	11.64	42.5

[1] Accidents per million vehicle miles

SOURCE: "A Study of One-Way Street Routings on Urban Highways in Oregon, by Oregon Highway Department, 1959, p. 20 (10).

Source: Mayer, 1971 [48], Table 6, pg. 5.

Table 36. The effects of one-way street conversion on accidents on Michigan State highways.

Location of Accidents	Lansing		Kalamazoo	
	Two-Way Street to One-Way Street	Two-Way Street No Change	Two-Way Street to One-Way Street	Two-Way Street No Change
Signalized Intersections				
Before	69	55	147	56
After	46	61	125	58
% Change	− 33.3	+ 10.9	− 15.0	+ 3.6
Non-Signalized Intersections				
Before	36	22	19	2
After	38	30	21	0
% Change	+ 5.6	+ 36.4	+ 10.5	NS [2]
Mid-Block				
Before	65	44	180	24
After	32	43	111	22
% Change	− 50.8	− 2.3	− 38.3	− 8.3
Total Accidents [1]				
Before	173	121	357	82
After	133	134	267	80
% Change	− 23.1	+ 10.7	− 25.2	− 2.4

[1] Includes accidents other than those tabulated by location.
[2] Not significant.

SOURCE DATA FROM: "Study of the Operational Aspects of One-Way and Two-Way Streets," by Nejad Enusson, Michigan Department of State Highways, 1969 (7).

Source: Mayer, 1971 [48], Table 7, pg. 6.

quently, this type of change may be regarded as an effective countermeasure. However, additional research is needed to determine the relationships between specific one-way street geometrics and traffic conditions on accidents. This research would be useful in identifying factors which enhance safety on these systems.

49. **McGee, H.W., W.A. Stimpson, J. Cohen, G.F. King, and R.F. Morris, "Right-Turn-On-Red: Volume I: Final Technical Report", prepared for the Federal Highway Administration, Washington, D.C., May, 1976.**

The objectives of the study were to examine the accident and energy saving aspects of permitting motorists to turn right on red at traffic lights. Accident data were collected and analyzed in the States of Colorado and Virginia and in the cities of Denver, Chicago, Los Angeles, and Dallas. Results of before and after studies in these areas are summarized below.

- Accident frequencies do not appear to be significantly influenced by permitting right-turn-on-red maneuvers.
- Accidents involving right-turn-on-red vehicles tend to be less severe and have a lower property damage value than other intersection accidents.
- Delay is significantly reduced by permitting right-turn-on-red maneuvers.

Analysis of the accident data indicate agreement with other researchers who concluded that right-turn-on-red does not increase the accident frequency at signalized intersections.

50. **McGuirk, William W. and Gilbert T. Satterly, Jr., "Evaluation of Factors Influencing Driveway Accidents", Transportation Research Record 601, Transportation Research Board, Washington, D.C., 1976.**

Because driveway related accidents were found to account for almost 12 percent of the total arterial highway accidents, this study was conducted to identify some of the characteristics of driveway accidents and their relationship to physical, environmental and traffic features of the roadway. Data were collected on 10 urban roadway sections in each of 10 Indiana cities (100 sites) whose population exceeded 30,000 persons. Site specific roadway features data were collected in the field and accident reports were obtained for the period January 1, 1968 to December 31, 1971 (4 years). The total study length was 96.85 km (60.18 miles) consisting of sections on one-way streets and two-way roadways with two to four lanes without median dividers. Stepwise multiple regression analysis was used to develop equations to predict driveway accidents for site specific conditions. The data revealed the following conclusions.

- Driveway accidents accounted for 13.95 percent of all reported accidents on the study sections.
- Of all driveway accidents, 71.62 percent occurred at commerical entrances and 85.56 percent resulted in property damage only.
- Factors found to be significantly related to driveway accidents were commercial driveways per mile (per km), number of through lanes, average daily traffic, and the total number of intersections per mile (per km).
- For each commercial driveway added to an arterial street an additional 0.1 to 0.5 driveway related accidents per mile per year (0.06 to 0.31 accidents per km per year) can be expected.
- Countermeasures such as median barriers, traffic signals, left-turn lanes, turn prohibitions, and eliminating driveways should improve highway safety on urban arterial roadways.

The following regression equations were developed to predict the number of driveway related accidents per mile per year.

Driveway accidents for one-way streets

$$Y = -1.592+8.996(X_2)+0.179(X_{18})-0.006(X_{19})$$

$$+0.970(X_{24})+1.096(X_2)(X_{19})$$

$$-32.035(X_2)(X_{24})$$

$$R^2 = 0.86$$

$$Y = +21.45+0.041(X_1)-11.070(X_6)+0.216(X_9)-0.378(X_{13})$$
$$+0.043(X_{16})-0.041(X_{17})$$
$$-0.053(X_{21})+0.060(X_6)(X_{16})$$
$$-0.022(X_1)(X_{16})+0.019(X_9)(X_{21})+2.475(X_6)$$
$$(X_2)+0.119(X_9)(X_{13})+0.029(X_9)(X_{16})$$
$$R^2 = 0.84$$

A list of the variables and the range of the significant variables are given in Tables 37 and 38 respectively.

Although the study data were limited to one state, the results indicate that site related geometric characteristics, i.e., number of lanes, traffic signals per mile (per km), intersections per mile (per km), and parking contribute to accident occurrences on urban arterial streets. Also, environmental features, i.e., area population, commercial versus residential driveways and traffic factors, i.e., average daily traffic significantly influence driveway accidents on urban streets.

51. **Moore, William L., Jr., and Jack B. Humphreys, "Sight Distance Obstructions on Private Property at Urban Intersections", Transportation Research Record 541, Transportation Research Board, Washington, D.C., 1975.**

The purpose of this paper was to examine problems encountered in removing sight obstructions on private property and to develop a model ordinance for improving sight distances at urban intersections. A synthesis of accident problems encountered due to sight distance obstructions on private property is given in the report. A before and after study conducted in Concord, California revealed that accidents at five intersections decreased by 67 percent (from 39 to 13) after sight distance obstructions were removed.

The sample size is too small to permit generalization of the results, however, it appears that the removal of sight distance restrictions at urban intersections is an effective countermeasure in reducing traffic accidents.

Table 37. List of variables used to predict driveway related accidents.

Index	Description
Y	Driveway accidents per mile per year
X_1	1970 urban area population in hundred thousands
X_2	1969 average daily traffic volume in hundred thousands
X_3	Street type: $X_3 = 0$ for one-way streets; $X_3 = 1$ for two-way streets
X_4	Roadway section speed limit (mph)
X_5	Curb-to-curb street width (ft)
X_6	Number of through-traffic lanes
X_7	Lane markings: $X_7 = 0$ for no lane markings; $X_7 = 1$ for lane markings visible
X_8	Number of stop signs and red flashing traffic signals per mile
X_9	Number of traffic signals per mile
X_{10}	Number of yield signs and yellow flashing traffic signals per mile
X_{11}	Number of 3-way intersections per mile
X_{12}	Number of 4-way intersections per mile
X_{13}	Number of total intersections per mile
X_{14}	Number of alleys per mile
X_{15}	Number of residential driveways per mile
X_{16}	Number of commercial driveways per mile
X_{17}	Number of industrial driveways per mile
X_{18}	Number of other driveways per mile
X_{19}	Number of total driveways per mile
X_{20}	Number of friction points per mile
X_{21}	Average spacing between adjacent driveways (ft)
X_{22}	Average spacing between driveways and adjacent intersection legs (ft)
X_{23}, X_{24}	Curb parking restrictions
X_{25}, X_{26}	Curb condition

Source: TRR 601, Table 4, pg. 70.

Table 38. Range of significant variables.

Sample	Variable	Index	Maximum	Minimum	Range
92 sections	Driveway accidents per kilometer per year	Y	17.0	0	17.0
	Urban area population	100 000(X_1)	744 624	31 403	713 221
	ADT	100 000(X_2)	31 034	1153	29 881
	Number of traffic lanes	X_6	4	1	3
	Lane markings	X_7	1	0	1
	Traffic signals per kilometer	X_9	7.3	0	7.3
	Total intersections per kilometer	X_{13}	14.7	1.7	13.0
	Alleys per kilometer	X_{14}	21.9	0	21.9
	Commercial driveways per kilometer	X_{16}	45.5	0	45.5
	Industrial driveways per kilometer	X_{17}	16.7	0	16.7
	Other driveways per kilometer	X_{18}	13.6	0	13.6
	Total driveways per kilometer	X_{19}	74.1	16.1	58.0
	Friction points per kilometer	X_{20}	81.0	22.0	59
	Driveway-driveway spacing (meters)	X_{21}	40.6	7.7	32.9
	Parking	X_{24}	1	0	1
64 two-way sections	Driveway accidents per kilometer per year	Y	17.0	0	17.0
	Urban area population	100 000(X_1)	744 624	31 403	713 221
	Number of traffic lanes	X_6	4	2	2
	Traffic signals per kilometer	X_9	5	0	5
	Total intersections per kilometer	X_{13}	12.9	1.7	11.2
	Commercial driveways per kilometer	X_{16}	45.5	0	45.5
	Industrial driveways per kilometer	X_{17}	16.7	0	16.7
	Driveway-driveway spacing (meters)	X_{21}	40.1	8.7	31.4

Note: 1 km = 0.62 mile; 1 m = 3.28 ft.

Source: TRR 601, Table 5, pg. 70.

52. **Mueller, Edward A., and Woodrow W. Rankin, "Pedestrians", Chapter 8 - Traffic Control & Roadway Elements, Highway Users Federation for Safety and Mobility, Washington, D.C., 1970.**

This study is a summary of research studies conducted on pedestrian safety. In 1965, more than 65 percent of the pedestrian deaths occurred on urban roads in the United States. Factors which have been shown to affect pedestrian accidents include alcohol content, roadway illumination, wet weather, and age of the pedestrian. Countermeasures to improve pedestrian safety include using one-way street systems, installation of traffic signals and pedestrian signals, pedestrian grade separation, illumination, increasing pedestrian visibility, and strict enforcement of pedestrian regulations.

The report identifies several general factors which affect pedestrian accidents and describes possible countermeasures to reduce these accidents. Additional research data are needed, however, to identify pedestrian problems and the effectiveness of countermeasures at site specific features of urban arterial roadways.

53. **Mulinazzi, T.E. and H.L. Michael, "Correlation of Design Characteristics and Operational Controls with Accident Rates on Urban Arterials", Joint Highway Research Project, Purdue University, Lafayette, Indiana, December, 1967.**

This study was conducted to examine the relationships between design and operational controls on traffic accidents on urban arterial highways. Accident, volume, and geometric data were collected for 100 sections of urban arterial roadways ranging in length from 0.254 mile to 4.167 miles (0.41 km to 6.70 km). Accident data were collected for the three year period 1963 through 1965. Traffic volumes on the sections ranged from 1,200 to 32,000 vehicles per day. Sixty-eight of the sections were two-lane urban roadways. A list of the 26 independent variables for which data were collected is given in Table 39. Multiple linear regression analysis was used to develop equations to predict the accident rate (number of accidents per 100 million vehicle miles or 160 million vehicles km) and the annual number of accidents per mile (per km). Accident rate, as a dependent variable, was eliminated because the independent variables explained less than 50 percent of the variability in the rate ($R^2<0.50$). The equations for estimating the number of accidents per mile had R^2 values greater than 0.50 and are reported below for four specific urban situations.

Table 39. List of independent variables used to examine relationships between design and operational controls on accidents.

Number	Variable Description
1	Average daily traffic on the arterial in thousands of vehicles
2	Number of intersections per mile (per km)
3	Number of heavy volume intersections per mile or km (intersections with arterial streets)
4	Number of medium volume intersections per mile or km (all cross streets except arterials and low volume Local)
5	Number of traffic signals per mile (per km)
6	Number of driveways per mile (per km)
7	Number of commercial driveways per mile (per km)
8	Number of medium and heavy volume commercial driveways per mile or km (rated on basis of commercial activity)
9	Number of light volume commercial and residential driveways per mile (per km)
10	Number of friction points per mile (per km)
11	Street width (in feet or m)
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 (per km)
22	One-way street operation (1,0) (one-way, two-way)
23	Number of three-way intersections per mile (per km)
24	Urban design of pavement cross-section (0,1) (curbed, uncurbed)
25	Number of yellow flashers per mile (per km)
26	Ratio of commercial driveways per mile (per km) to total number of driveways per mile (per km)

Source: Mulinazzi and Michael, 1967 [53], Table 2, pg. 11.

- <u>Using data from all 100 study sections</u>

  $Y = -0.261 + 1.256(X_1) + 3.909(X_3) + 6.086(X_5)$

Where:

  Y = Number of accidents per mile (per km) per yr

  X_1 = Average daily traffic on the section in thousands of vehicles

  X_3 = Number of heavy volume intersections per mile (per km)

  X_5 = Number of traffic signals per mile (per km)

  $R^2 = 0.74$

- <u>Using data from the 35 low volume sections (ADT between 1,200 and 5,800).</u>

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

Where:

  X_8 = Number of heavy and medium volume commercial driveways per mile (per km)

  X_{16} = Parking allowed

  $R^2 = 0.52$

- <u>Using data from the 32 high volume sections in Indianapolis</u>

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

Where:

  X_3 = Number of heavy volume intersections per mile (per km)

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

  $R^2 = 0.62$

- <u>Using data from the 68 two-lane sections.</u>

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

Where:

X_1 = Average daily traffic on the section in thousands of vehicles

X_5 = Number of traffic signals per mile (per km)

R^2 = 0.62.

The results of the analysis indicate that the following factors have a significant effect on accident frequencies on urban roadways.

- On-street parking
- Traffic signals per mile (per km)
- High volume intersections per mile (per km)
- Average daily traffic
- Number of heavily used driveways per mile (per km)
- Number of intersections and driveways per mile (per km)
- Quality of signing and pavement markings

Although the data were collected in only one state, the results of the study indicate that accidents on urban roadway sections can be predicted with a reasonable degree of accuracy from site specific geometric, operational, and environmental features. The applicability of equations developed should be verified using current accident data and roadway features.

54. Nemeth, Zoltan A., "Development of Guidelines for the Application of Continuous Two-Way, Left-Turn Median Lanes", Engineering Experiment Station, Ohio State University, Columbus, Ohio, July, 1976.

Before and after studies were conducted to evaluate the effectiveness of continuous two-way, left-turn median lanes. Three urban arterial routes in Ohio were selected for study. Average daily traffic on the routes ranged from 12,940 to 17,610 vehicles per day. The improvements consisted of restriping a two-lane roadway (which operated as four lanes) to accomodate two through lanes and a two-way median lane; restriping a two-lane highway to provide for two lanes with a left-turn median lane, and remarking a four lane road to allow for four through lanes and a left-turn median lane. Travel speeds, volumes, and traffic conflicts data were collected before and after the improvements were made at each site. Accident data were not obtained for this study. At the site where four through lanes were restriped to allow two through lanes and a left-turn median lane, the results were increased travel times, increased weaving, and fewer traffic conflicts. The restriping of a two-lane roadway to provide two through lanes and a median left-turn lane resulted in reduced travel times and delays with some increase in average running speed. Traffic conflicts were reduced by 37 percent in spite of the fact that mainline volumes increased by 2.5 percent, cross traffic volumes increased by 25.8 percent, and left-turns increased by 16 percent. The restriping of a four-lane undivided roadway to allow for four through lanes and a left-turn median lane resulted in a slight increase in running speeds, however, the increase was not statistically significant. Traffic conflicts were reduced.

Although the study did not include an accident analysis, it was one of the few published reports that addressed operational effectiveness and hazard potential reduction of implementing two-way, left-turn median lanes on urban roadways. The report also provides a comprehensive review of the literature pertaining to median turn lanes, including accident studies, and offers guidelines for traffic engineers to use when considering the installation of a median turn lane. While the study data at three sites are not sufficient to permit a statistical inference, the results suggest that a two-way, left-turn median lane can improve travel time and reduce conflicts created by left-turning vehicles.

55. **Olson, R.M., G.D. Weaver, H.E. Ross, Jr., and E.R. Post, "Effect of Curb Geometry and Location on Vehicle Behavior", NCHRP Report 150, Transportation Research Board, Washington, D.C., 1974.**

This investigation was undertaken to examine the effects of vehicle behavior on 4- and 6-inch (10.2- and 15.2-cm) concrete curbs and a special 13-inch (33.0-cm) curb. The 6-inch (15.2-cm) curbs are commonly used on divided arterial routes in the U.S. Eighteen full scale crash tests were conducted and simulation impacts were made using the Highway Vehicle Object Simulation Model. The major finding was that concrete curbs 6-inches (15.2-cm) high or less do not redirect vehicles at speeds above 45 miles per hour (72 kph) and encroachment angles greater than 5 degrees.

The results of the crash tests suggest that 6-inch (15.2-cm) concrete curbs commonly used on urban streets should not be used if speeds are expected to exceed 45 mph (72 kph). An analysis of crash data on urban sections with and without concrete curbs for roadways exceeding 45 miles per hour (72 kph) would help establish the magnitude and severity of the problem suggested by the results of the crash tests. Comparative data for roadways with vehicle speeds of less than 45 miles per hour (72 kph) would also be useful to confirm the hypothesis that raised curbs do not pose safety problems on these roadways.

56. Parker, Martin R., Jr., "Guidelines For Selecting Median Treatments for Urban Areas", Compendium of Technical Papers, 49th Annual Meeting of Institute of Transportation Engineers, Toronto, Canada, September, 1979.

The purpose of the study was to develop a process for evaluating the impacts of alternative median design treatments for site specific conditions to enable selection of the safest and most operationally efficient design. Accident data were collected for 50 urban roadway sections in 31 urban areas in Virginia for the years 1975, 1976, and 1977. Geometric and operational data were also collected for each study site. Median treatments included in the investigation were raised medians with six-inch (15.2-cm) concrete curbs, traversable median left-turn lanes, and undivided roadways as shown in Table 40. All of the study sites had four through lanes. Multiple linear stepwise regression analysis was used to develop equations to estimate the impacts of alternative designs on accidents and left-turn vehicle delay. Dependent variables examined included annual number of accidents per mile (per km), accident rate, accident severity rate, and the delay in seconds per left-turn vehicle. The list of independent variables is shown in Table 41 and the range of the independent variables is shown in Table 42. The regression equations are shown in Table 43.

Table 40. Median treatments studied in Virginia.

Median Treatment	No. of Locations	Length, Miles
Raised (6-in. or 15.2-cm curbs)	19	28.22
Traversable		
Two-way left-turn lane	13	12.24
Alternating left-turn lanes	3	2.06
Continuous left-turn lanes	1	0.87
Undivided	14	16.59
	50	59.98

Note: 1 mile = 1.6 km

Source: Parker, 1979 [56].

Table 41. Independent variables included in the regression analysis.

• Average daily traffic
• Main line volume, in vehicles per hour, recorded during the field studies
• Average number of left-turns per hour
• Number of signalized intersections per mile (per km)
• Number of public streets per mile or per km (A four-way intersection would be counted as two streets whereas a tee intersection has only one street approach. The number of approach legs at signalized intersections should also be included.)
• Number of driveways per mile or per km (including all intersections except public streets)
• Number of intersections per mile (per km)
• Median openings per mile or per km (applies only to raised median projects)
• Area population

Table 42. Range of independent variables.

Variable	Symbol	Range	
		Minimum	Maximum
Signals per mile	Sig	0.00	6.98
Average daily traffic	ADT	5,460	33,590
Design hourly volume	DHV	138	1,367
Driveways per mile	Dr.	12.42	116.36
Area population	Pop	1,111	286,694
Streets per mile	St	2.61	32.59
Median openings per mile	Open	5.21	16.65

Source: Parker, 1979 [56], Table 7, pg. 76.

Table 43. Regression equations for predicting annual accidents per mile and midblock left-turn delay.

Median Type	Regression Equations	R^2	Standard Error
Raised	$A_R = 8.040\ Sig + 0.00155\ ADT - 0.0228\ Dr - 0.00000926\ Pop - 12.718$	0.73	10.29 acc/mile
	$D_R = -1.362\ Sig + 0.0184\ DHV - 0.205\ Open - 0.0000332\ Pop + 2.937$	0.81	3.37 seconds
Traversable	$A_T = 5.432\ Sig + 0.00173\ ADT + 2.157\ St - 0.0000058\ Pop - 28.797$	0.71	20.77 acc/mile
	$D_T = -0.525\ Sig + 0.0198\ DHV - 0.0676\ Dr - 0.0000214\ Pop + 0.920$	0.75	2.74 seconds
Undivided	$A_u = 3.055\ Sig + 0.00212\ ADT - 0.264\ St + 0.557\ Dr - 36.507$	0.79	13.40 acc/mile
	$D_u = -1.073\ Sig + 0.0142\ DHV + 0.367\ St - 0.0000203\ Pop - 3.177$	0.57	3.01 seconds

Source: Parker, 1979 [56], Table 6, pg. 75.

The results of the analysis are summarized below.

- Mean accident rates are not significantly different for raised, traversable, and undivided median sections. However, accident severity is significantly higher on undivided roadways.
- The type of median treatment influences the type of collision based on the data provided in Table 44.
- Factors which significantly affect the accident frequency on urban roadways with raised medians are the number of traffic signals per mile (per km) and the average daily traffic.
- Factors affecting accident frequency on urban roadways with traversable medians are the number of traffic signals and streets per mile (per km) and the average daily traffic.

Table 44. Percent of collision type for each type of median treatment.

Category	Percent of Collisions: Raised	Traversable	Undivided	Significant Differences, α = 0.05
Rear-end	37.48	35.69	34.67	None
Angle	38.70	42.63	39.98	Trav. greater
Sideswipe	8.62	11.90	11.75	Raised lower
Head-on	1.05	0.98	1.97	Undiv. greater
Pedestrian	0.94	1.65	1.61	None
Bicycle	1.00	0.80	0.48	None
Fixed-object	10.45	5.12	8.53	Raised greater
Miscellaneous	1.77	1.25	1.01	None
U-turn accidents	1.27	0.15	0.36	Raised greater

Soruce: Parker, 1979, [56], Table 5, pg. 74.

- Factors affecting accident frequency on four-lane undivided urban roadways include the number of traffic signals, streets, and driveways per mile (per km) and the average daily traffic.

- Midblock left-turn delay was found to be affected significantly by the number of traffic signals per mile (per km), the area population, the mainline hourly volume, and the number of driveways and streets per mile (per km).

- The midblock left-turn delay was not significantly related to the accident frequency for any median treatment.

Further verification of equations should be made to test their validity in other urban areas. The equation developed for predicting accidents per mile (per km) for traversable sections was compared to the equation developed by Walton and Machemehl using Texas data and the results appear to yield similar values.

57. **Parker, Martin R., Jr., Robert F. Jordan, Jr., Jeffrey A. Spencer, Melvin D. Beale, and Larry M. Goodall, "Right-Turn-on-Red", Virginia Highway & Transportation Research Council, Charlottesville, Virginia, September, 1975.**

The purpose of the study was to determine the energy and accident effects of implementing the general permissive right-turn-on-red rule at signalized intersections in Virginia. The study included collection of delay and traffic conflict data and accident data at 20 locations before and after right-turns-on-red were permitted. While a statistically significant reduction in delay time was found after right-turns-on-red were permitted, no significant differences were detected in the accident frequency, accident rate, or number of traffic conflicts. The data were collected at rural and urban signalized intersections in Virginia. As a result of the findings, the General Assembly adopted the general permissive rule on January 1, 1977.

The study results concur with the findings of other investigators who found that implementation of right-turn-on-red maneuvers does not increase accident frequency at signalized intersections.

58. **Post, Theodore, J., Robinson, H. Douglas, and Price, Harold E., "A User's Guide to Positive Guidance", report prepared for the Federal Highway Administration, Office of Traffic Operations, Washington, D.C., June, 1977.**

Positive guidance is the combination of traffic engineering and human factors to develop a system of driver information about a hazard so that accidents can be avoided. The concept is based on the premise that information can be provided to the driver when he needs it, and in a form he can use to enable him to avoid an accident. This report is a user's guide giving step-by-step instructions for applying the concept of positive guidance in rural and urban highway situations. A case study of an urban signalized intersection is presented to illustrate the procedures involved in applying positive guidance to specific sites.

The user's guide presents a systematic method of integrating human factors and traffic engineering to reduce accidents and improve the operational efficiency of a location. The extent to which the procedure is being used to identify safety deficiencies and develop countermeasures in U.S. urban areas is unknown but there have been some reported applications of the tecnnique.

59. **Ricci, Leda, "National Crash Severity Study Statistics", DOT-HS-805-227, prepared by Highway Safety Research Institute for the National Highway Traffic Safety Administration, Washington, D.C., October, 1979.**

This report presents tabulations of crash data collected between January 1977 and March 1978 in seven urban areas of the U.S. The data were collected by investigators trained by the National Highway Traffic Safety Administration. The report contains only crashes for passenger cars and occupants which were severe enough to require that the vehicles be towed from the scene of the accident. Numerous tables and figures are given of crash statistics including crash and injury distributions by location, degree of urbanization, roadway type, time of day, road condition, speed limit, and accident type. Also vehicle, occupant, and severity tables are presented.

The statistics presented in the report were not used to establish relationships between accidents and roadway features but the data can be used to compare crash reports by accident type, roadway type, etc. with accident data collected in other urban areas.

60. Roy Jorgensen Associates, "Cost and Safety Effectiveness of Highway Design Elements", National Cooperative Highway Research Program Report 197, Transportation Research Board, Washington, D.C., 1978.

The purpose of this report was to develop a method of assessing the cost and safety relationships for various design elements. The report contains an extensive summary of accident and design relationships for a variety of highway conditions including urban arterials. However, only cost and accident relationships were developed for lane width, shoulder width, and shoulder type for rural two-lane roads. Specific safety relationships noted in the report which pertain to urban arterial highways are discussed in other sections of this bibliography.

61. Sawhill, Roy B. and Dennis R. Neuzil, "Accidents and Operational Characteristics on Arterial Streets with Two-Way Median Left-Turn Lanes", Highway Research Record 31, Highway Research Board, Washington, D.C., 1963.

The purpose of this investigation was to examine the safety and operational effects of using continuous two-way, left-turn median lanes on arterial roadways located in commercial and industrial areas of Seattle, Washington. Before and after accident data collected at three sites were examined. The study sections ranged in length from 0.46 to 1.49 miles (0.74 to 2.40 km) and traffic volumes ranged from 15,800 to 27,500 vehicles per day. Trends in accidents, accident rates, type of collision, and accident severity were examined at the study sites.

An analysis of the accident data is provided below.

- Only 9.4 percent of the total accidents were related to the use of the median lanes.
- The median related accidents were less severe than nonmedian accidents.
- The number of head-on accidents in the median lane was negligible.
- At one site accidents decreased from 66.75 per year to 49.5 per year, a reduction of 25.8 percent. Most of the decrease was in rear-end accidents.

Analysis of the operational data revealed the following results.

- Motorists using the two-way, left-turn lane ranged from 3 to 23 percent of the traffic.

- The beneficial effects of the median lane included the following items.

  a. The lane provided a refuge area for pedestrians,

  b. Emergency vehicle movements were enhanced, especially during peak hours,

  c. The lane permits space for detouring traffic during utility work and street maintenance.

  d. Few drivers used the median lane for passing other vehicles.

This report is one of the first efforts to document the effectiveness of constructing a continuous two-way, left-turn median lane on arterial streets. The limited number of sites examined does not permit general inferences, however, the data indicates that safety and operational factors were enhanced at the study locations after the median lanes were installed.

62. **Shaw, Robert B. and Harold L. Michael, "Evaluation of Delays and Accidents at Intersections to Warrant Construction of a Median Lane", Highway Research Record 257, Highway Research Board, Washington, D.C., 1968.**

The purpose of this study was to examine the effects of a left-turn median lane on delay time and accident rates. Delay time and accident data were collected at 11 intersections located in rural and suburban areas in Indiana. Traffic volumes at the intersections ranged from 7,100 to 27,500 vehicles per day. Intersections were classified as suburban when the approach speed was less than 45 miles per hour (72 kph). Accident data were collected for a five year period from January 1961 through August 1965. The accident and delay data were analyzed by multiple linear regression analysis. The results of the analysis are summarized below.

- Delay caused by left-turning vehicles was found to be significantly related to the total hourly volume and the number of left-turn vehicles per hour.

- Shown in Table 45 are the independent variables examined for predicting the accident rates at the rural and suburban intersections.

- The equation developed for predicting the accident rate caused by left-turning vehicles is given below.

  $$Y_{AS} = 3.6203 - 1.1407(X_7) + 1.2446(X_{12}) - 0.7723(X_{13}) + 0.0371(X_{14})$$

  The multiple correlation coefficient is 0.74. The variables explain approximately 55 percent (R^2) of the variation in the number of accidents per million vehicles caused by left-turning vehicles on a suburban intersection approach. The significant variables related to accidents are approach and opposing average daily traffic, the number of approach lanes, the weekday approach average daily traffic and the total intersection average daily traffic.

- The installation of a median lane to provide storage space for left-turning vehicles significantly reduces delay time to through vehicles and reduces the accident frequency.

The study results indicate that median left-turn lanes are effective in reducing left-turning accidents and delay at suburban intersections. Significant relationships were found between accident rates, and the number of approach lanes and the average daily traffic. The applicability of the results to urban arterial streets is plausible because the locations used to develop the findings for suburban intersections were located near metropolitan areas.

63. Snyder, James C., "Environmental Determinants of Traffic Accidents: An Alternate Model", <u>Transportation Research Record 486</u>, Transportation Research Board, Washington, D.C., 1974.

The purpose of this study was to identify environmental factors related to traffic accidents. Accident and environmental data were collected on 135 two-mile (3.2-km) segments in Oakland County, Michigan. The county encompasses urban, suburban, and rural environments. The accident data covered the years 1968 through 1970. Dependent variables analyzed were accident frequency and accident rate per million vehicle miles (per 1.6 million vehicles km) of travel. The independent variables were road type, number of lanes, percent of population ages, popula-

Table 45. Independent variables examined for predicting suburban and rural accident rates.

Number	Variable
2	Type of area, suburban or rural
3	Flasher (stop) controlled
4	Fixed-time controlled signalization
5	Semitraffic-actuated controlled signalization
6	Fully traffic-actuated controlled signalization
7	Number of approach lanes
8	Width of approach roadway at the intersection, ft
9	Width of opposing roadway at the intersection, ft
10	Approach volume per hour at time the accident occurred, vph
11	Opposing volume per hour at time the accident occurred, vph
12	Weekday approach, ADT, vpd
13	Weekday approach ADT plus weekday opposing ADT, vpd
14	Total intersection weekday ADT, vpd
15	Ratio of approach volume per hour to capacity of approach direction
16	Ratio of opposing volume per hour to capacity of opposing direction
17	Average speed through the intersection for a nondelayed through vehicle, ft/sec

Source: HRR 257, Table 6, pg. 27.

tion density, percent of commercial frontage, percent of developed frontage, and value of homes. Multiple classification analysis and regression techniques were employed to analyze the data. The results of the analysis are summarized below.

- Accident frequency can be predicted from traffic volumes and accident rates.

- Accident rates are best predicted from type of road, intensity of road frontage development, and percentage of the population between 16 and 24 years old.

The relationships developed in the study are of interest but do not provide results that can be used by highway engineers to influence traffic accident reduction. For example, the percentage of population between 16 and 24 years old may be related to accidents, but this variable is clearly not controlled by the traffic engineer. The other variables have also been identified as accident related by several investigators.

64. **Stark, Richard E., "Studies of Traffic Safety Benefits of Roadway Lighting", Highway Research Record 440, Highway Research Board, Washington, D.C., 1973.**

The purpose of this study was to examine some of the investigations undertaken to determine the relationship between illumination level and accidents on urban streets and freeways. The following discussion pertains only to the studies related to urban streets.

A study of 97 miles (156.1 km) of street relighting in Kansas City, Missouri revealed that property damage accidents were reduced by 4 percent, injury accidents by 18 percent and fatal crashes by 28 percent. The study data are given in Tables 46 and 47. Based on the study findings, it has been suggested that a serious night accident problem exists when the ratio of night-day accidents is more than 1.5 times the average ratio for similar locations or sections on the same system of roads and streets. Also, it was found that approximately 25 percent of the travel in urban areas occurs at night.

The study data tend to support the hypothesis that low illumination levels are associated with high accident occurrences. Additional studies, however, should be undertaken to determine the specific effects of various illumination levels on accidents, including the cost-effectiveness of each illumination level.

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64. Stark, Richard E., "Studies of Traffic Safety Benefits of Roadway Lighting", Highway Research Record 440, Highway Research Board, Washington, D.C., 1973.

The purpose of this study was to examine some of the investigations undertaken to determine the relationship between illumination level and accidents on urban streets and freeways. The following discussion pertains only to the studies related to urban streets.

A study of 97 miles (156.1 km) of street relighting in Kansas City, Missouri revealed that property damage accidents were reduced by 4 percent, injury accidents by 18 percent and fatal crashes by 28 percent. The study data are given in Tables 46 and 47. Based on the study findings, it has been suggested that a serious night accident problem exists when the ratio of night-day accidents is more than 1.5 times the average ratio for similar locations or sections on the same system of roads and streets. Also, it was found that approximately 25 percent of the travel in urban areas occurs at night.

The study data tend to support the hypothesis that low illumination levels are associated with high accident occurrences. Additional studies, however, should be undertaken to determine the specific effects of various illumination levels on accidents, including the cost-effectiveness of each illumination level.

Table 46. Change in proportion of accidents at night on relighted streets in Kansas City.

Traffic	Vehicles per Hour	Accident Type	Before			After		
				Night			Night	
			Day	Number	Percent	Day	Number	Percent
Light	150 to 500	Property damage	324	201	40	365	200	35
		Injury	47	45	49	57	34	37
		Fatality	3	3	50	2	1	33
Medium	500 to 1,200	Property damage	1,411	828	37	1,443	789	35
		Injury	172	210	55	152	135	47
		Fatality	10	17	63	6	5	45
Heavy	1,200 to 2,400	Property damage	547	323	37	672	340	34
		Injury	75	96	56	59	51	46
		Fatality	3	8	73	2	4	67
Total		Property damage	2,282	1,352	37	2,480	1,329	35
		Injury	294	351	54	268	220	45
		Fatality	16	28	64	10	10	50

Source: HRR 440, Table 2, pg. 23.

Table 47. Fatal and injury accidents after major route relighting in Kansas City.

Lighting Level (EFC)	Route Miles	Day Accidents		Night Accidents					
				Before		After		Change	
		Before	After	Number	Percent	Number	Percent	Number	Percent
0.2 to 0.39	38.7	80	99	67	46	86	46	+19	+28
0.4 to 0.59	40.8	126	99	173	58	82	45	-91	-53
0.6 to 0.79	7.2	45	23	43	49	23	50	-20	-47
0.8 to 0.99	5.9	31	36	72	70	28	44	-44	-61

Source: HRR 440, Table 3, pg. 23.

65. Stover, Vergil G., William G. Adkins, and John C. Goodknight, "Guidelines For Medial and Marginal Access Control on Major Roadways", National Cooperative Highway Research Program Report 93, Highway Research Board, Washington, D.C., 1970.

The objective of this investigation was to develop guidelines for selecting the degree and type of access control for a site specific roadway situation. The scope of the study was limited to a survey of the literature and state-of-the-art practices used in the states. The guidelines suggested for controlling access on roadways in urban areas consisted of the following elements.

- Minimum spacing requirements should be developed for signalized intersections i.e., 1,600 to 2,000 foot (488 to 610 m) spacing on primary arterial highways.

- Reduction or elimination of residential driveways. On secondary arterial roadways, minimum driveway spacing should be one driveway per 200 foot (61 m) of frontage.

- A median width of 16 feet or 4.9 m (14 foot or 4.3 m absolute minimum).

- A minimum spacing for median openings of 500 feet (152.4 m).

- Provision of left-turn storage lanes at median openings.

- Use of a barrier curb to prevent crossing of the median.

- The use of a two-way, left-turn continuous median lane was not recommended for arterial roads on a new location, but they have applications on existing arterial highways.

The guidelines developed by the researchers apply to the control of access on urban arterials and if followed, may lead to a reduction in accidents. However, the guidelines are vague in specifying the choice of median type and other design features based on site specific conditions. Also, the recommendation concerning continuous two-way, left-turn median lanes does not appear to be based on the results of research data.

66. **Telford, Edward T. and Rudolph J. Israel, "Median Study (California)", Highway Research Board Proceedings, Thirty-Second Annual Meeting, Vol. 32, Washington, D.C., 1953.**

The objective of this report was to examine the influence of various median treatments on accident frequency. Accident data were collected for a two year period (1947-48) on suburban and rural highways in California. Only the results of the study pertaining to suburban roadways are discussed below.

A total of 90 miles (145 km) of suburban roadways were included in the study. The median types consisted of undivided roadways, paved traversable, curbed, and barrier type medians. All intersection accidents were eliminated from the accident data base. The results of the investigation are summarized below.

- Narrow deterring medians, including medians with curbs had lower accident rates than other median treatments.
- The accident rates on undivided roadways did not differ substantially from the accident rates on divided roadways for the volume conditions studied.

The sample size on suburban roadways was too small to determine if there was a statistically significant difference in mean accident rates for the median types included in the investigation.

67. **Terry, D.S., and Arthur L. Kassan, "Effects of Paint Channelization on Accidents", Traffic Engineering, Institute of Traffic Engineers, Washington, D.C., December, 1968.**

This study was conducted to determine the effectiveness of paint channelization (left-turn lanes and medians) on an urban arterial roadway in Los Angeles. A 1.14-mile (1.83-km) roadway was evaluated using an 18-month before and after period of study. Also, two adjacent streets were selected as experimental control sections. After the left-turn lanes and median were painted on the study section, total accidents decreased from 129 to 85; an annual reduction of 31 percent which was statistically significant. Also significant were reductions in left-turn accidents (42 percent) and rear-end accidents (50 percent). Injury accidents decreased by 40 percent from 95 before the improvement to 57 after the change. The authors concluded that painted channelization was effective in reducing accident and injury crashes on urban arterial streets.

The authors are one of a very limited number of traffic safety investigators who used control sections to determine the effectiveness of a traffic control feature on urban roadways. The results appear to confirm the findings also reported by other investigators, however, because only one site was studied it was not possible to examine the effects of other variables, i.e., number of streets, signals, driveways, etc. on accidents.

68. **Thomas, Richard C. "Continuous Left-Turn Channelization and Accidents", Traffic Engineering, Vol. 37, No. 3, Institute of Traffic Engineers, Washington, D.C., December, 1966.**

The objective of this study was to examine the relationship between accidents and continuous directional left-turn lanes on urban arterial streets in Denver. The study scope was limited to a one-year before (1961) and one-year after (1963) accident analysis on a 4-mile (6.4-km) urban street carrying four lanes of traffic. The results of the investigation are given below.

- Rear-end type accidents decreased by 52 percent at locations which previously had no left-turn lanes.
- There was a 22 percent decrease in injury accidents on the four-mile (6.4-km) study section.
- Total accidents for the entire project were reduced by 20 percent (462 accidents in the before period and 368 in the after period).

Based on the study findings, the installation of painted channelized left-turn lanes on major arterial streets appears to reduce total accidents and injury crashes. The sample size is too small to permit the identification of other variables, i.e., driveways, average daily traffic, etc. which may also have a significant effect on accidents.

69. **Torres, J.F. "The Effects of Street Geometrics and Signalization on Travel Time and Their Relationships to Traffic Operations Evaluation", Highway Research Record 211, Highway Research Board, Washington, D.C., 1967.**

The purpose of this study was to examine the relationships between travel time on urban arterial streets and specific street characteristics such as geometrics and signalization. The objective of the research was to develop a methodology that could be used to evaluate the effects of roadway improvements on traffic operations based on simple measurements of roadway features. Geometric and operational data were collected on 158 street sections in 7 U.S. cities. Variables collected included volume, pavement width, signal density, speed zoning, and travel time.

The results of the analyses indicated that signal density has a highly significant (statistical) effect on travel time. Lane width, percent of green time, and parking also affect travel time but to a much lesser extent that signal density. A methodology is suggested which can be used to estimate the effects of pavement width, signal density, and volume on travel time.

While accident data were not used in the study, the relationships found between travel time and signal density help provide a link to understanding relationships found between accidents and signal density on urban streets. Thus, hypotheses linking geometric roadway features to operational and accident measures can be formulated. Although the methodology for predicting travel time based on easily obtained geometric features is a desirable product, the use of the procedure given in the paper does not appear to have received widespread use as an evaluation tool. Further research combining the expected values of accident and operational measures based on site specific geometric and environmental characteristics would be an extremely valuable tool for evaluating the effects of alternative countermeasures.

70. **Walton, C. Michael and Randy B. Machemehl, "Continuous Two-Way Left-Turn Median Lanes: An Effective TSM Option", Compendium of Technical Papers, 49th Annual Meeting, Institute of Transportation Engineers, Toronto, Canada, September, 1979.**

The purpose of this study was to identify relationships and characteristics of accidents associated with left-turn lanes and to develop guidelines for selecting median treatments. Regression techniques were used to examine relationships between accidents and site characteristics. Study sites were aggregated into sections of 0.4 miles (0.64 km) in length to provide homogeneous sections. All data were collected on urban roadways in the State of Texas. The following equation was developed to predict the annual number of accidents per mile for site specific conditions on four-lane highways with continuous two-way, left-turn median lanes.

Accidents/mile = -43.5 + 0.00203(ADT)+0.000175(City Population)

+0.491(Number of Driveways/mile or km)

+9.20(Number of Signals/mile or km)

The standard error of the estimate is 33 accidents/mile (or km), the F value is 34 and the value of $R^2 = 0.75$. Estimates of the number of accidents per mile (per km) for four-lane urban sites with two-way, left-turn median lanes and various site characteristics are given in Table 48.

The results of this investigation indicate that urban arterial accident rates are significantly affected by the number of traffic signals per mile (per km), the number of driveways per mile (per km), the city population, and average daily traffic. Data were also collected for raised median sections, however, the data were limited and did not permit the development of comparable regression equations. Operational data, (i.e., lateral placement and maneuvering distance data) were collected and the analyses of these factors indicated that two-way left-turn median lanes 11 and 12 feet (3.4 and 3.7 m) in width had no significant adverse effect on traffic operations, however, lane widths of 15 feet (4.6 m) and more created some driver confusion.

The guidelines for estimating accident frequencies for continuous two-way, left-turn median projects will assist designers and traffic engineers in determining the benefits of using this design feature, however, the user is cautioned to use data within the range of the variables used to develop the regression equations. Unfortunately, these values are not given in the report. Also, other sources must be consulted to estimate benefits of using alternate designs such as raised grass medians with 6-inch concrete curbs.

71. Webb, G.M. "The Relation Between Accidents and Traffic Volumes at Signalized Intersections", Proceedings, Institute of Traffic Engineers, Washington, D.C., 1955.

This study was conducted at 97 signalized intersections in rural, suburban, and urban locations in California to examine the relationships between accidents and traffic volumes. The results of the analysis are summarized below.

- Three-way intersections have fewer accidents with lower posted speeds and more accidents with higher posted speed limits.

Table 48. Estimated accidents per mile on two-way, left-turn median sections.

Four-Lane Urban Streets Average Section Length = 0.44 miles		Under 15,000 ADT (10,540)			15,000 - 20,000 ADT (17,900)			Over 20,000 ADT (26,500)		
		50,000 pop.	250,000 pop.	400,000 pop.	50,000 pop.	250,000 pop.	400,000 pop.	50,000 pop.	250,000 pop.	400,000 pop.
Over 3 spm (4.63)	Over 60 dpm (87.7)	72.3	107.3	133.5	86.4	121.4	147.6	100.6	135.6	161.8
	40-60 dpm (50)	53.9	88.9	115.1	68.0	103.0	129.2	82.2	117.2	143.4
	Under 40 dpm (22.7)	40.4	75.4	101.6	54.5	89.5	115.7	68.7	103.7	129.9
1 - 3 spm (2.0)	Over 60 dpm	48.1	83.1	109.3	62.2	97.2	123.4	76.4	111.4	137.6
	40-60 dpm	29.7	64.7	90.9	43.8	78.8	105.0	58.0	93.0	119.2
	Under 40 dpm	16.2	51.2	77.4	30.8	65.3	91.5	44.5	79.5	105.7
0 spm	Over 60 dpm	29.7	64.7	90.9	43.8	78.8	105.0	58.0	93.0	119.2
	40-60 dpm	11.3	46.3	72.5	25.4	60.4	86.6	39.6	74.6	100.8
	Under 40 dpm	0.0	32.0	59.0	11.9	46.9	73.1	26.1	61.1	87.3

ADT = Weekday Average Daily Traffic
spm = signals/mile
dpm = driveways/mile

( ) = Average values used for table development

Source: Walton and Machemehl, 1979 [70], Table 6, pg. 176.

- Skewed intersections had fewer accidents than cross-type intersections. Seven of the eight semi-urban skewed approaches had 43 percent fewer accidents than the straight legged approaches.

- Intersection approaches on curves had more accidents than approaches with straight sections. Three of the intersections (two semi-urban and one rural) with curved approaches had 30 percent more accidents than the straight legged approaches.

While the results may delineate general relationships, the sample size is too small to permit establishment of statistically valid conclusions.

72. **Wootan, C.V., H.G. Meuth, N.J. Rowan, and T.G. Williams, "A Median Study in Pleasanton-Baytown-San Antonio, Texas", Texas Transportation Institute, Texas A&M University, College Station, Texas, August, 1964.**

This study was conducted to examine the effect of installing a raised curbed median on traffic operations, safety, and the economic activity of local businesses. Three urban sites located in a large, medium, and small town were selected for investigation. Before and after traffic and accident data were collected and analyzed. The data indicated that after the median was installed, there was a significant reduction in rear-end collisions involving vehicles making left-turns. There was an increase in accidents involving drivers making improper lane changes and an increase was reported in fixed-object crashes. In the San Antonio study, total accidents were reduced from 234 to 72 (69 percent) in a one-year before and one-year after period. Personal injury accidents decreased from 40 to 14 (65 percent). The overall effect of the raised median at the study sites was a reduction in traffic accidents.

The study reports provide a comprehensive review of economic and operational effects that are influenced by installing a raised median on an urban arterial street. While there was a significant reduction in accidents due to the installation of the median, the data and number of sites studied are too limited to identify the specific effects of other variables, i.e., signals, driveways, etc. on accident experience.

73. **Wright, Paul H. and King K. Mak, "Statistical Analysis of Single Vehicle Accident Relationships", Traffic Engineering, Vol. 46, No. 1, Institute of Transportation Engineers, Arlington, Virginia, January, 1976.**

The objective of this study was to identify relationships between single-vehicle, fixed-object accidents and roadway features on two-lane urban roadways. Accident and geometric data were collected on 45 sections of two-lane roadway in Atlanta, Georgia. Each section was approximately one mile (1.6 km) in length. The accident data were obtained for a three year period. The dependent variables investigated were single-vehicle, fixedobject accident rate per mile (per km) per year and the singlevehicle, fixed-object accident rate per million vehicle miles (per 1.6 million vehicles km). The roadway and traffic variables and socio-economic variables are shown in Table 49.

Correlation and factor analysis and stepwise multiple linear regression analysis was used to examine relationships between the variables. The correlation coefficients for the roadway and socio-economic variables are given in Tables 50 and 51. Development of a regression equation to predict the off-road accident rate per million vehicle miles (per 1.6 million vehicle km) revealed that average daily traffic, number of curves greater than 4 degrees, and the population density explain 45 percent of the variation in the accident rate. Details of the model are shown in Table 52.

The results of the study indicate that single-vehicle, fixedobject accidents are significantly related to average daily traffic, horizontal curvature, and population density. However, the equations developed do not account for a majority of the variance in accidents and should not be used to predict accident rates on two-lane urban roads. Also, the relation between accidents and population density is of little value as an independent variable because it cannot be controlled through roadway design or traffic regulations.

74. **Zegeer, Charles V., "Identification of Hazardous Locations on City Streets," Research Report 436, Bureau of Highways, Division of Research, Lexington, Kentucky, November, 1975.**

The purpose of the study was to develop a method for identifying hazardous locations in cities with a population exceeding 2,500 persons. Accident data for 1974 were supplied by

Table 49. Roadway, traffic and socio economic variables used to identify relationships between single vehicle, fixed-object accidents and roadway features.

Roadway and Traffic Variables
X_1 = Average daily traffic (ADT)
X_2 = Total pavement width
X_3 = Speed limit (mph or kph)
X_4 = Number of intersections per mile (per km)
X_5 = Number of driveways per mile (per km)
X_6 = Horizontal alinement (No. of curves >4°)
X_7 = Horizontal alinement (Avg. degree of curve for curves >4°)
X_8 = Vertical alinement (percent of roadway with gradient >4 percent)
X_9 = Vertical curvature (percent per station)
X_{10} = Number of discrete objects 0-5 ft. (0-1.6 m) from pavement edge
X_{11} = Continuous objects 0-10 ft. (0-3.1 m) from pavement edge
Socio-Economic Variables
S_1 = Population density (persons per square mile or square km)
S_2 = Driving population (percent of persons 16 years and older)
S_3 = Percent of Negro population
S_4 = Number of housing units per square mile (per square km)
S_5 = Annual median income per housing unit
S_6 = Median number of automobiles per housing unit
S_7 = Median number of years of education
S_8 = Percent of employment
S_9 = Percent driving to work

Source: Traffic Engineering, Vol. 46, No.1

Table 50. Correlation coefficient matrix for roadway and traffic variables.

Variable	1	2	3	4	5	6	7	8	9	10	11
1 ADT	1.00	0.33	0.48	0.14	0.21	-0.26	-0.25	-0.28	-0.26	-0.01	-0.17
2 Pavement Width		1.00	0.38	-0.05	0.06	-0.23	-0.22	-0.11	-0.06	0.23	-0.05
3 Speed limit			1.00	-0.21	-0.25	-0.29	-0.30	-0.15	-0.09	-0.48	0.21
4 Number of Intersections				1.00	0.30	-0.09	-0.22	-0.07	-0.01	0.35	-0.06
5 Number of Driveways					1.00	-0.22	-0.18	0.06	0.15	0.55*	-0.40
6 Number of cruves > 4°						1.00	0.56	0.10	0.12	0.08	-0.08
7 Degree of curve for curves > 4°							1.00	0.22	0.12	0.21	0.05
8 % roadway with gradient > 4°								1.00	0.68	0.17	0.31
9 Vertical curvature									1.00	0.16	0.19
10 Discrete objects, 0-5'										1.00	-0.30
11 Continuous objects, 0-10'											1.00

Source: Wright and Mak, 1976 [73], Table 1, pg. 13.

Table 51. Correlation coefficient matrix for socio-economic variables.

Variable	1	2	3	4	5	6	7	8	9
1 Population density	1.00	-0.01	0.36	0.94	-0.59	-0.73	-0.52	0.11	-0.74
2 Driving population		1.00	-0.59	0.28	0.34	0.37	0.47	0.05	0.44
3 Negro population			1.00	0.15	-0.48	-0.55	-0.43	0.30	-0.66
4 Housing density				1.00	-0.49	-0.61	-0.38	0.17	-0.58
5 Annual income per family					1.00	0.85	0.91	-0.50	0.72
6 Number of automobiles per family						1.00	0.83	-0.12	0.95
7 Years of education							1.00	-0.24	0.72
8 % employment								1.00	-0.00
9 % driving to work									1.00

Source: Wright and Mak, 1976 [73], Table 5, pg. 20.

Table 52. The relationship between off-road accidents per MVM and roadway, traffic and socio-economic characteristics.

$$Y_2 = -0.000097\, X_1 + 0.15\, X_6 + 0.0001\, S_1 + 1.75$$

Variables in Equation

Variable	Coefficient	Standard Error
X_1, ADT	-0.000097	0.000024
X_6, Number of curves > 4°	0.15	0.053
S_1, Population density	0.0001	0.000061

F Ratio = 10.93	$R = 0.67$
Multiple Correlation Coefficient	$R^2 = 0.45$
Standard Error of Estimation	= 0.73

Source: Wright and Mak, 1976 [73], Table 9, pg. 26.

69 Kentucky cities for analysis as shown in Table 53. The average number of accidents and the critical number of accidents for arterial street midblocks and intersections was determined for six population groups and the results are shown in Table 54.

The study provides an effective method of identifying hazardous midblock and intersection locations on urban arterial highways. The average and critical numbers shown in Table 54 are useful for purposes of comparing frequencies obtained in other urban areas, however, these values should only be used as a guideline as the data were obtained only in Kentucky. While the method can be used to identify hazardous locations, it cannot be used to identify specific accident problems or geometric, operational, environmental, and human factor elements that may have contributed to the hazard.

Table 53. Population groups of cities.

POPULATION GROUP	POPULATION	NUMBER OF CITIES
1	Over 200,000	1
2	50,000 to 200,000	3
3	20,000 to 50,000	7
4	10,000 to 20,000	15
5	5,000 to 10,000	28
6	2,500 to 5,000	43

Source: Zegeer, 1975 [74], Table 1, pg. 4

Table 54. Average and critical accidents on arterial collector streets.

POPULATION GROUP	ANNUAL ACCIDENTS PER LOCATION		CRITICAL ACCIDENTS PER LOCATION*	
	MIDBLOCKS	INTERSECTIONS	MIDBLOCKS	INTERSECTIONS
1	5.0	10.2	11	19
2	4.1	6.6	10	14
3	2.7	4.5	7	10
4	1.5	2.4	5	7
5	1.0	1.9	4	6
6	0.8	1.2	4	4

*Computed from $A_c = A_a + 2.576\sqrt{A_a} + 1/2$

Source: Zegeer, 1975 [74], Table 5, pg. 7.

APPENDIX C - SAMPLING PLAN AND DATA COLLECTION PROCEDURE

Introduction

The major efforts of this research included the selection of study sites representative of the population of urban arterial roadways, the collection of detailed roadway elements and accident data, and extensive analyses of these data. To accomplish the study objectives, a comprehensive systematic process was proposed. The process included a sampling plan which outlined the criteria that was used to select the study sites; a data collection plan which identified the variables that were collected and procedure that was followed during the data collection activities; and an analysis plan which described the mathematical techniques that were used to analyze the data. The details of each of the sampling plan and data collection procedure are discussed in the following sections of this appendix to provide guidance to highway officials and future researchers who are interested in the processes used to develop the study results or to those who wish to conduct other analyses using the computerized data base.

Classification of Urban Arterial Roads and Streets

Prior to the devlopment of a sampling plan it was necessary to define the basic characteristics of an urban arterial roadway. While roadways are often classified both functionally and administratively in urban areas, there is no widely accepted standard for differentiating between an urban arterial highway and another type of urban street. Based upon guidelines used in other studies, the following general criteria were used in this research to identify urban arterial streets [1,2,3,]*.

- The roadway must be a signalized surface street or part of a network of signalized surface streets which operate as a system, as opposed to a series of isolated signalized intersections.
- The roadway must provide service for major portions of through traffic.
- The roadway must serve the major activity centers of a metropolitan area, be a high volume travel corridor and give priority service to long distance urban trip desires.

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* The numbers in bracket identifies the publications provided on the reference list in this appendix.

- The roadway must carry a high proportion of total urban area vehicular travel.

- The roadway must serve a major portion of the vehicle trips either entering or leaving the urban area, central business district, or trips within the urban area or between major urban centers, and or intersect major rural roads at the metropolitan boundary.

- Urban freeways, expressways, and other limited access highways are excluded for the purposes of the study.

The selection of urban arterial highways within the context of the study must provide a set of roadways from which a sample suitable for data collection and analysis can be drawn, and provide a basis for the explanation of a portion of the accident variance occurring on urban arterials.

Because there is a wide range of arterial highway facilities classified as arterial, the criteria must be structured in a manner such that identification of urban arterials can occur without difficulty and result in an adequate number of miles of roadway to ensure that all variables that describe the safety characteristics are respresented.

The classification of arterials was based upon the following characteristics.

1. City Population
2. Facility Type
3. Land Use

These characteristics were stratified in the following manner.

1. City Population

    - Large - population over 250,000 persons
    - Medium - population between 50,000 an 250,000 persons
    - Small - population between 2,500 and 50,000 persons

2. Facility Type

    - One-Way
    - Two-Lane/Two-Way
    - Multilane Divided
    - Multilane Undivided

3. Land Use

    - Industrial and Commercial
    - Residential
    - Vacant
    - Other Land Use

The advantages of this scheme include the following items.

- The three-level scheme describing the characteristics of urban arterial streets does not contain a burdensome number of cells.
- The characteristics represent discrete rather than continuous values. The discrete characteristics minimize the arbitrary setting of boundaries within the classification scheme.
- The classification scheme will facilitate identification of arterials within each class, enhancing the probability that every class will contain a sufficient sample.
- By defining a preliminary hypothesis that there will be statistical differences in the accident characteristics between the classes, the scheme provides a basis for beginning an analysis of accident experience for urban arterial roads.

The characteristics selected in the classification scheme were chosen because of their reported relationships with accidents. The relationships between accidents and city population, and accidents and type of facility, and access control are shown in Tables 55 and 56, and in Figure 7. These data also imply that some accident variance can be explained by the stratifications within these roadway characteristics.

Sampling Plan

The purpose of sampling is to collect a manageable amount of data which is representative of the population. To perform an unbiased and reliable analysis of the population of national urban arterial roadway accident experience, it is necessary that a sample data set satisfy several constraints including the following:

1. It must represent a cross section of the United States in terms of various regional, climatological, and terrain conditions.
2. It must have an adequate number of data points for each of several logical categories to be derived from urban area population, type of land use, location within the urbanized area, and type of facility.
3. The error of estimate should be within acceptable limits.
4. It should also meet the target values of fatal accidents, injury accidents and property damage accidents as specified in the Contract.

Table 55. Motor vehicle accidents, deaths, and injuries by city population, 1974.

City Population	Fatal Accidents	Injury Accidents	Property Damage Accidents	Injuries	Deaths No.	Deaths Rate**
Total	40,200	1,200,000	14,400,000	1,800,000	46,200	21.9
Urban	15,000	770,000	10,400,000	1,050,000	16,000	11.4
Over 1,000,000	1,800	150,000	2,000,000	200,000	1,900	10.2
250,000-1,000,000	2,800	150,000	2,300,000	200,000	3,000	12.3
100,000-250,000	2,100	110,000	1,600,000	150,000	2,200	14.5
50,000-100,000	1,900	110,000	1,400,000	150,000	2,000	11.3
10,000-50,000	3,700	150,000	2,050,000	200,000	4,000	9.6
Under 10,000	2,700	100,000	1,050,000	150,000	2,900	13.1

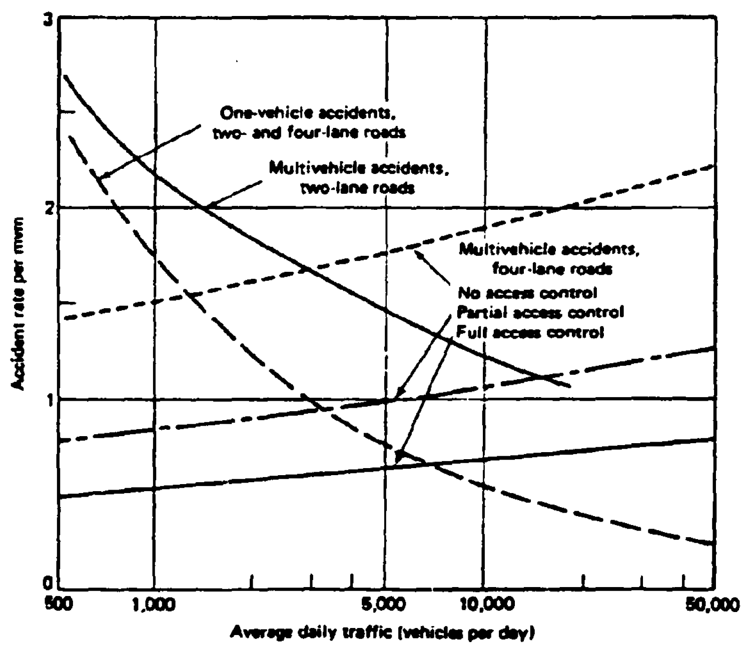
**Deaths per 100,000 population

Source: Accident Facts-1975, National Safety Council, Chicago, Illinois

Table 56. Relationship between city population and traffic fatalities.

City Population	Deaths/100,000 Population	Deaths/10,000 Registered Vehicles
Over 1,000,000	10.1	2.8
750,000-1,000,000	11.4	2.5
500,000-750,000	12.8	2.5
350,000-500,000	14.0	2.4
200,000-350,000	13.3	2.1
100,000-200,000	11.9	2.0
50,000-100,000	9.7	1.6
25,000-50,000	9.3	1.5
10,000-25,000	10.9	1.6
Over 200,000	11.73	
50,000-200,000	10.68	
2,500-50,000	9.94	

Source: Accident Facts-1975 National Safety Council [1]



Source: J.K. Kihlberg and K.J. Tharp, Accident Rates as Related to Design Elements of Rural Highways, Report 48 (Washington, D.C.: Highway Research Board, 1968, p. 23. [2].

Figure 7. Predicted accident rates for various roadway types and access conditions.

To meet the above criteria, the first decision should have involved the random selection of the study cities. However, the study cities were tentatively selected by the Federal Highway Administration. Representatives of 25 candidate urban areas volunteered for this study, and it was decided, based upon practical reasons, to include each of these areas in the study. Preliminary review of the data availability and other factors resulted in the selection of the following urban areas - Boston, Charlottesville, Detroit, Toledo, Lansing, Kalamazoo, Saginaw, Big Rapids, Fort Wayne, Zanesville, Milwaukee, Rochester, Minneapolis, Topeka, New Orleans, San Antonio, Seattle, Santa Fe, Longmont, san Francisco, Milpitas, Coronado, La Mesa, Los Gatos, and Lafayette.

The following are the regional classifications of the candidate urban areas:

Northeast - Boston

Southeast - Charlottesville

North Central - Detroit, Toledo, Lansing, Kalamazoo, Saginaw, Big Rapids, Fort Wayne, Zanesville, Milwaukee, Rochester, Minneapolis, Topeka

South Central - New Orleans, San Antonio

Northwest - Seattle

Southwest - Santa Fe, Longmont, San Francisco, Milpitas, Coronado, La Mesa, Los Gatos, Lafayette

The following are climatological classifications:

Northern - Boston, Charlottesville, Detroit, Toledo, Lansing, Kalamazoo, Saginaw, Big Rapids, Fort Wayne, Zanesville, Milwaukee, Rochester, Minneapolis, Topeka, Longmont

Temperate - New Orleans, San Antonio, Seattle, Sante Fe, San Francisco, Milpitas, Coronado, La Mesa, Los Gatos, Lafayette

The following are terrain classifications:

Generally Flat - Boston, Detroit, Toledo, Lansing, Kalamazoo, Saginaw, Big Rapids, Fort Wayne, Milwaukee, Rochester, Minneapolis, Topeka, New Orleans, San Antonio, Santa Fe, Coronado, Lafayette

Generally Hilly - Charlottesville, Zanesville, Seattle, San Francisco, Milpitas, Longmont, Los Gatos

The sites were preselected based on the willingness of the city representatives to participate, and while the sample of urban areas selected for the study may not statistically unbiased, it does include a wide variation of city types, city sizes, regional classifications, climatological conditions, and terrain classifications. This bias should not affect the study results, since it is anticipated that accident relationships will be more dependent on traffic, geometric, environmental, and other factors than on geographic location.

A roadway length of 0.1 mile was selected as the unit base for data collection and analysis. Data on the characteristics of every 0.1 mile roadway section in the study sites will be collected in the field or extracted from data files, maps, or other sources. The accident data was also recorded for each 0.1 mile of the roadway under study. The variables may then be expressed in terms of accidents per unit, such as accidents per mile or per 0.1 mile segment.

All cities used in this study were required to have at least 3 years of accident records available. The Contract specified that the sample for this study should include at least 1,000 fatal accidents, since fatal accidents are the rarest type of accident. If this requirement is satisfied, it is expected that the total data set will contain the required number of injury and property damage accidents. Based on the unit sample concept presented in the technical proposal, a minimum of 2,002 miles of arterial roadway would be needed to obtain the required 1,000 fatal accident sample for a three-year period. The distribution of these samples are shown in Table 57 for various city sizes.

Table 57. Required miles of arterial roadway.

	City Population			
	over 250,000	50,000 to 250,000	2,500 to 5,000	Total
Total Miles	702	676	624	2,002

A review of the candidate cities was conducted to determine the average number of miles of arterial street per city within each city size category. The review process consisted of map examinations, discussions with city traffic engineers, and site visits. All major streets, county primary roads, State highways, and Federal routes, (except freeways or expressways), were considered to be urban arterial roadways. The average miles of urban arterials per city were 350 miles (large cities), 55 miles (medium cities), and 10 miles (small cities).

Based on average mileage data, an estimate was made of the number of cities which would be required to meet the minimum mileage requirements (2,002 miles), as determined by the unit sample approach. The minimum mileage requirement (based on 3 years of accident data from Table 57) was divided by the average number of arterial miles for each city size category. The required number of cities is shown in Table 58.

Table 58. Required number of cities.

City Size	Number of Years of Accident Data	
	1 Yr. Acc. Data	3 Yr. Acc. Data
Large	6	2
Medium	36	12
Small	186	62

Only 25 urban areas were available to the research team for data collection based on the requirement of a computerized accident reporting system and the interest of the cities in participating in the study. These 25 included 10 large cities, 5 medium cities, and 10 small cities. The number of required small (62) and medium (12) size cities is larger than the number available (10 small and 5 medium cities). Thus, the use of the originally proposed sampling plan would not result in a fatal accident sample of adequate size if data collection was constrained by the total of 25 communities.

As an alternative, a sampling strategy based solely on arterial mileage was developed for this study. The research team believes that a mileage based sample should be used instead of an accident based sample, since the use of an accident based sample could lead to biased results. The use of an accident based sample could lead to the selection of those sites exhibiting unusually high levels of accidents, in order to meet the sample requirements. Selection of an inordinate number of high accident locations would lead to inaccuracies in conclusions made as a result of the analysis. The objective of this mileage based sampling plan is to assure that the number of accidents within each arterial classification cell will be adequate to achieve a predetermined level of confidence. This is accomplished using the standard sampling algorithm for samples randomly selected from a normal distribution. It is the assumption that the frequency of occurrence of accidents is normally distributed across the 0.1 mile sample sections, as shown in Figure 8.

The number of units to be selected can then be determined from the following equation:

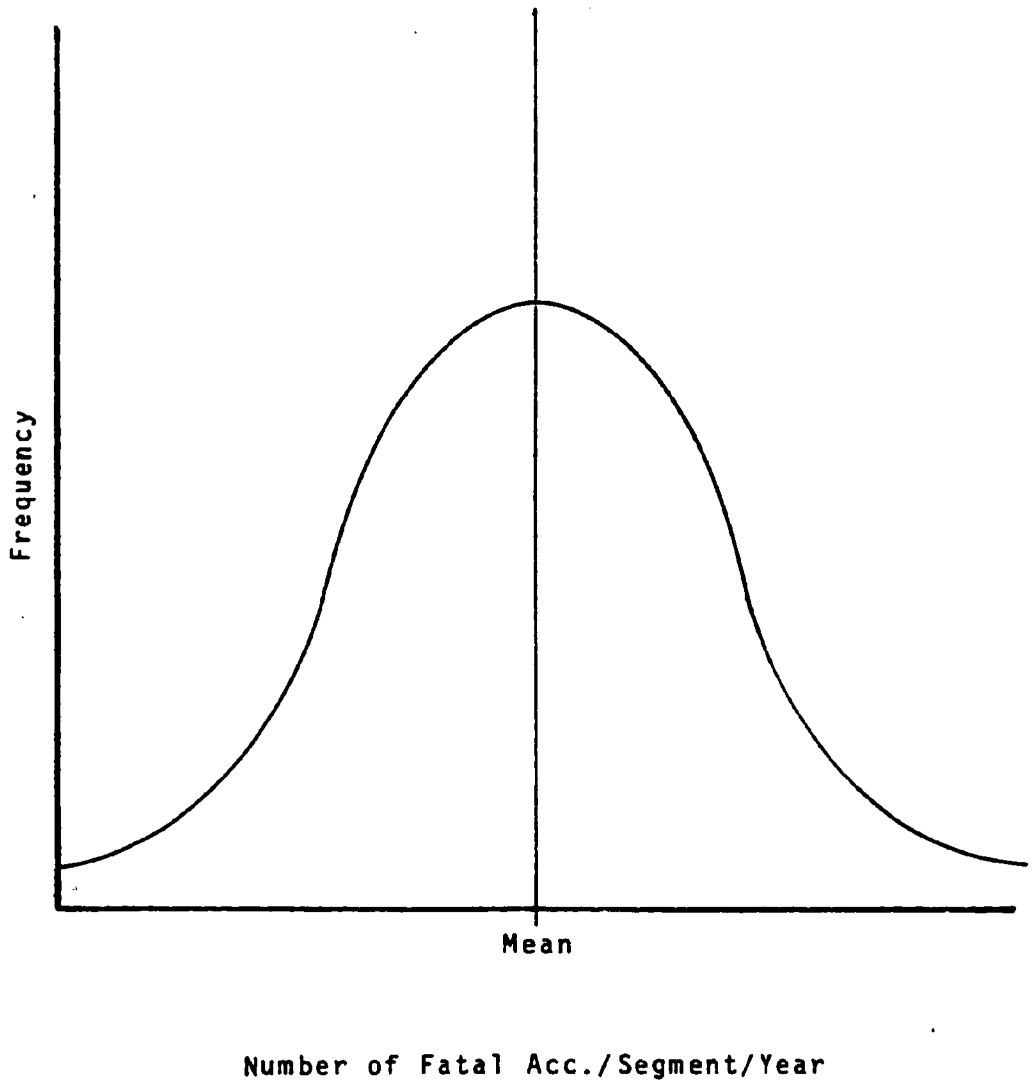


Figure 8. Assumed distribution of accident frequency.

$$n = \frac{K^2 \quad \sigma^2}{e^2}$$

Where:

n = sample size, which is the minimum number of units (a 0.1-mile highway segment) required in the sample (with the average number of fatal accidents per unit being normalized and set equal to 1),

K = the number of standard deviations about the mean, which corresponds to the desired confidence level,

σ = the standard deviation of the number of fatal accidents per mile,

e = the limits of the tolerable error.

The use of the above algorithm requires that certain parameters be prespecified. A level of confidence of 95 percent has been chosen for this application, which corresponds to a K value of 1.96 for the above equation. Also, the relationship between σ (the standard deviation), and e (the limits of tolerable error) is critical. For this analysis, e is set at the level of 0.5 times σ. Setting e at this level means that the total tolerance is equal to one half the standard deviation, which is a conservative estimate. Substituting the above values yields:

$$n^* = \frac{(3.84)}{(.5 \quad)^2} \times \quad \sigma^2 = 15.4$$

Using 0.1667* fatal accidents per mile, the minimum number of 0.1 mile roadway segments necessary for each classification cell is 15/0.1667=90 segments (0.1 mile each) or 9 miles.

Therefore, a sample which contains 15 fatal accidents for each classification cell is required. However, the use of the sampling plan would result in a total sample of only 810 fatal accidents, where 810 is the product of 15 fatal accidents per cell multiplied by 54 classification cells. Based on an annual fatal accident rate of 0.1667 fatal accidents per mile*, this sample will require data from 4859 mile-years of arterial roadway.

To obtain a sample with a minimum of 1,000 fatal accidents, it would be necessary to utilize (1,000/810) or 1.23 times the minimum number of sample units.

---

* Source: National Safety Council, "Accident Facts", 1977.

That is, 4,859 miles x 1.23 = 5,998 mile-years of roadway must be sampled.

Therefore, the total number of road miles required to meet both the minimum sample size requirement for a 95 percent confidence level, and a 1,000 fatal accident minimum is 5,998 miles for a single year of accident data, or 1,999 miles using 3 years of accident data.

Based on the estimate of arterial road mileage and the number of candidate cities, the total number of arterial road miles from which to sample is 3,875 miles, distributed as follows.

10 small cities at 10 miles each = 100 miles
5 medium cities at 55 miles each = 275 miles
10 large cities at 350 miles each = 3,500 miles

Total Miles = 3,875 miles

A comparison of the total number of miles available and the required sample indicates that there are enough miles of total arterial roadway to sample, but the mileage is not distributed uniformly across city size groupings.

To maintain the best possible distribution by city size for the 1,999 miles of sample roadway, the 10 small cities and the 5 medium cities should be sampled at the 100 percent level. This will contribute 375 miles of roadway to the sample. The remaining 1,624 miles will be sampled from the large cities. With 3,500 total arterial miles in large cities, only 46 percent of available mileage for large cities will be necessary:

(1,624 miles/3,500 miles) x 100 = 46 percent

Based on this distirbution of sample miles, the miles per city are given by city size group in Table 59.

Table 59. Sample miles per city.

City Size Group	Number Of Cities Available	Avg. Miles Per City	Estimated Available Arterial Miles	Total Miles To Be Sampled	Percent Of Miles Sampled	Avg. Miles Per City
Large	10	350	3500	1624	46	162
Medium	5	55	275	275	100	55
Small	10	10	100	100	100	10
Total	25	—	3875	1999	52	—

Using a fatal accident rate of 0.5 accidents per mile per 3 years and a sample of 1,999 arterial road miles, 1,000 fatal accidents can be expected from the sample. Assuming a ratio of fatal to injury accidents of 1 to 30 and fatal to property damage of 1 to 360, as taken from National Safety Council Accident Facts, it is anticipated that about 30,000 injury accidents and about 360,000 property damage accidents will be in the sample data set collected.

As part of the analysis of the street networks for available cities, an estimate of the distribution of the arterial road miles within the classification plan was made. The results of this analysis are presented in Table 60, which gives the expected distribution of mileages based on the average mileage for each city size. The total number of miles by cell that will be sampled in this project is given in Table 61.

The selection of candidate arterial roadway segments from the large cities will be made using random number tables. This process included:

- Establishing a roadway segment selection rule. For example, all candidate roadway segments can be sequentially arranged and tested against a random number generated or selected from a statistical table. If, for example, the random number is odd the roadway segment will be selected. If the number is even the roadway segment will be rejected. The process will be continued or each city until the required number of roadway samples have been obtained.

As the sampling of road miles reaches a conclusion, each cell within the classification plan will be reviewed and a check will be made as to the sample size within each. At that time, the confidence level for each cell will be determined.

There is still some uncertainty as to the total number of fatal accidents that will be included in the sample, since the sampling plan was based on certain assumptions. For example, the assumption was made that the rate of 0.1667 fatal accidents per mile was applicable across all city sizes and all arterial classifications. If the assumption is not valid, the sample will not contain the prescribed 1,000 fatal accidents.

In calculation of the number of sample units required, the assumption was made that each year of a three year accident history on a unit segment of roadway constituted an independent sample point. Thus, when determining the sample size to be used, the assumption was made that the same of the three years of data would be condensed for this analysis. It is anticipated that these minor assumptions will not result in a biased sample. In fact, they are of much lesser significance than the lack of an adequate number of sample miles from small and medium size cities - a factor which was not within the control of the research team.

Table 60. Estimated number of miles available from 25 candidate cities*.

	1 Way & Div.	2 Ln 2 Way	Multi Ln 2 Way
10 Large City			
Industrial & Commercial			
CBD	140	140	420
FR	84	84	252
OL	56	56	168
Residential & Vacant			
CBD	84	84	252
FR	105	105	315
OL	231	231	693
5 Medium City			
Industrial & Commercial			
CBD	16.5	16.5	49.5
FR	7.0	7.0	20.5
OL	4.1	4.1	12.5
Residential & Vacant			
CBD	4.0	4.0	12.5
FR	7.0	7.0	20.5
OL	16.5	16.5	49.5
10 Small City			
Industrial & Commercial			
CBD	9.0	9.0	27.0
FR	1.8	1.8	5.0
OL	1.2	1.2	4.0
Residential & Vacant			
CBD	1.2	1.2	4.0
FR	2.0	2.0	6.0
OL	4.8	4.8	14.0

* Derived from the current candidate cities.

Table 61. Number of miles from candidate cities using three years accident data.

	1 Way & Div.	2 Ln 2 Way	Multi Ln 2 Way
Large City			
Industrial & Commercial			
CBD	64.4	64.4	193.2
FR	38.6	38.6	115.9
OL	25.8	25.8	77.3
Residential & Vacant			
CBD	38.6	38.6	115.9
FR	48.3	48.3	144.9
OL	106.3	106.3	318.8
Medium City			
Industrial & Commercial			
CBD	16.5	16.5	49.5
FR	7.0	7.0	20.5
OL	4.1	4.1	12.5
Residential & Vacant			
CBD	4.0	4.0	12.5
FR	7.0	7.0	20.5
OL	16.5	16.5	49.5
Small City			
Industrial & Commercial			
CBD	9.0	9.0	27.0
FR	1.8	1.8	5.0
OL	1.2	1.2	4.0
Residential & Vacant			
CBD	1.2	1.2	4.0
FR	2.0	2.0	6.0
OL	4.8	4.8	14.0

Accident Data Sources

The data analysis performed in this study requires the accumulation of accident data from a number of candidate city locations. This accumulation necessitates a procedure whereby accident data from variables sources is reformatted into a standard form. In addition to the accident information, the final data record will contain the associated roadway and environmental characteristics pertaining to the particular 0.1 mile segment.

The existence of a computerized accident inventory system greatly enhances the task of data collection. If accidents are located by a node and/or mile point convention, it is rather easy to select the accidents for a particular section of arterial roadway. Generally, accident data is entered into a computerized inventory system through the following procedure as shown in Figure 9.

Source Document

The source document, accident report, is prepared by the officer investigating the accident. Generally, the location of the accident is identified by specifying the county, city, or township and the distance and direction from some reference point.

Data Review

Accident reports are collected at a centralized location and reviewed. This review process assures that the form is complete as prepared by the officer and in some cases, allows for the addition of supplemental information. This additional information may include such data as street type, node designations, link designations, roadway defects, etc.

Data Entry

Upon completion of the review, the accident reports are transferred to computer media, either punched cards or magnetic tape and submitted for processing.

Processing

Based on the design of the inventory system, a variety of processing may be performed on the accident reports at this time. Systems that utilize a geographic location file will access that file and generate the corresponding location appendix for each accident. Generally,

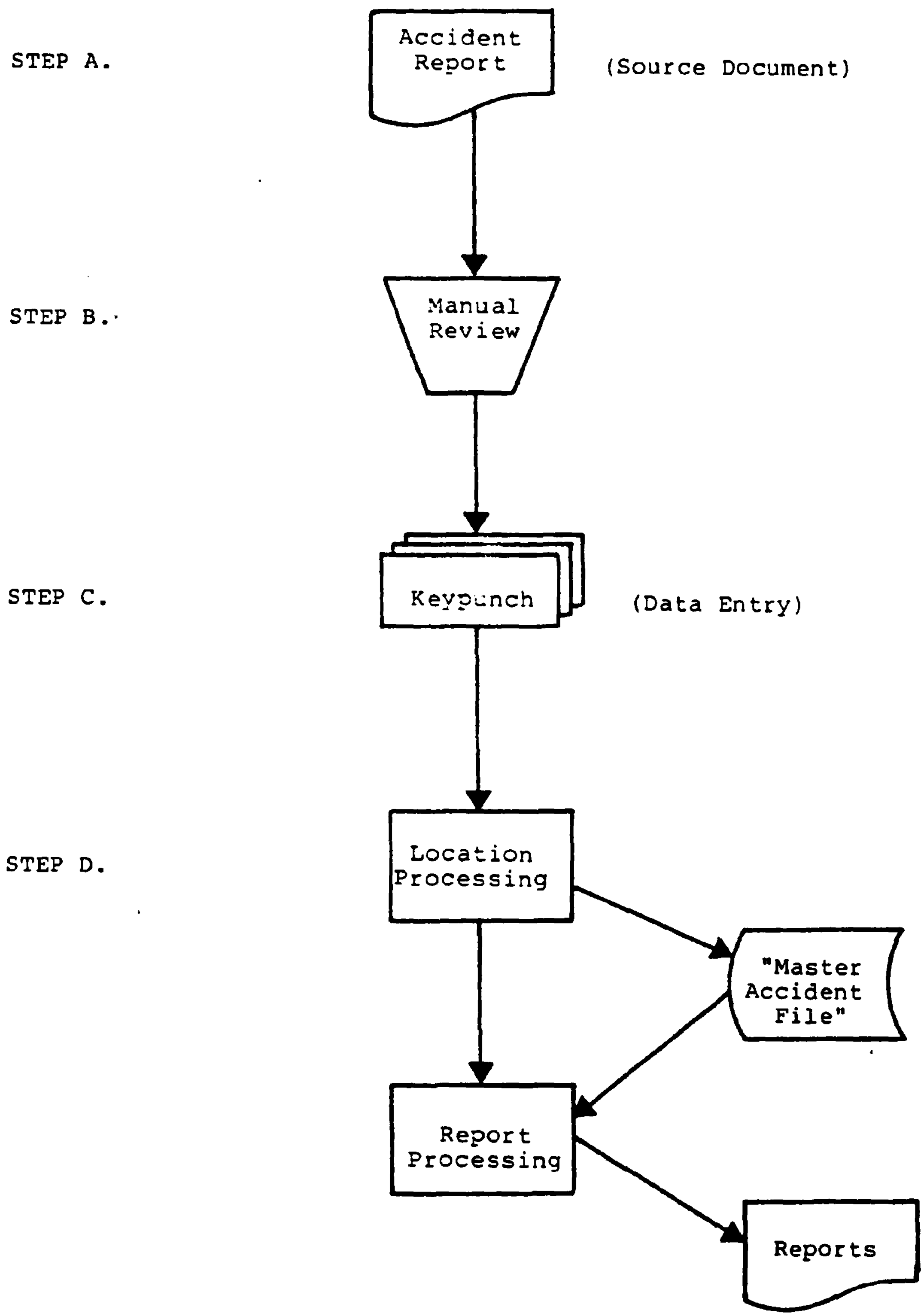


Figure 9. Computerized accident inventory procedure.

some reformating and data expansion is also accomplished during this task. The last step of this procedure provides for the merging of each accepted and located accident to the Master Accident File.

Reports

After the Master Accident File is formed, there are a variety of reports which may be generated from the data base. Many times these reports make use of supplemental information such as; volume files, roadway configurations, traffic characteristics, and driver files.

The data analysis for this study required roadway segments of 0.1 mile. The data records come from the Master Accident File of a computerized system (Step D above). Additionally, the records would contain a unique roadway identity and some form of mileage point indication. Availability of data records containing the above information would require the least amount of additional processing. Initially, all that would be required is one program to reformat the records into a single standard record format.

Accident records available only from Step C (Data Entry), requires extensive time and manual processing. Each record had to be altered to include the information necessary to assign the accident to a particular 0.1 mile roadway segment. In addition to developing programs to alter the data, man-hours were expended determining the correct street identity and location distance. These records were processed through a program to reformat the data into a single standard record format.

In the worst case, accident data were obtainable only from Step A (Source Document) or Step B (Data Review). Extreme effort had to be expended verifying the source document and supplying additional information such a standardized location information (both street names and distances). In both cases, the source document must be key punched and verified prior to the processes explained for Step C.

Clearly, with the volume of data anticipated (some 100,000 accidents) it is desirable to obtain all accident records from a computerized Master Accident File. The data available from each of the candidate cities was reviewed and classified to it's acceptance in terms of the above steps. To this end, a preliminary form was developed to document and classify the accident data available from each candidate city. A sample form is included as Figure 10. Further, refinement and procedural steps were needed for those cities where data is available only form Steps A, B or C. A summary of the accident data availability for the cities contacted in this study is provided on the following accident data classification forms.

ACCIDENT DATA CLASSIFICATION

City: ______________________________ Date: ________________

1. How many years of accident data exist? ________

2. Is a record description (format) available? ________

3. Does G&G have a copy of the record description (format)? ________

4. How is the location of the accident defined? (Describe)

____

____

____

5. Is there a unique code (node number of link #) relating to the accident location? ________

6. Is a distance from a reference point (node) available? ________

7. Is the file available on magnetic tape (1600 bpi)? ________

8. Indicate Step data is available from:
   A. Source Document
   B. Data Review
   C. Date Entry
   D. Past Location Processing ________

9. Is further investigation of manual processing warranted? ________

Figure 10. Accident data classification.

ACCIDENT DATA CLASSIFICATION

City: Kalamazoo, MICH Date: 5-7-79

1. How many years of accident data exist? 5 yrs
2. Is a record description (format) available? yes
3. Does G&G have a copy of the record description (format)? yes
4. How is the location of the accident defined? (Describe)

Distance and Direction from intersection (node) and mileage point of accident

MALI

5. Is there a unique code (node number of link #) relating to the accident location? yes
6. Is a distance from a reference point (node) available? yes
7. Is the file available on magnetic tape (1600 bpi)? yes
8. Indicate Step data is available from:
    - A. Source Document
    - B. Data Review
    - C. Date Entry
    - D. Past Location Processing

   D
9. Is further investigation of manual processing warranted? no

ACCIDENT DATA CLASSIFICATION

City: Lansing MICH Date: 5-7-78

1. How many years of accident data exist? 5

2. Is a record description (format) available? yes

3. Does G&G have a copy of the record description (format)? yes

4. How is the location of the accident defined? (Describe)

MALI

5. Is there a unique code (node number of link #) relating to the accident location? yes

6. Is a distance from a reference point (node) available? yes

7. Is the file available on magnetic tape (1600 bpi)? yes

8. Indicate Step data is available from:
   A. Source Document
   B. Data Review
   C. Date Entry
   D. Past Location Processing D

9. Is further investigation of manual processing warranted? no

ACCIDENT DATA CLASSIFICATION

City: Royal Oak, Mich   Date: 5-7-79

1. How many years of accident data exist? 4
2. Is a record description (format) available? yes
3. Does G&G have a copy of the record description (format)? yes
4. How is the location of the accident defined? (Describe)

   [illegible]

5. Is there a unique code (node number of link #) relating to the accident location? yes
6. Is a distance from a reference point (node) available? yes
7. Is the file available on magnetic tape (1600 bpi)? yes
8. Indicate Step data is available from:
   A. Source Document
   B. Data Review
   C. Date Entry
   D. Past Location Processing
   D
9. Is further investigation of manual processing warranted? no

ACCIDENT DATA CLASSIFICATION

City: Saginaw MICH Date: 5-7-79

1. How many years of accident data exist? 5

2. Is a record description (format) available? yes

3. Does G&G have a copy of the record description (format)? yes

4. How is the location of the accident defined? (Describe)

MALI

5. Is there a unique code (node number of link #) relating to the accident location? yes

6. Is a distance from a reference point (node) available? yes

7. Is the file available on magnetic tape (1600 bpi)? yes

8. Indicate Step data is available from:
   A. Source Document
   B. Data Review
   C. Date Entry
   D. Past Location Processing D

9. Is further investigation of manual processing warranted? no

ACCIDENT DATA CLASSIFICATION

City: Southfield MICH Date: 5-2-79

1. How many years of accident data exist? 4
2. Is a record description (format) available? yes
3. Does G&G have a copy of the record description (format)? yes
4. How is the location of the accident defined? (Describe)

   MALT

5. Is there a unique code (node number of link #) relating to the accident location? yes
6. Is a distance from a reference point (node) available? yes.
7. Is the file available on magnetic tape (1600 bpi)? yes
8. Indicate Step data is available from:
   - A. Source Document
   - B. Data Review
   - C. Date Entry
   - D. Past Location Processing

   D
9. Is further investigation of manual processing warranted? NO

ACCIDENT DATA CLASSIFICATION

City: Big Rapids MICH Date: 5-7-79

1. How many years of accident data exist? 2
2. Is a record description (format) available? yes
3. Does G&G have a copy of the record description (format)? yes
4. How is the location of the accident defined? (Describe)

   MIFIT

5. Is there a unique code (node number of link #) relating to the accident location? Yes
6. Is a distance from a reference point (node) available? yes
7. Is the file available on magnetic tape (1600 bpi)? yes
8. Indicate Step data is available from:
   - A. Source Document
   - B. Data Review
   - C. Date Entry
   - D. Past Location Processing

   D
9. Is further investigation of manual processing warranted? n.

ACCIDENT DATA CLASSIFICATION

City: Birmingham MICH Date: 5-7-79

1. How many years of accident data exist? 4
2. Is a record description (format) available? yes
3. Does G&G have a copy of the record description (format)? yes
4. How is the location of the accident defined? (Describe)

   MiALE

5. Is there a unique code (node number of link #) relating to the accident location? yes
6. Is a distance from a reference point (node) available? yes
7. Is the file available on magnetic tape (1600 bpi)? yes
8. Indicate Step data is available from:
   - A. Source Document
   - B. Data Review
   - C. Date Entry
   - D. Past Location Processing

   D
9. Is further investigation of manual processing warranted? no

ACCIDENT DATA CLASSIFICATION

City: Farmington MICH Date: 5-7-79

1. How many years of accident data exist? 4
2. Is a record description (format) available? yes
3. Does G&G have a copy of the record description (format)? yes
4. How is the location of the accident defined? (Describe)

   MALT

5. Is there a unique code (node number of link #) relating to the accident location? yes
6. Is a distance from a reference point (node) available? yes
7. Is the file available on magnetic tape (1600 bpi)? yes
8. Indicate Step data is available from:
   - A. Source Document
   - B. Data Review
   - C. Date Entry
   - D. Past Location Processing

   D
9. Is further investigation of manual processing warranted? no

ACCIDENT DATA CLASSIFICATION

City: Farmington Hills Mich   Date: 5-7-79

1. How many years of accident data exist? 4

2. Is a record description (format) available? yes

3. Does G&G have a copy of the record description (format)? yes

4. How is the location of the accident defined? (Describe)

MALI

5. Is there a unique code (node number of link #) relating to the accident location? yes

6. Is a distance from a reference point (node) available? yes

7. Is the file available on magnetic tape (1600 bpi)? yes

8. Indicate Step data is available from:
   A. Source Document
   B. Data Review
   C. Date Entry
   D. Past Location Processing
   D

9. Is further investigation of manual processing warranted? no

ACCIDENT DATA CLASSIFICATION

City: Novi Mich Date: 5-7-79

1. How many years of accident data exist? 4
2. Is a record description (format) available? yes
3. Does G&G have a copy of the record description (format)? yes
4. How is the location of the accident defined? (Describe)

   MALI

5. Is there a unique code (node number of link #) relating to the accident location? yes
6. Is a distance from a reference point (node) available? yes
7. Is the file available on magnetic tape (1600 bpi)? yes
8. Indicate Step data is available from:
   A. Source Document
   B. Data Review
   C. Date Entry
   D. Past Location Processing D
9. Is further investigation of manual processing warranted? No

ACCIDENT DATA CLASSIFICATION

City: Oak Park, MICH Date: 5-2-79

1. How many years of accident data exist? 4
2. Is a record description (format) available? Yes
3. Does G&G have a copy of the record description (format)? Yes
4. How is the location of the accident defined? (Describe)

   MALT

5. Is there a unique code (node number of link #) relating to the accident location? Yes
6. Is a distance from a reference point (node) available? Yes
7. Is the file available on magnetic tape (1600 bpi)? Yes
8. Indicate Step data is available from:
   A. Source Document
   B. Data Review
   C. Date Entry
   D. Past Location Processing D
9. Is further investigation of manual processing warranted? No

ACCIDENT DATA CLASSIFICATION

City: Troy Mich Date: 5-7-79

1. How many years of accident data exist? 4

2. Is a record description (format) available? yes

3. Does G&G have a copy of the record description (format)? yes

4. How is the location of the accident defined? (Describe)

MALI

5. Is there a unique code (node number of link #) relating to the accident location? yes

6. Is a distance from a reference point (node) available? yes

7. Is the file available on magnetic tape (1600 bpi)? yes

8. Indicate Step data is available from:
    A. Source Document
    B. Data Review
    C. Date Entry
    D. Past Location Processing D

9. Is further investigation of manual processing warranted? no

ACCIDENT DATA CLASSIFICATION

City: Minneapolis Minn   Date: 5-8-79

1. How many years of accident data exist? 4 (3)
2. Is a record description (format) available? yes
3. Does G&G have a copy of the record description (format)? no
4. How is the location of the accident defined? (Describe)

   Distance + Dir. [illegible]

5. Is there a unique code (node number of link #) relating to the accident location? [illegible]
6. Is a distance from a reference point (node) available? yes
7. Is the file available on magnetic tape (1600 bpi)? yes
8. Indicate Step data is available from:
   - A. Source Document
   - B. Data Review
   - C. Date Entry
   - D. Past Location Processing D
9. Is further investigation of manual processing warranted? no

ACCIDENT DATA CLASSIFICATION

City: Charlottesville Va Date: 5-8-79

1. How many years of accident data exist? 4
2. Is a record description (format) available? yes
3. Does G&G have a copy of the record description (format)? no
4. How is the location of the accident defined? (Describe)

   link & node

5. Is there a unique code (node number of link #) relating to the accident location? yes
6. Is a distance from a reference point (node) available? yes
7. Is the file available on magnetic tape (1600 bpi)? yes
8. Indicate Step data is available from:
   - A. Source Document
   - B. Data Review
   - C. Date Entry
   - D. Past Location Processing D
9. Is further investigation of manual processing warranted? no

ACCIDENT DATA CLASSIFICATION

City: Longmont Co   Date: 5-8-79

1. How many years of accident data exist? ~2
2. Is a record description (format) available? yes
3. Does G&G have a copy of the record description (format)? no
4. How is the location of the accident defined? (Describe)

   Intersection Distance from
   street intersection

5. Is there a unique code (node number of link #) relating to the accident location? yes
6. Is a distance from a reference point (node) available? yes
7. Is the file available on magnetic tape (1600 bpi)? no
8. Indicate Step data is available from:
   A. Source Document
   B. Data Review
   C. Date Entry
   D. Past Location Processing

   D
9. Is further investigation of manual processing warranted? no

ACCIDENT DATA CLASSIFICATION

City: Santa Fe, N.M. Date: 5-8-79

1. How many years of accident data exist? 2
2. Is a record description (format) available? Yes
3. Does G&G have a copy of the record description (format)? Yes
4. How is the location of the accident defined? (Describe)

   Dist. + Dir. from intersection.

5. Is there a unique code (node number of link #) relating to the accident location? Yes
6. Is a distance from a reference point (node) available? Yes
7. Is the file available on magnetic tape (1600 bpi)? No
8. Indicate Step data is available from:
   A. Source Document
   B. Data Review
   C. Date Entry
   D. Past Location Processing

   D
9. Is further investigation of manual processing warranted? No

ACCIDENT DATA CLASSIFICATION

City: Milwaukee Wisconsin Date: 5-7-79

1. How many years of accident data exist? 10
2. Is a record description (format) available? yes
3. Does G&G have a copy of the record description (format)? No
4. How is the location of the accident defined? (Describe)

   node + link
   node = 2 street names
   link = [illegible] Number

5. Is there a unique code (node number of link #) relating to the accident location? yes
6. Is a distance from a reference point (node) available? ?
7. Is the file available on magnetic tape (1600 bpi)? ?
8. Indicate Step data is available from:
   A. Source Document
   B. Data Review
   C. Date Entry
   D. Past Location Processing
   C
9. Is further investigation of manual processing warranted? yes

ACCIDENT DATA CLASSIFICATION

City: Toledo OH Date: 5-7-79

1. How many years of accident data exist? 2

2. Is a record description (format) available? [illegible]

3. Does G&G have a copy of the record description (format)? [illegible]

4. How is the location of the accident defined? (Describe)

   [illegible]

   [illegible]

   [illegible]

5. Is there a unique code (node number of link #) relating to the accident location? [illegible]

6. Is a distance from a reference point (node) available? yes

7. Is the file available on magnetic tape (1600 bpi)? [illegible]

8. Indicate Step data is available from:
   A. Source Document
   B. Data Review
   C. Date Entry
   D. Past Location Processing [illegible]

9. Is further investigation of manual processing warranted? [illegible]

ACCIDENT DATA CLASSIFICATION

City: Fort Wayne Ind Date: 5-7-79

1. How many years of accident data exist? 9

2. Is a record description (format) available? ______

3. Does G&G have a copy of the record description (format)? no

4. How is the location of the accident defined? (Describe)

[illegible]

5. Is there a unique code (node number of link #) relating to the accident location? yes

6. Is a distance from a reference point (node) available? ?

7. Is the file available on magnetic tape (1600 bpi)? ______

8. Indicate Step data is available from:
   A. Source Document
   B. Data Review
   C. Date Entry
   D. Past Location Processing

   C

9. Is further investigation of manual processing warranted? yes

ACCIDENT DATA CLASSIFICATION

City: Zanesville Oh Date: 5-9-79

1. How many years of accident data exist? ________

2. Is a record description (format) available? ________

3. Does G&G have a copy of the record description (format)? ________

4. How is the location of the accident defined? (Describe)

____

____

____

5. Is there a unique code (node number of link #) relating to the accident location? ________

6. Is a distance from a reference point (node) available? ________

7. Is the file available on magnetic tape (1600 bpi)? ________

8. Indicate Step data is available from:
   - A. Source Document
   - B. Data Review
   - C. Date Entry
   - D. Past Location Processing ________

9. Is further investigation of manual processing warranted? yes

ACCIDENT DATA CLASSIFICATION

City: Rochester, Minn Date: 5-8-71

1. How many years of accident data exist? 5
2. Is a record description (format) available? yes
3. Does G&G have a copy of the record description (format)? no
4. How is the location of the accident defined? (Describe)

   intersection + mid block

5. Is there a unique code (node number of link #) relating to the accident location? [illegible]
6. Is a distance from a reference point (node) available?
7. Is the file available on magnetic tape (1600 bpi)? [illegible]
8. Indicate Step data is available from:
   A. Source Document
   B. Data Review
   C. Date Entry
   D. Past Location Processing

   C
9. Is further investigation of manual processing warranted? yes

ACCIDENT DATA CLASSIFICATION

City: Burton Miss   Date: 5-8-78

1. How many years of accident data exist? 4
2. Is a record description (format) available? yes
3. Does G&G have a copy of the record description (format)? no
4. How is the location of the accident defined? (Describe)

   link node

5. Is there a unique code (node number of link #) relating to the accident location? yes
6. Is a distance from a reference point (node) available? ?
7. Is the file available on magnetic tape (1600 bpi)? yes
8. Indicate Step data is available from:
   - A. Source Document
   - B. Data Review
   - C. Date Entry
   - D. Past Location Processing

   C
9. Is further investigation of manual processing warranted? yes

ACCIDENT DATA CLASSIFICATION

City: San Francisco, Ca. Date: 5-8-79

1. How many years of accident data exist? 4

2. Is a record description (format) available? [illegible]

3. Does G&G have a copy of the record description (format)? [illegible]

4. How is the location of the accident defined? (Describe)

   [illegible]

5. Is there a unique code (node number of link #) relating to the accident location? [illegible]

6. Is a distance from a reference point (node) available? [illegible]

7. Is the file available on magnetic tape (1600 bpi)? [illegible]

8. Indicate Step data is available from:
   A. Source Document
   B. Data Review
   C. Date Entry
   D. Past Location Processing

9. Is further investigation of manual processing warranted? [illegible]

ACCIDENT DATA CLASSIFICATION

City: Seattle [illegible] Date: 5-8-79

1. How many years of accident data exist? 3

2. Is a record description (format) available? [illegible]

3. Does G&G have a copy of the record description (format)? [illegible]

4. How is the location of the accident defined? (Describe)

[illegible]

5. Is there a unique code (node number of link #) relating to the accident location? [illegible]

6. Is a distance from a reference point (node) available? ?

7. Is the file available on magnetic tape (1600 bpi)? [illegible]

8. Indicate Step data is available from:
   A. Source Document
   B. Data Review
   C. Date Entry
   D. Past Location Processing
   C

9. Is further investigation of manual processing warranted? [illegible]

ACCIDENT DATA CLASSIFICATION

City: [illegible] Date: [illegible]

1. How many years of accident data exist? 3
2. Is a record description (format) available? [illegible]
3. Does G&G have a copy of the record description (format)? [illegible]
4. How is the location of the accident defined? (Describe)

   [illegible]

5. Is there a unique code (node number of link #) relating to the accident location? [illegible]
6. Is a distance from a reference point (node) available? [illegible]
7. Is the file available on magnetic tape (1600 bpi)? [illegible]
8. Indicate Step data is available from:
   - A. Source Document
   - B. Data Review
   - C. Date Entry
   - D. Past Location Processing

   C
9. Is further investigation of manual processing warranted? [illegible]

ACCIDENT DATA CLASSIFICATION

City: [illegible] Date: 5-8-79

1. How many years of accident data exist? 3
2. Is a record description (format) available? Yes
3. Does G&G have a copy of the record description (format)? Yes
4. How is the location of the accident defined? (Describe)

   [illegible]

5. Is there a unique code (node number of link #) relating to the accident location? Yes
6. Is a distance from a reference point (node) available? No
7. Is the file available on magnetic tape (1600 bpi)? [illegible]
8. Indicate Step data is available from:
   - A. Source Document
   - B. Data Review
   - C. Date Entry
   - D. Past Location Processing

   C
9. Is further investigation of manual processing warranted? Yes

Selection of Data Variables

As a major activity in the development of the data collection plan, variables involved or associated with the urban arterial and the urban arterial accident were identified and reviewed. The identification process was intitiated by a literature search for variables that have been to some degree previously identified with the urban arterial or urban arterial accidents and possibly have had some relationship developed. However, the process also involves the practical and research experience of the research team members. The variables identified by these sources are compiled and then reviewed for their suitability to be included in the final list of variables. Review of the variables involves the consideration of at least the following items: previous determined relationships that have related the variable to the urban arterial or the urban arterial accident; availability of such variables in existing data files or for collection in the field; and the amount of processing necessary to place the variable in the proper form for analysis. The review process evaluates the practicality of each candidate variable for use in describing more completely the urban arterial accident and the factors that may characterize urban arterial accidents.

Four major categories of variables were considered, physical, traffic, control, and environmental. The variables may also be described in terms of descriptive, exposure breakdowns and locational factors. The following variables were included in the analysis:

		Section Descriptors	Spot Descriptors
• Locational	Average Daily Traffic	X	X
• Locational	Speed Limit	X	X
• Locational	Average Operating Speed	X	
• Locational	Number of Lanes/Lane Width	X	X
• Locational	Type of Condition of Pavement	X	X
• Locational	Horizontal Curvature		X
• Locational	Vertical Curvature		X
• Locational	Type of Object Struck		X
• Locational	Extent of Illumination		X
• Locational	Traffic Control Devices	X	X
• Exposure	Driveways Per Mile	X	
• Exposure	Intersections Per Mile	X	
• Exposure	Utility Poles Per Mile	X	
• Exposure	No. of Fixed Objects Per Mile	X	
• Exposure	Bus Stops Per Mile	X	
• Locational	Locations of Accidents		X
• Locational	Driver Information Load	X	X

Each of the variables listed above require further definition as to the stratification and detail to be obtained. The designation as a section or spot descriptor relates to the applicability of the variable to either spot locations (intersections) or sections of the arterial roadway.

In addition, variables to describe such items as weather conditions, winter maintenance procedures, location within the urban area and levels of police enforcement may be included. Such variables include the following:

	Section Descriptors	Spot Descriptors
• Pounds of Salt Application per Mile	X	
• Wind Direction and Intensity	X	X
• Barometric Pressure	X	X
• Direction of Major Street	X	X
• Miles from CBD		X
• Bus Headways	X	
• Number of Citations per Day	X	
• Patrol Hours per Day	X	
• Vehicle Miles of Police Patrols per Day	X	

The identification and review procedure is a pre-requisite to the data collection plan and analysis approach. The analysis plan will define the analysis techniques that will be utilized and the order in which they will be used. The techniques may require the preparation of data in specific forms in order that the analysis can take place. The sampling plan will define the amount of data to be collected in order that the objective level of significance can be maintained. Therefore, the variables were reviewed for their consistency with the analysis techniques and the levels of significance in order that each selected variable can contribute the utmost to the analysis.

For each of the variables listed previously, a number of associated (secondary) variables were defined. The following list illustrates these variables.

Primary Variable	Secondary Variable
• Average Daily Traffic	Highest hourly volume count, percent highest hourly count to average daily traffic, length of peak period, vehicle mix, peak hour factors, hourly traffic at the time of the accident, V/C

Primary Variable	Secondary Variable
• Speed Limit	Speed limit changes per mile, general vs. speed zone.
• Average Operating Speed	Off peak speed, peak period speeds, differences in speeds by direction, speed at the time of the accident.
• Number of Lanes/Lane Width	Crown rate, curbs/shoulders, median width.
• Type and Condition of Pavement	Surface type, type of skid treatment, joint spacing.
• Horizontal Curvature	Sight distance-degree of curvature, amount of superelevation, superelevation run off, amount of cross-slope, location of point of rotation, pavement widenings, curve radius, design speed, ratio of curve design speed to tangent design speed.
• Vertical Curvature	Sight distance, average grade, rate of vertical curvature.
• Type of Object Structure	Type of anchorage, distance from edge of road, slope to object continuous vs. single objects, location of object (on curve vs. tangent section).
• Extent of Illumination	Average intensity, luminaire spacing, luminaire height, color of light, uniformity.
• Traffic Control Devices	Number traffic signals per mile, number of signs per mile, existence of pavement markings, types of pavement markings, sizes of signal lenses, types of device mountings.
• Driveways Per Mile	Types of driveways per mile, traffic controls at driveways, radius of curvature at entrances and exists, driveway volumes.

Primary Variable	Secondary Variable
• Intersections Per Mile	Geometrics, type of traffic control, left turn prohibitions, left turn facilities.
• Utility Poles Per Mile	Type of materials, type of foundation, distance from edge of curb, luminaire mounting.
• Number of Fixed Objects Per Mile	Distance from edge of curb, type of object, location on curve vs. tangent section.
• Bus Stops Per Mile	Nearside/farside location, headways, bus turnouts.
• Locations of Accidents	Intersection/midblock/driveway.
• Driver Information Load	Bicycle path, distance of buildings from roadway, type of roadside development, rail highway crossings, pedestrian volumes, left and right turn volumes, signalized vs. non-signalized, number of signs per mile.

Based upon the literature review, and other sources previously discussed, the list shown in Tables 62 and 63 were defined. The variables are separated into two major categories, intersections and road sections.

Using this shopping list of variables, a review of each was conducted to eliminate redundant and related items from the list. As a result of this review, a reduced variable was defined, as was a list of redundant and related items.

For each of the two major classifications intersections and road sections a reduced variable list is given in Tables 64 and 65. Following each is a list of proposed variables to be eliminated. The list of redundant and related items contains the reasoning behind the elimination of each item.

Table 62. Intersections - reduced variable list.

Approach Width - Associated with intersection capacity, is a measure of intersection complexity.

Distance to 1st. Parked Vehicle - Measure of intersection complexity, also associated with intersection capacity.

Type of Parked Vehicle - Associated with intersection capacity, relates to intersection complexity.

Parking Turnover Rate - Associated with intersection complexity and side friction, related to intensity and type of land use.

Angle vs. Parallel Parking - Associated with intersection capacity and side friction, related to intensity and type of land use as well as turnover and trip type.

Lane Control (Divided vs. Undivided) - Associated with intersection capacity and quality of flow.

Signal Spacing - Associated with the quality of flow as it approaches a particular intersection, also affects capacity and approach speeds as well as pedestrian crossings.

Table 62. Intersections - reduced variable list (continued).

Bus Stop Location - Associated with the quality of flow and intersection capacity, also a factor in the amount of side friction when considered with parking.

Type of Bus Stop - Associated with intersections capacity and side friction, also quality of flow.

Painted Crosswalk - Associated with pedestrian activity and side friction.

Lane Width - Associated with intersection capacity and quality of flow.

Number of Lane Approaches - Associated with intersection capacity and turning provisions, also a measure of facility type.

Approach Grades - Associated with quality of flow as well as contributor to intersection complexity.

Approach Alignment - Associated with intersection complexity and capacity.

Sight Distance - Associated with intersection complexity as well as quality of flow on both major and minor streets.

Right-Turn Lane - An indicator of the quality of flow as well as of intersection complexity. Also associated with capacity.

Table 62. Intersections - reduced variable list (continued).

Left-Turn Lane - Associated with intersection complexity as well as with quality of flow and complexity. Also affects timing and special phasing.

Pavement Composition - Associated with quality of flow.

Pavement Maintenance Condition - Associated with quality of flow.

Obstacles Per Mile - Associated with quality of flow and side friction as well as complexity.

Peak Hour Factor - Associated with capacity and quality of flow.

Discharge Headways - Associated with capacity and quality of flow.

Bus Dwell Time - Associated with capacity, and quality of flow as well as intersection complexity.

Distribution of Trip Purpose - Associated with quality of flow as it relates to turning movements and travel speeds.

Non-Motorized Vehicles - Associated with quality of flow and intersection complexity as well as side friction.

Construction Work - Associated with quality of flow, intersection complexity as well as capacity.

Table 62. Intersections - reduced variable list (continued).

Intersection ADT (total) - Associated with quality of flow.

Approach ADT - Associated with quality of flow.

Intersection Capacity - Affects quality of flow.

Pedestrian Crossing Volumes - Associated with intersection complexity and intersection capacity.

Vehicle Mix - Associated with quality of flow and intersection capacity.

Bus Stops/Mile - Associated with quality of flow, capacity, and side friction, as well as intersection capacity.

V/C - Measure of quality of flow.

Parking Regulations - Associated with quality of flow and side friction, as well as capacity.

Right-Turn On Red - Associated with capacity, intersection complexity, as well as quality of flow.

Type of Signal Control - Associated with capacity and intersection complexity.

Total Amount of Green/Approach - Associated with capacity.

Table 62. Intersections - reduced variable list (continued).

Number of Times Approach Records Green - Associated with capacity.

Scramble Phase - Associated with intersection capacity as well as side friction.

Type of Approach Control - Associated with capacity and intersection complexity.

Pedestrian Signalized Approach - Associated with intersection complexity.

Lane Marking Type - Associated with capacity, quality of flow and complexity.

Approach Signing - Associated with quality of flow and complexity.

Posted Speed Approaching Intersection - Associated with quality of flow.

Turn Restrictions - Associated with quality of flow, intersection complexity and capacity.

SMSA Population - Associated with intersection complexity and capacity.

Urbanized Area Population - Associated with intersection complexity and capacity.

City Population - Associated with intersection complexity and capacity.

Table 62. Intersections - reduced variable list (continued).

Density of Land Use - Associated with intersection complexity and side friction, as well as quality of flow.

Highway Lighting - Associated with intersection complexity as well as quality of flow.

Land Use Type - Associated with intersection complexity and quality of flow as well as side friction.

Number of Curb Cuts Within 200' - Associated with intersection complexity and quality of flow as well as side friction.

Seasonal Rainfall - Associated with quality of flow.

Seasonal Snowfall - Associated with quality of flow.

Directional Orientation of Intersection - Associated with quality of flow as well as complexity.

Area Type (Urban, Rural, CBD) - Associated with quality of flow as well as capacity.

Location Within City - Associated with intersection capacity.

Table 63. Road segment - reduced variable list.

Type of parked vehicle - Associated with road section capacity, relates to complexity.

Parking Turnover rate - Associated with complexity and side friction, related to intensity and type of land use.

Bus stop location - Associated with the quality of flow and road section capacity, also a factor in the amount of side friction when considered with parking.

Type of bus stop - Associated with capacity and side friction, also quality of flow.

Pavement composition - Associated with quality of flow.

Pavement maintenance condition - Associated with quality of flow.

Non-motorized vehicles - Associated with quality of flow and complexity as well as side friction.

Construction work - Associated with quality of flow, capacity, and side friction.

V/C - Measure of quality of flow.

Table 63. Road segment - reduced variable list (continued).

Parking regulations - Associated with quality of flow and side friction, as well as capacity.

Lane marking type - Associated with capacity, quality of flow and complexity.

SMSA population - Associated with complexity and capacity.

Urbanized area population - Associated with complexity and capacity.

City population - Associated with complexity and capacity.

Density of land use - Associated with complexity and side friction, as well as quality of flow.

Highway lighting - Associated with complexity as well as quality of flow.

Land use type - Associated with complexity and quality of flow as well as side friction.

Seasonal rainfall - Associated with quality of flow.

Seasonal snowfall - Associated with quality of flow.

Directional orientation of intersection - Associated with quality of flow as well as complexity.

Table 63. Road segment - reduced variable list (continued).

Area type (urban, rural, CBD) - Associated with quality of flow as well as capacity.

Location within City - Associated with capacity.

Curb/shoulder presence - Associated with capacity, and complexity of the road section.

Driveways per mile - Associated with complexity and quality of flow.

Length of parking - Associated with complexity and quality of flow.

Number of lanes - Associated with capacity and complexity of the road section.

Shoulder width - Associated with capacity and complexity as well as side friction along the section.

Shoulder composition - Associated with complexity.

Guard rail type - Associated with capacity and complexity as well as side friction.

Verticle Alignment - Associated with capacity, quality of flow, and the complexity of the road section.

Table 63. Road segment - reduced variable list (continued).

Horizontal Alignment - Associated with quality of flow and section complexity as well as side friction.

Superelevation - Associated with quality of flow.

Truck climbing lane - Associated with quality of flow.

Facility type - Associated with capacity, and quality of flow. In addition affects the complexity of the road section.

Number of roadside fixed objects - Associated with side friction of section and overall complexity.

Roadside slope - Associated with quality of flow side friction and overall complexity.

Lane width - Associated with capacity and quality of flow.

Intersections per mile - Associated with quality of flow and complexity of the road section.

Peak hour factor - Associated with capacity and quality of flow.

Midblock demand - Associated with quality of flow and complexity.

Table 63. Road segment - reduced variable list (continued).

Truck classification - Associated with road section capacity and quality of flow.

Local buses per hour - Associated with road section capacity and quality of flow.

Bus dwell time- Associated with quality of flow.

Corridor ADT - Associated with quality of flow.

Distribution of trip purpose - Associated with quality of flow.

Major traffic generators - Associated with quality of flow, complexity and side friction.

No passing zone control - Associated with quality of flow and complexity.

Major pedestrian generators - Associated with road section complexity and side friction.

Delineators - Associated with road section complexity.

Traffic control devices - Associated with road section complexity and quality of flow as well as road section capacity.

Table 63. Road segment - reduced variable list (continued).

Number of driveways per mile - Associated with road section complexity and quality of flow.

Minor intersection control type - Associated with road section complexity.

Vehicle classification - Associated with quality of flow and capacity.

Table 64. Eliminated intersection variables.

Configuration - Measure of the complexity of an intersection - described by approach width, number of approach lanes, approach alignment.

Parking condition - Measure of complexity of an intersection, roadside friction - described by distance to first parked vehicle, type of parked vehicle, turnover rate, angle vs. parallel parking, also a factor of approach width.

Intersections per mile - Not applicable to intersections.

Wet skid resistance - Measure of pavement quality - described by pavement composition, pavement maintenance condition, posted speed limit.

Demand by movement - Measure of quality of service of the intersection - described by intersection ADT (total) and approach ADT.

Gap acceptance character - Measure of quality of flow and level of service - described by intersection ADT, approach ADT, intersection capacity, V/C ratio and discharge headways.

Side street demand - Measure of quality of flow - described by approach ADT.

Truck classification - Measure of quality of flow and complexity of intersection, as well as locational characteristics - described by Bus fre-

Table 64. Eliminated intersection variables (continued).

quency/headway, vehicle mix, discharge headway, land use type, area type, location within city.

Local buses per hour - Measure of quality of flow - described by bus stop location, type of bus stop, bus dwell time, bus frequency/headway, vehicle mix, bus stops/mile.

Types of buses - Measure of quality of flow - described by vehicle mix, bus stops/mile.

Approach speeds - Measure of quality of flow - described by posted speed limit.

Bus stops - Measure of intersection complexity, and quality of flow - described by bus stops per mile, bus dwell time, vehicle mix, bus stop location, type of bus stop, and bus frequency/headway.

Distance from parking zone (Bus Stop) - Measure of intersections complexity - described by bus stop location, type of bus stop, distance to list parked vehicle.

Percent truck and buses - Described by vehicle mix.

Center marking type - Measure of intersection complexity - described by lane control, number of approach lanes, exclusive turn lanes, lane marking type.

Table 64. Eliminated intersection variables (continued).

Surface condition (Roadway) - Measure of facility quality - described by pavement composition.

Ambient light condition - Described by highway lighting.

Background noise - Measure of land use and development (intensity) - described by land use type, SMSA population, urbanized area population, city population, density of land use.

Table 65. Eliminated road segment variables.

Median treatment - Measure of the complexity of a road section - described by type of facility and curb/shoulder presence.

Guard rail - Measure of the complexity of the road section as well as the side friction - described by guardrail type.

Pavement type - Described by pavement composition.

Wet skid resistance - Measure of intersection complexity, and quality of flow - described by pavement composition and pavement maintenance condition.

Curbed - Described by curb/shoulder presence.

Curbed height - Described by curb/shoulder presence.

Degree of curvature - Described by horizontal alignment.

Facility type - Measure of complexity and capacity - described by number of lanes, lane width.

Grade - Described by verticle alignment.

Table 65. Eliminated road segment variables (continued).

Types of buses - Measure of quality of flow and capacity - described by local buses per hour.

Lane blockage - Measure of quality of flow - described by construction work.

Capacity - Described by V/C ratio.

% trucks and buses - Measure of quality of flow and capacity - described by vehicle classification.

On-street parking - Measure of quality of flow, road section complexity and capacity - described by parking regulations.

Length of parking - Measure of road section complexity - described by parking regulations, turnover.

Edgelining - Described by lane marking.

Center marking - Described by lane marking.

Visibility of marking - Described by pavement maintenance condition.

Speed limit - Measure of quality of flow - described by posted speed limit.

Training of Data Collectors

To collect the data in the cities, two teams of data collectors were trained. One team consisted of employees of Goodell-Grivas, Inc. which will handle cities in the south, east, and in the midwest. The second data collection team was composed of graduate students from the Univeristy of Notre Dame, who handled the cities primarily in the west, with some in the midwest.

Training sessions were conducted in two parts including (1) classroom lecture and discussion, and (2) field training. The Goodell-Grivas, Inc. team was first trained through extensive trial runs in the Detroit area. Several stages of modifications in data collection forms and procedures was made to insure maximum data accuracy with minimum wasted effort. After the data collection procedure was finalized, additional training was completed through open discussions between the project engineer and the data collection team during and after further data collection. All specific procedures related to data collection were listed and included in the field training manual.

The second data collection team from Notre Dame University was trained by the principal investigator and the Goodell-Grivas, Inc. study team. The training included a total of about 6 to 8 hours of classroom lecture, discussion, and field training. At least one member of the Goodell-Grivas, Inc. team accompanied the Notre Dame team on initial data collection runs.

Field Data Collection

The data were taken from three sources which included (1) field data collection by the data collection team, (2) data provided by cities, and (3) reduction of data from other sources (such as maps). The source of data collection for each variable is shown in Table 66. The data collection discussed herein refers only to the field data collection and the procedures that were used for obtaining the information.

Data collection was made using trained data collectors who rode in a test vehicle. The vehicle was driven at approximately 10 to 20 mph in the right-hand lane or sometimes on the roadway shoulder. Occasional stops were necessary to record data when the section was particularly crowded with signs, roadside obstacles, or driveways. Emergency flashers were

Table 66. Data collection source.

Variable	Office Collection Forms	Field Collection Forms
ADT - Measured Value	X	
V/C Ratio - Calculated Value	X	
Peak Hour Factor - Calculated Value	X	
Number of Lanes - Measured Amount		X
Vehicle Mix - Calculated Percentage Ranges	X	
Parking Turnover Rate - Calculated Value	X	
Local Buses Per Hour - Measured Rate	X	
Bus Stops Per Mile - Measured Value		X
Intersections Per Mile - Measured Rate	X	
Driverways Per Mile - Measured Rate		X
Lane Width - Measured Amount	X	
Curb Shoulder Presence - Category Values		X
Horizontal Alignment - Category Values	X	
Special Turn Facilities - Category Values		X
Median Type - Category Values		X
Pavement Composition - Category Values		X
Vertical Alignment - Category Values	X	
Type of Bus Stop - Category Values		X
Density of TC Devices - Measured Rates		X
Signal Interconnect - Category Values	X	
Number of Roadside Fixed Objects - Measured Rate		X
Curb Lane Usage - Category Values		X
Posted Speed Limit - Measured Value		X
Lane Marking Type - Category Values		X
Average Cycle Length - Calculated Value	X	
Bus Stop Location - Category Value		X
Density of Land Use - Category Values	X	
Land Use Type - Category Values	X	
Highway Lighting - Category Values		X
Maj. Ped. Generator - Calculated Rate	X	
Location Factor - Category Value	X	
Urbanized Area Population - Measured Value	X	
Seasonal Rainfall - Measured Value	X	
Distribution of Trip Purpose - Category Value	X	
Seasonal Snowfall - Measured Value	X	
Directional Orientation - Measured Value	X	

activated during data collection, and a portable flashing light was mounted on top of the test vehicle to reduce the chance for a rear-end collision. Collection of data consisted of one driver and two other data collectors. Work duties were alternated to even out work loads and relieve boredom.

The data collection begin at a defined point in the road which was defined as point 0.0. All data were recorded in 0.1 mile increments on the data sheets. The driver operated the motor vehicle and keep track of the 0.1 mile highway sections. At the end of each 0.1 mile, the driver alterted the others so data could be recorded on the next set of horizontal columns on their data forms. After the hihgway section was inventoried, the vehicle was turned around, and data collection began in the other direction starting at the exact endpoint. The length of the section should come out the same for both directions of travel and was checked. Problems in data collection was minimal, however, inventory duplication was necessary in some cases.

The data that were collected is summarized in six forms as shown in Table 67. Data collection on each section consisted of three complete runs in each direction (total of six runs). The two data collectors used three of the six data sheets to collect the necessary data. The six data sheets (Data Form A through F) are attached as Figures 11 through 16 along with the guidelines that were used for data collection.

Data Form A

These variables include an inventory of signs and trees, which are further classified by their location on the median or on the right side of the road. All signs should be counted which are visible to the driver and pertain to the driver's direction of travel, regardless of their distance to the road. In many cases several signs will be mounted on the same post and each sign face should be counted separately. Figure 17, 18, and 19 which illustrates many of the various regulatory, warning, and guide signs. The data collectors should be familiar with the type of each sign to reduce confusion and error while counting and classifying signs.

Trees should also be counted on Data Form A and classified as median or right side of road. Where a vertical curb exists on the road edge, only trees within 5 feet of the road should be counted. Where a mountable curb or no curb exists, trees within 12 fet of the road edge should be counted.

This criteria should be used for all obstacles near the road except the numbers of sign faces as mentioned previously. Also trees behind a guardrail should not be counted, since a vehicle could not hit the tree without first hitting the guardrail. Trees less than 3 inches in diameter should not be counted.

Table 67. Summary of field data variables collected.

Data Form A - Signing and Trees

Regulatory Signs (Median and Right)

Warning Signs (Median and Right)

Guide Signs (Median and Right)

Trees (Median and Right)

Data Form B - Supports and Obstacles

Thin Supports (Median and Right)

Heavy Supports (Median and Right)

Utility and Light Poles (Median and Right)

Mail Boxes and Others ((Light) Median and Right)

Hydrants and Others ((Heavy) Median and Right)

Data Form C - Lane Usage and Turns

Number of Through Lanes

Continuous Left Turn Lane (One Direction or Two Direction)

Continuous Right Turn Lane

Parking Lane (Continuous or Partial)

Number of Right Turn Lanes (Intersection)

Number of Left Turn Lanes (Intersection)

Number of Right Turn Lanes (Midblock)

Data Form D - Median, Curb and Shoulder

Median Width

Median Type (Curb or No Curb; Paved or Unpaved)

Curb Type (Mountable or Vertical)

Shoulder Type (Paved or Unpaved)

Shoulder Width

Percent of Guardrail

Table 67. Summary of field data variables collected (Continued).

Data Form E - Alignment, Intersections, and Driveways

Vertical Alignment (Level, Mild, or Steep)

Horizontal Alignment (Straight or Curves)

Number of Intersections (Signalized or Non-signalized)

Number of Driveways (Single Family or Commercial)

Number of Lanes on Cross Street

Data Form F - Roadway Environment

Posted Speed Limit

Lighting (Yes, or No)

Surface Type (Bituminous or Concrete)

Land Use (Residential, Commercial, Industrial, Recreational, Educational, or Vacant)

Bus Stop Location (Near, Far, or Midblock)

Bus Stop Type (Curbside or Pullout)

DATA FORM A - SIGNS AND TREES

CITY ________________ ROUTE NO. ________________ ROUTE NAME ________________

DATE ________________ OBSERVER ________________ DIRECTION ________________

	Regulatory Signs		Warning Signs		Guide Signs		Trees*	
	In Median	Right Side	In Median	Right Side	In Median	Right Side	In Median	Right Side

*Note: Trees are counted only if they are within 5 feet (vertical curb present) or 12 feet (no vertical curb) of road-way.

Figure 11. Data form A.

DATA FORM P - SUPPORTS AND OBSTACLES

CITY ____________________ ROUTE NO. ____________________ ROUTE NAME ____________________

DATE ____________________ OBSERVER ____________________ DIRECTION ____________________

Note: Objects are counted only if they are within 5 feet (vertical curb present) or 12 feet (no vertical curb) of roadway. Obstacles behind guardrail are not counted.

	Thin Supports		Heavy Supports		Utility & Light Poles		Mail Boxes & Others (Light)		Hydrants and Others (Heavy)	
	In Median	Right Side	In Median	Right Side	In Median	Right Side	In Median	Right Side	In Median	Right Side

DATA FORM C - LANE USAGE AND TURNS

CITY ____________ ROUTE NO. ____________ ROUTE NAME ____________

DATE ____________ OBSERVER ____________ DIRECTION ____________

	Number Through Lanes	Continuous Left Turn Lane (Midblk.)		Continuous Right Turn Lane (Midblk.)	Parking Lane (Cont. or Partial)	Number Right Turn Bays (Inters.)	Number Left Turn Bays (Inters.)	Number Right Turn Bays (Midblk.)
		One Dir.	Two Dir.					

Figure 13. Data form C.

DATA FORM D - MEDIAN, CURB, AND SHOULDER

CITY ________________ ROUTE NO. ________________ ROUTE NAME ________________

DATE ________________ OBSERVER ________________ DIRECTION ________________

	Median Width (Ft)	Median Type (Curb or No Curb)	Median Type (Paved or Unpaved)	Curb Type (Mountable or Vertical)	Shoulder Type (Paved or Unpaved)	Shoulder Width (Ft)	Percent of Guardrail

Figure 14. Data form D

DATA FORM E - ALIGNMENT, INTERSECTIONS, AND DRIVEWAYS

CITY ____________________ ROUTE NO. ____________________ ROUTE NAME ____________________

DATE ____________________ OBSERVER ____________________ DIRECTION ____________________

	Vertical Alignment (Level, Mild, or Steep)	Horizontal Alignment (Straight or Curves)	Number of Intersections		Number of Driveways		Number of Lanes on X-St. (2,3,4,5 or other)
			Sig.	Non. Sig.	Single Family	Comm. & Other	

Figure 15. Data form E.

DATA FORM F - ROADWAY ENVIRONMENT

CITY ______________ ROUTE NO. ______________ ROUTE NAME ______________

DATE ______________ OBSERVER ______________ DIRECTION ______________

	Posted Speed Limit	Lighting (Yes or No)	Surface Type (Bit. or Con.)	Land Use *	Curb Lane Usage (Thru, Bike, Bus, Parking Cont. or Limited; Restricted or Unrestricted)	Bus Stops Location (Near, Far, Mid)	Bus Stops Type (Curbside, Pullout)

* Residential, Commerical, Industrial, Recreation, Educational, Vacant

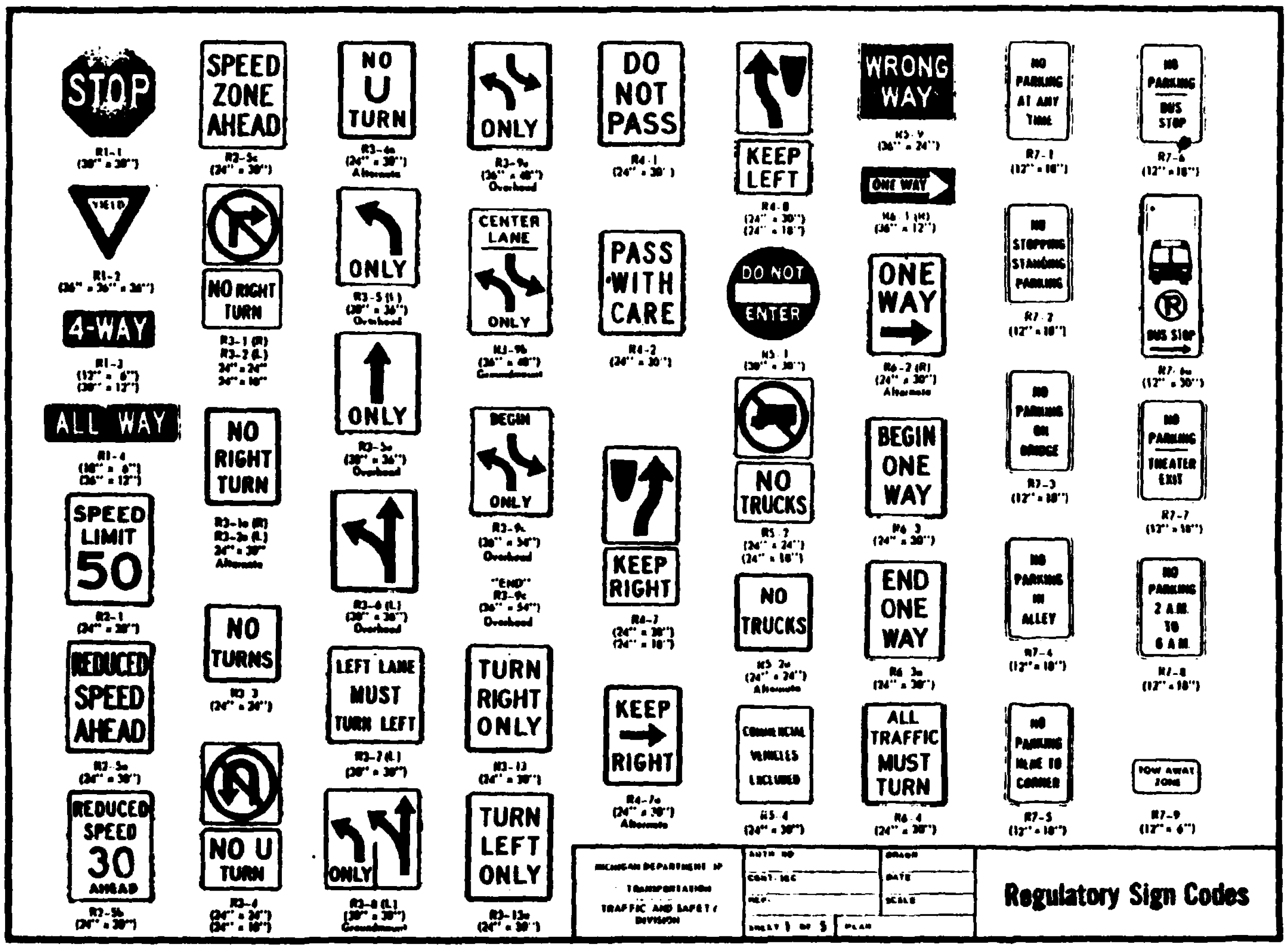


Figure 17. Regulatory sign codes.

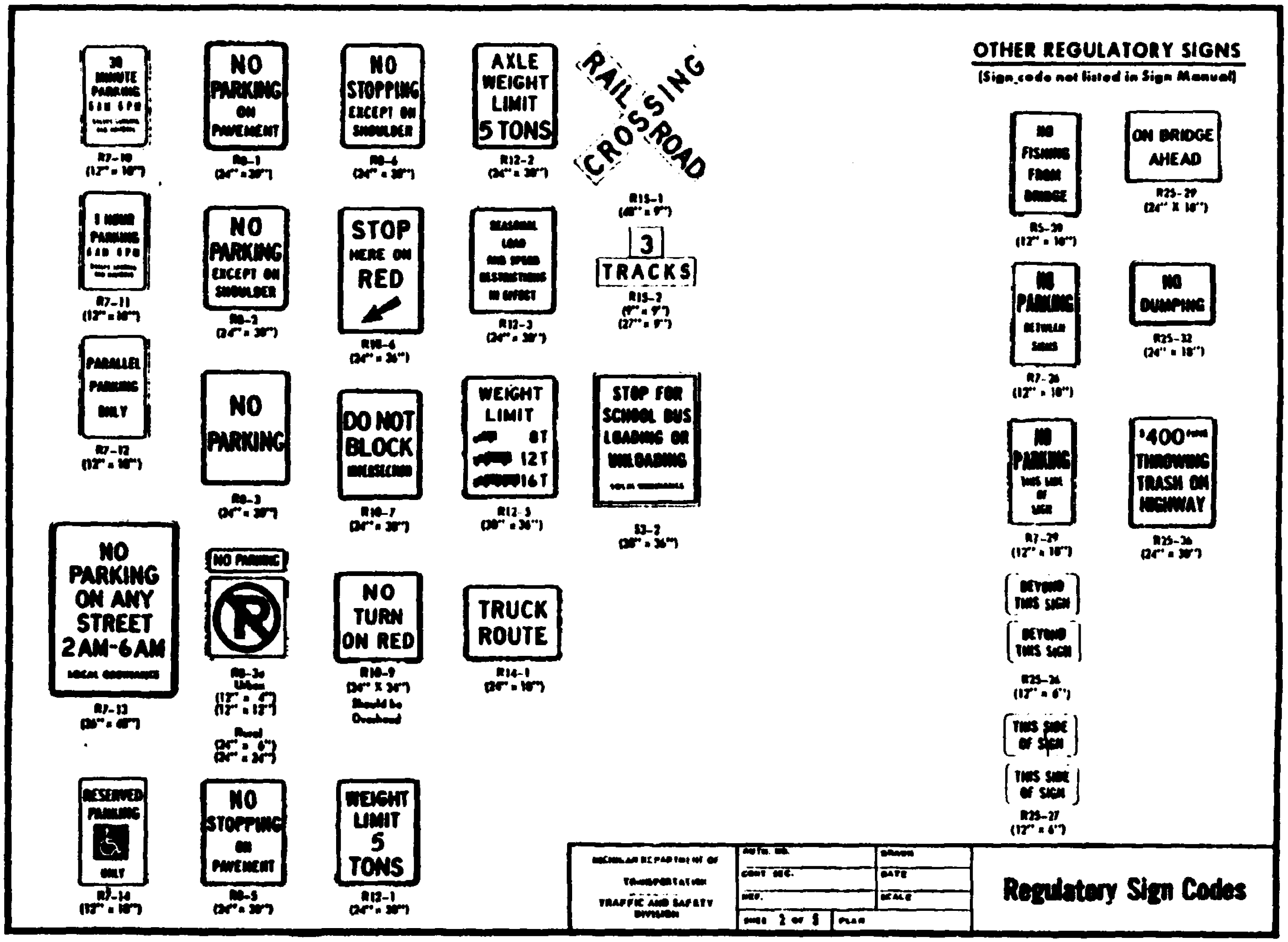


Figure 17. Regulatory sign codes (Continued).

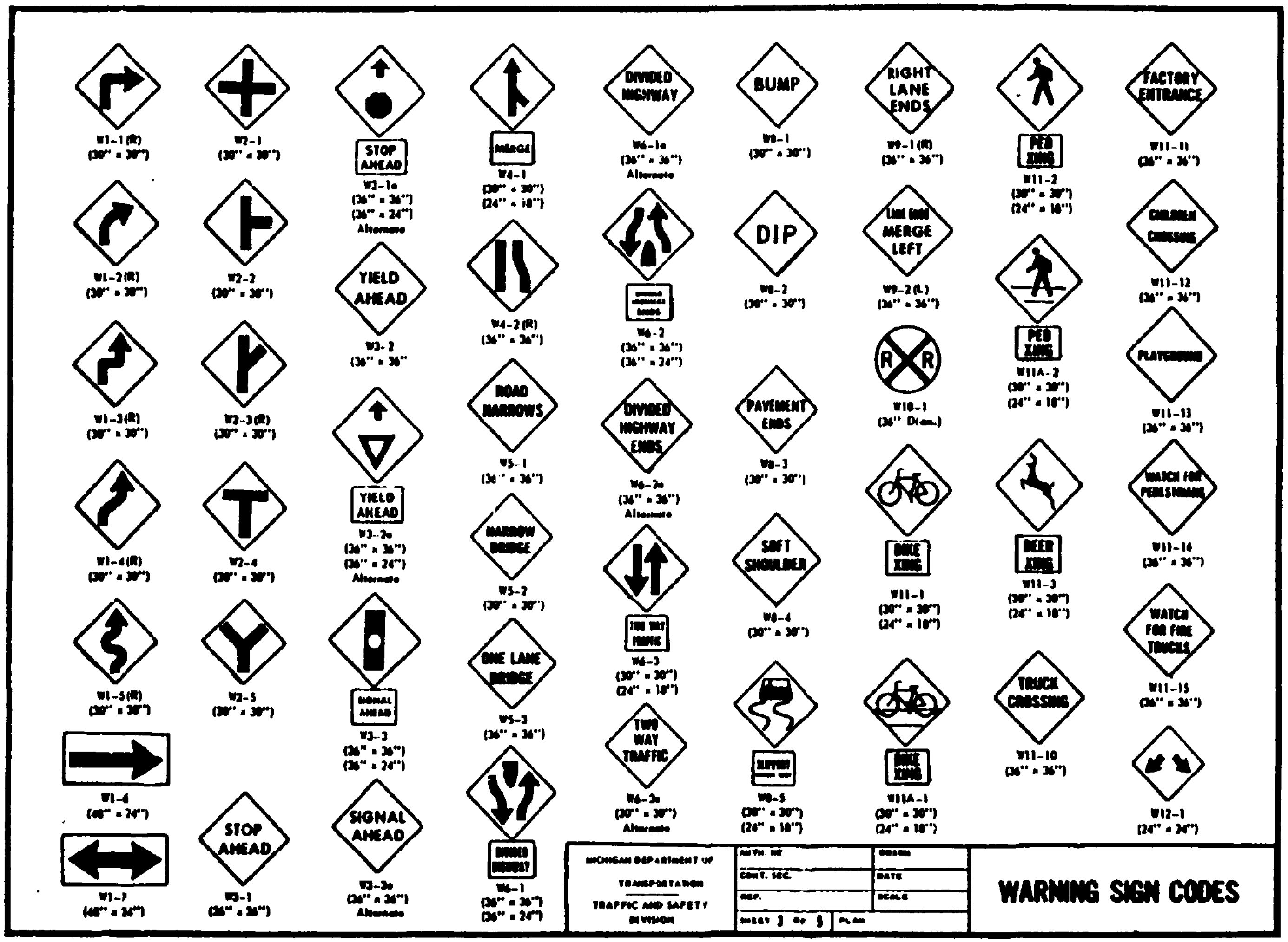


Figure 18. Warning sign codes.

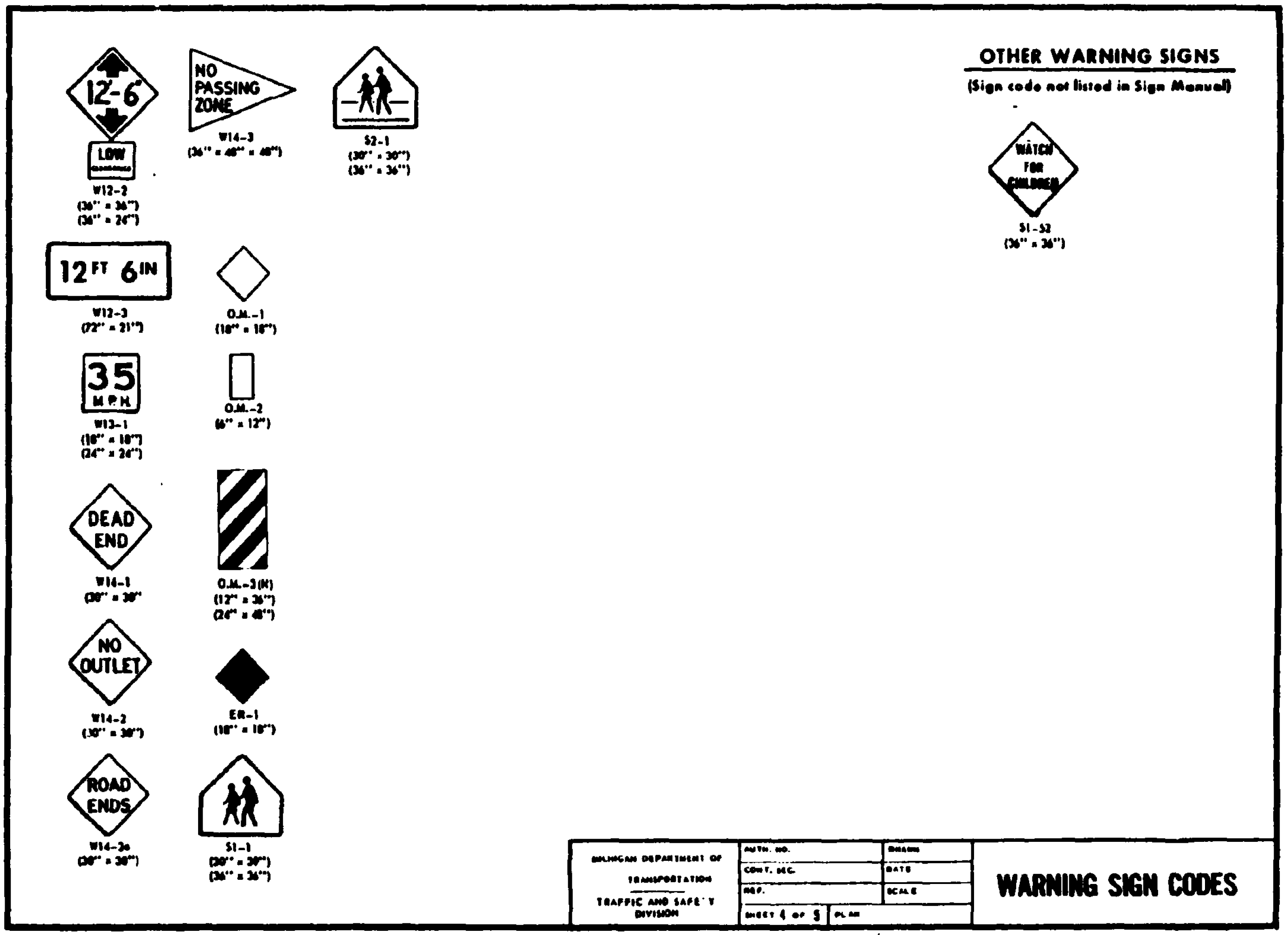


Figure 18. Warning sign codes (Continued).

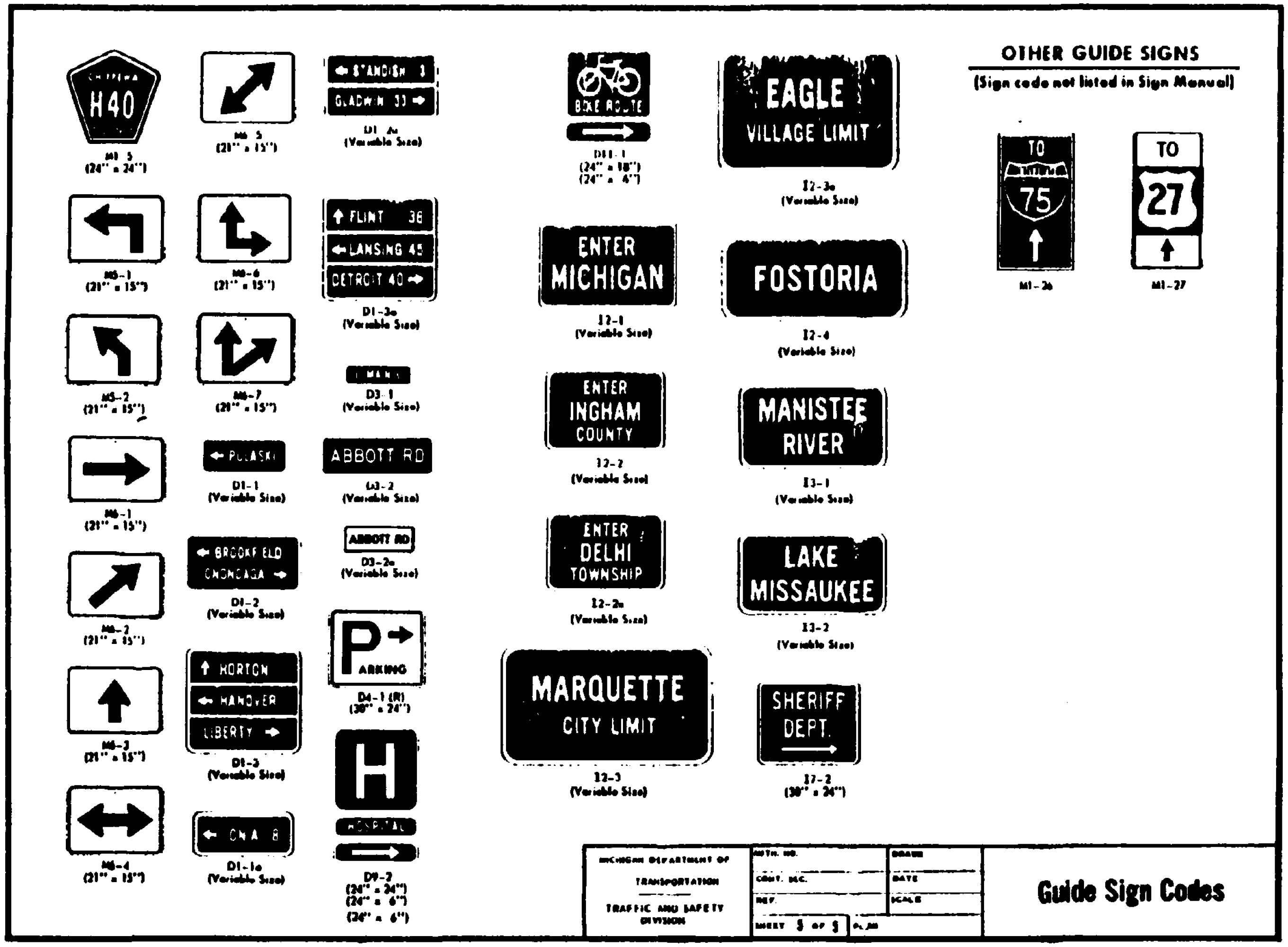


Figure 19. Guide sign code.

Counts of all data on Form A should be made by making slash marks in appropriate boxes if possible. When numerous signs or trees make this impossible at desired vehicle speeds, mechanical traffic counter boards were used to eliminate the problem.

Data Form B

The highway variables on Form B include sign supports and other roadside obstacles which are classified by median or right side of road locations. Sign supports are classified as heavy or light. Light supports include most U-channel posts (light gages). Heavy sign supports include double or heavy gage U-channel posts, steel I-beams, and concrete supports.

All utility and light poles were counted, regardless of the diameter or type of base. All mail boxes and other light objects including wood posts, water pumps, newspaper boxes, litter barrels, fences and other miscellaneous objects were included in this category.

Fire hydrants and other heavy obstacles is the final category which also included such obstacles as:

1. support poles for pedestrian signals and pole-mounted traffic signals,
2. concrete block, posts, and boxes for trees and shrubbery,
3. culvert pipe and head walls,
4. gasoline pumps,
5. railroad crossbucks and signals, and
6. stone walls.

The criteria for counting all obstacles in 5 feet where vertical curbs exist and 12 feet for mountable curbs or no curbs was also used for data collection in this category. Objects behind guardrails or otherwise shielded were not counted. Obstacles should normally be counted with slash marks in appropriate columns, but may be counted with counter buttons.

Data Form C

Variables related to lane usage and turns are recorded on data sheet C. The number of through lanes is counted including those lanes in which both through and turning movements are allowed. For example, a lane marked for through or left turns would be counted only as a through lane.

The next column is for continuous left turn lanes. This applies for example in the case of a 3-lane, 5-lane, or 7-lane road, where the center lane is used for left turns by vehicles in one or both directions. Pavement arrows are usually provided in such cases. A continuous right turn lane should be recorded where there is a shoulder lane intended only for right turns into and out of driveways. These categories of left and right turn lanes relate to midblock lanes and do not include intersection-related turn bays.

Separate parking lanes are noted in the next column. These facilities are further described as continuous or partial, although the number of actual parking spaces is not recorded.

The number of intersection-related turn bays is counted for right turns and left turns, where the bays are provided only for turning maneuvers. If two intersections were present within a section, each turn bay would be counted separately. For these cases, intersections do not include driveways but normally include signed cross streets with some form of control. The number of midblock right turn bays is noted in the last column.

Data Form D

Variables related to median, curb, and shoulder are included on Form D. The median width should be estimated as closely as possible and expressed in units of feet in the first column. For streets with medians, the median type should be given as curb or no curb and also asp aved or unpaved. A median is considered here to be four feet or more of space between opposing traffic lanes.

Where shoulders exist, the shoulder type (paved or unpaved) and width (in feet) should be given, where the width is estimated as close as possible by the data collector. For sections with guardrails present, the percent of the section with guardrail should be estimated. For example, if a 0.1-mile section has about 100 feet of guardrail, then the percent is about 100/500 or 20 percent.

Data Form E

The alinement of the roadway and the number of intersections and driveways are inventoried on this form. The vertical alinement of each section should be classified as level, mild, or steep. Horizontal alinement should be noted as straight or curved. These evaluations are subjective, and care should be taken to insure consistency in ratings.

The number of intersections should be counted as signalized or unsignalized. Also, the driveways on the right side of the road are to be classified as single family or commercial. A single family driveway includes a driveway to any house, while commercial types normally include restaurants, apartment buildings, gasoline stations, parking lots, and others where considerable traffic usage might be expected.

For each cross street, the number of lanes is noted in the final category. This should be the number of through lanes only which may include continuous turn lanes. If more than one intersection occurs in a 0.1-mile section, the number of lanes should be given for each cross street.

Data Form F

Variables related to the roadway environment are included on this form. The value given for posted speed limit may be the last speed limit sign along the section if no speed limit signs exist on the section. The presence of lighting means that at least 10 light poles exist n the section, regardless of the apparent condition. The surface type should only be noted as bituminous or concrete. In the case of both surface types within a section, both types should be noted on the form.

Land use pertains to the predominant type of development along the right side of the roadway. Possible types include residential, commercial, industrial, recreational, educational, or vacant (parking lot, field, etc.). Curb lane usage is the next category which includes through lane, bike lane, bus lane (exclusive), and curb parking lane. For a curb parking lane, further classifications include continuous or limited and restricted (specific hours only) or unrestricted.

Bus stop descriptions constitute the final category. The location of the bus stop with reference to a signed intersection is given as either near-side (just before intersection), far-side (just beyond intersection, or midblock). Bus stops may be either curbside or pullout, where a pullout defines a special area provided for buseds to pull off of the main traffic lane.

REFERENCES

1. Federal Highway Administration, "Highway Functional Classification-Concepts: Criteria and Procedures", Washington, D.C., July, 1974.

2. Institute of Transportation Engineers", System Considerations for Urban Arterial Streets: An Informational Report", Washington, D.C., October, 1969.

3. Alan M. Voorhees & Associates, Inc., "Application of Existing Strategies to Arterial Signal Control", prepared for the Federal Highway Administration, Washington, D.C., 1980.

APPENDIX D - DESCRIPTION OF THE COMPUTERIZED DATA BASE

Introduction

Creation of the master file began with the collection of three consecutive years of data from existing computerized accident files of the cities selected for study. Operational, geometric, and environmental data were also collected for the roadway sites of these selected cities for the purpose of developing a computerized data base that would be representative of the accident and roadway characteristics of urban arterial highways in the United States.

Data Base Layout

The data base was structured in a manner that would provide enough detail to associate accidents occurring at a particular location with the decription of that location. This provided the analyst with a more analytical option in addressing the contract objectives.

Because of the large number of accidents desired, only those cities that could provide a computerized accident file were considered eligible for sample site selection. Data from 19 cities were eventually selected for the file, with the final determination based upon a number of considerations including; the availability of sufficient locational data to enable assignment of individual accidents to 0.1-mile (0.16-km) segments of corresponding roadway; and the availability of sufficient information on severity, accident type, and other descriptive information that would allow the accident to be used for the proposed analyses.

Based on data availability and sampling requirements, the completed data file consists of descriptive roadway information, plus the appropriate accident data in the form of total numbers of fatal, personal injury, and property damage accidents, as well as the accident data categorized by accident type for 8,678 one-tenth-mile (0.16-km) roadway segments. Because of programming constraints, each 0.1-mile case was broken into three records containing data grouped in the following categories:

- Operational Data
- Geometric Data
- Environmental Data
- Accident Data

The general arrangement of the data within the master file including a description of the data tape, the data base format and the variable lables is shown in Table 68.

Table 68. Format of the computerized data base.

REPORT NO. FHWA/RD-82/(DOT-FH-11-9500)
ANALYSIS OF URBAN ARTERIAL ROAD AND STREET ACCIDENT EXPERIENCE

THE DATA TAPE IS A 1600BPI 9TP NONLABELED MAGNETIC TAPE

File #	Block count	Tapelen (feet)	Block len av.	Block len max.
1	6	1.30	2120	2400
2	1042	210.08	2823	2825

Total tape length = 211.38 feet.

THE TAPE CONTAINS TWO FILES. THE FIRST IS AN OUTLINE OF THE FORMAT AND VARIABLE DESCRIPTION OF THE DATA BASE. THIS FILE CONTAINS 106 RECORDS AND IS FIXED BLOCK FORMATTED AT (2400,120).

THE SECOND FILE IS THE URBAN ARTERIAL DATA BASE. THIS FILE CONTAINS 26034 RECORDS AND IS FIXED BLOCK FORMATTED AT (2825,113).
THE DATA BASE FORMAT PROVIDES FOR 75 VARIABLES.
IT PROVIDES FOR 3 RECORDS PER CASE. A MAXIMUM OF 113 'COLUMNS' ARE USED ON A RECORD.
THE DATA BASE CONTAINS A TOTAL OF 8678 CASES.

```
DATA BASE FORMAT   FIXED(2(I6,1X),I1,1X,I2,I3,2I2,I4,5I2,I4,
                   5I2,2X,11I2,4X,16I2/9I4,1X,I5,I3,2I2,F3.1,
                   I3,I2,1X,I2,2I3,2F4.1,I2,3X,I5/5(F7.3,1X))
```

ACCORDING TO THE DATA BASE FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

VARIABLE	FORMAT	RECORD	COLUMNS	VARIABLE LABEL	VALUE LABEL
VAT01	I 6	1	1- 6	ROUTE NUMBER	
VAT02	I 6	1	8- 13	STREET ID	
VAT03	I 1	1	15- 15	TRAFFIC FLOW	(0)MISSING(1)ONEWAY(2)TWOWAY(3)1WY DIVIDED (4)2WY DIVIDED
VAT04	I 2	1	17- 18	TRAFFIC SIGN FACES	
VAT05	I 3	1	19- 21	LARGE OBSTACLES	
VAT06	I 2	1	22- 23	SMALL OBSTACLES	
VAT07	I 2	1	24- 25	THRU LANES	
VAT08	I 4	1	26- 29	MEDIAN WIDTH	(0)MISSING
VAT09	I 2	1	30- 31	MEDIAN TYPE-CURB	(0)MISSING(1)CURB(2)NO CURB
VAT10	I 2	1	32- 33	MEDIAN TYPE-PAVED	(0)MISSING(1)PAVED(2)UNPAVED
VAT11	I 2	1	34- 35	CURB TYPE-RIGHT SIDE	(0)NONE(1)VERTICAL(2)MOUNTABLE
VAT12	I 2	1	36- 37	CURB TYPE-LEFT SIDE	(0)NONE(1)VERTICAL(2)MOUNTABLE
VAT13	I 2	1	38- 39	AVERAGE SHOULDER WIDTH	(99)MISSING
VAT14	I 4	1	40- 43	PERCENT GUARDRAIL	
VAT15	I 2	1	44- 45	VERTICAL ALIGNMENT	(0)MISSING(1)LEVEL(2)MODERATE(2)STEEP
VAT16	I 2	1	46- 47	HORIZONTAL ALIGNMENT	(0)MISSING(1)STRAIGHT(2)CURVE
VAT17	I 2	1	48- 49	DRIVEWAYS	
VAT18	I 2	1	50- 51	SIGNALIZED INTERSECTIONS	
VAT19	I 2	1	52- 53	NONSIGNALIZED INTERSECTIONS	
VAT20	I 2	1	56- 57	POSTED SPEED	(0)MISSING
VAT21	I 2	1	58- 59	LIGHTING	(0)MISSING(1)YES(2)NO
VAT22	I 2	1	60- 61	SURFACE TYPE	(0)MISSING(1)BITUMINOUS(2)CONCRETE(3)DIRT
VAT23	I 2	1	62- 63	LAND USE	(0)MISSING(1)COMMERICAL(2)RESIDENTIAL (3)VACANT(4)OTHER
VAT24	I 2	1	64- 65	CURB LANE USAGE	(0)OTHER(1)THRU(2)BIKE(3)BUS(4)RESTRICTED (5)UNRESTRICTED(6)LIMITED
VAT25	I 2	1	66- 67	NO. BUS STOPS	
VAT26	I 2	1	68- 69	BUS STOP TYPE-CURB	(0)NO(1)YES
VAT27	I 2	1	70- 71	BUS STOP TYPE-PULL OUT	(0)NO(1)YES

Table 68. Format of the computerized data base (continued).

VAT28	I 2	1	72-	73	SECTIONS PER CITY	(1)BIG RAPIDS(2)KALAMAZOO(3)LANSING(4)SAGINAW (5)BIRMINGHAM(6)FARMINGTON(7)FARMINGTON HILLS (8)NOVI(9)OAK PARK(10)ROYAL OAK(11)SOUTHFIELD (12)TROY(13)TOPEKA(14)NEW ORLEANS (15)MILWAUKEE(16)SAN FRANCISCO(17)FORT WAYNE (18)SEATTLE(19)MINNEAPOLIS
VAT29	I 2	1	74-	75	CITY SIZE	(1)SMALL(2)MEDIUM(3)LARGE
VAT30	I 2	1	76-	77	ROADWAY CLASS	(1)ONEWAY(2)TWO WAY,TWO-LANE (3)MULTILANE DIVIDED(4)MULTILANE UNDIVIDED
VAT31	I 2	1	82-	83	REGULATORY SIGNS	
VAT32	I 2	1	84-	85	WARNING SIGNS	
VAT33	I 2	1	86-	87	GUIDE SIGNS	
VAT34	I 2	1	88-	89	TREES	
VAT35	I 2	1	90-	91	UTILITY POLES	
VAT36	I 2	1	92-	93	LEFT TURN LANE-1 DIRECTION	(99)MISSING
VAT37	I 2	1	94-	95	LEFT TURN LANE-2 DIRECTION	(99)MISSING
VAT38	I 2	1	96-	97	RIGHT TURN LANE-MIDBLOCK	(0)NONE(1)YES(2)NO
VAT39	I 2	1	98-	99	PARKING LANE-RIGHT SIDE	(0)NONE(1)PARTIAL(2)CONTINUOUS
VAT40	I 2	1	100-	101	PARKING LANE-LEFT SIDE	(0)NONE(1)PARTIAL(2)CONTINUOUS
VAT41	I 2	1	102-	103	RIGHT TURN BAY-INTERSECTION	
VAT42	I 2	1	104-	105	LEFT TURN BAY-INTERSECTION	
VAT43	I 2	1	106-	107	RIGHT TURN BAY-MIDBLOCK	
VAT44	I 2	1	108-	109	BUS STOP-NEAR	
VAT45	I 2	1	110-	111	BUS STOP-FAR	
VAT46	I 2	1	112-	113	BUS STOP-MIDBLOCK	
VADO1	I 4	2	1-	4	TOTAL ACCIDENTS	(9999)MISSING
VADO2	I 4	2	5-	8	FATAL ACCIDENTS	(9999)MISSING
VADO3	I 4	2	9-	12	INJURY ACCIDENTS	(9999)MISSING
VADO4	I 4	2	13-	16	PROPERTY DAMAGE ACCIDENTS	(9999)MISSING
VADO5	I 4	2	17-	20	HEAD ON ACCIDENTS	(9999)MISSING
VADO6	I 4	2	21-	24	REAR END ACCIDENTS	(9999)MISSING
VADO7	I 4	2	25-	28	SIDESWIPE ACCIDENTS	(9999)MISSING
VADO8	I 4	2	29-	32	ANGLE ACCIDENTS	(9999)MISSING
VADO9	I 4	2	33-	36	ALL OTHER ACCIDENTS	(9999)MISSING
VACO1	I 5	2	38-	42	ADT	(999.999)MISSING
VACO2	I 3	2	43-	45	PHF	(999.999)MISSING
VACO3	I 2	2	46-	47	VEHICLE MIX-CARS	(999.999)MISSING
VACO4	I 2	2	48-	49	VEHICLE MIX-COMMERICAL	(999.999)MISSING
VACO5	F 3. 1	2	50-	52	PARKING TURNOVER RATE	(999.999)MISSING
VACO6	I 3	2	53-	55	LOCAL BUS PER HOUR	(999.999)MISSING
VACO7	I 2	2	56-	57	LANE WIDTH	(999.999)MISSING
VACO8	I 2	2	59-	60	AVERAGE CYCLE LENGTH	(999.999)MISSING
VACO9	I 3	2	61-	63	LOCATION FACTOR	(999 999)MISSING
VAC10	I 3	2	64-	66	CITY POPULATION	(999.999)MISSING
VAC11	F 4. 1	2	67-	70	RAINFALL	(999.999)MISSING
VAC12	F 4. 1	2	71-	74	SNOWFALL	(999.999)MISSING
VAC13	I 2	2	75-	76	OPERATOR SPEED	(999.999)MISSING
VAC15	I 5	2	80-	84	CAPACITY	(999.999)MISSING
VAC16	F 7. 3	3	1-	7	VC RATIO	(999.999)MISSING
VAC17	F 7. 3	3	9-	15	TOTAL ACCIDENT RATE	(999.999)MISSING
VAC18	F 7. 3	3	17-	23	FATAL ACCIDENT RATE	(999.999)MISSING
VAC19	F 7. 3	3	25-	31	INJURY ACCIDENT RATE	(999.999)MISSING
VAC20	F 7. 3	3	33-	39	PROPERTY DAMAGE ONLY RATE	(999.999)MISSING

A description of the data variables is given below.

Geometric/Operational Data

1.	Route Number	- (Arterial Reference Number)
2.	Street I.D.	- (City & Section Code)
3.	Traffic Flow	- (Directional Use)
4.	Traffic Sign Faces	- (Total of Guide, Regulatory, and Warning Sign Faces)
5.	Large Obstacles	- (Total of Trees, Heavy Supports, Utility Poles, Hydrants, and Other Large Objects
6.	Small Obstacles	- (Total of Light Supports, Mail Boxes, and Other Small Objects)
7.	Number of Thru Lanes	-
8.	Median Width	-
9.	Median Type	- (With Curb)
10.	Median Type	- (Paved)
11.	Curb Type	- (Right Approach)
12.	Curb Type	- (Left Approach)
13.	Average Shoulder Width	
14.	Percent Guardrail	
15.	Vertical Alignment	
16.	Horizontal Alignment	
17.	Number of Driveways	
18.	Number of Intersections Signalized	
19.	Number of Intersections Nonsignalized	

Geometric/Operational Data (Continued)

20. Posted Speed
21. Lighting
22. Surface Type
23. Predominant Lane Use
24. Curb Lane Usage
25. Number of Bus Stops
26. Bus Stop Type - (Location at Curb)
27. Bus Stop Type - (Special Lane - Pull Out)
28. Number of Sections per City - (Tenth of a Mile)
29. City Size
30. Roadway Classification
31. Number of Regulatory Signs
32. Number of Warning Signs
33. Number of Guide Signs
34. Number of Trees
35. Number of Utility Poles
36. Number of Left Turn Lanes - (With One Approach)
37. Number of Left Turn Lanes - (With Two Approach)
38. Right Turn Lanes - (Midblock)
39. Parking Lane - (Right Approach)
40. Parking Lane - (Left Approach)
41. Number of Right Turn Bays - (At Intersections)

42. Number of Left Turn Bays - (At Intersections)

43. Number of Right Turn Bay - (Midlock)

44. Number of Bus Stops - (Nearside)

Geometric/Operational Data (Continued)

45. Number of Bus Stops - (Farside)

46. Number of Bus Stops - (Midblock)

Accident Data (Frequency of occurance per tenth of a mile section)

1. Total Accidents
2. Fatal Accidents
3. Injury Accidents
4. Property Damage Only Accidents
5. Head on Accidents
6. Rear End Accidents
7. Side Swipe Accidents
8. Angle Accidents
9. All Other Accidents

Operational/Environmental Data

1. ADT - (Average Daily Traffic - Volumes)
2. PHF - (Peak Hour Factor - Ratio of the Volumes Occuring During Peak Hour)
3. Vehicle Mix - (Cars - Percent of Cars in Normal Traf- fic).

4. Vehicle Mix - (Commercial - Percent of Commercial Vehicles in Normal Traffic)

5. Parking Turnover Rate

6. Local Bus per Hour

7. Average Lane Width (each approach)

8. Location Factor (weighted-city population)

9. City Population

10. Average Rainfall

11. Average Snowfall

12. Operator Speed

13. Capacity - (Maximum - Number of Vehicles which has a Reasonable Expactation of Passing Over a Given Section)

14. VC Ratio

Accident Data (Per Million Vehicle Miles)

15. Total Accident Rate

16. Fatal Accident Rate

17. Injury Accident Rate

18. Property Damage Only Rate

Problems Encountered Creating the Master File

One of the primary problems encountered in developing the master file was that of coding accident data to a 0.1 mile (0.16 km) section of roadway. This was found to be due primarily to the non-standardization of information on the computerized accident record systems of the cities selected for the study. It was found that the criteria for recording an accident as well as what information is recorded varied considerably between the selected study cities. Variable classification and accident location information either did not exist or was unusble in some of the selected sites.

This difficulty made the identification of accident severity, accident type, and other factors associated with or contributing to an accident, difficult to associate with a specific roadway segment. These problems particularly created a major problem in providing the detailed accident and geometric information necessary to throughly address the contract objectives. Because of this problem, the accident sample size outlined in the analysis plan was considerably reduced.

Programming

Programming used in the performance of the analysis plan of the study were SPSS (Statistical Package for the Social Science), and OSIRIS IV. (Statistical Analysis and Data Management Software System).

In addressing the objectives of the research study, SPSS was used for Bivariate Frequency Analysis, One Way and Multivariate Analysis of Variance, Contingency Table Analysis, Correlation Analysis, and Regresssion Analysis. OSIRIS IV's Search (searching for structure) was used for branching analysis.

Other programs used in the study were designed specificly to process the various accident and geometric data from each city to meet the standard format outlined in the master file description.

An example of the SPSS program and typical output is displayed in Table 69.

An example of the OSIRIS V's program and typical output is given in Table 70.

Table 69. Example SPSS program and output.

```
******* ANALYSIS OF VARIANCE - ROADWAY CLASS BY CITY SIZE - TOTAL DATA BASE *******
SPSS BATCH SYSTEM                                                                    07/13/82        PAGE     1

MTS/SPSS, VERSION H, RELEASE 9.1, FEBRUARY 1, 1982

                                   CURRENT DOCUMENTATION FOR THE SPSS BATCH SYSTEM
ORDER FROM MCGRAW-HILL:  SPSS, 2ND ED. (PRINCIPAL TEXT)       ORDER FROM SPSS INC.:  SPSS STATISTICAL ALGORITHMS
                         SPSS UPDATE 7-9 (USE W/SPSS,2ND FOR REL. 7, 8, 9)           KEYWORDS: THE SPSS INC. NEWSLETTER
                         SPSS POCKET GUIDE, RELEASE 9
                         SPSS PRIMER (BRIEF INTRO TO SPSS)

DEFAULT SPACE ALLOCATION..      ALLOWS FOR..    102 TRANSFORMATIONS
WORKSPACE      71680 BYTES                      409 RECODE VALUES + LAG VARIABLES
TRANSPACE      10240 BYTES                     1641 IF/COMPUTE OPERATIONS

             1 RUN NAME          URBAN ARTERIAL STUDY
             2 FILE NAME         URBAN.A
             3 VARIABLE LIST     VAT01 TO VAT19,VAT21 TO VAT31,VAT34 TO VAT49,
             4                   VAD01 TO VAD09,VAC01 TO VAC13,VAC15 TO VAC20
             5 INPUT MEDIUM      DISK
             6 INPUT FORMAT      FIXED(2(F6.0,1X),F1.0,1X,F2.0,F3.0,2F2.0,F4.0,5F2.0,F4.0,
             7                   5F2.0,2X,11F2.0,4X,10F2.0/9F4.0,1X,F5.0,F3.0,2F2.0,F3.1,
             8                   F3.0,F2.0,1X,F2.0,2F3.0,2F4.1,F2.0,3X,F5.0/5(F7.3,1X))

              ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS
```

VARIABLE	FORMAT	RECORD	COLUMNS
VAT01	F 6. 0	1	1- 6
VAT02	F 6. 0	1	8- 13
VAT03	F 1. 0	1	15- 15
VAT04	F 2. 0	1	17- 18
VAT05	F 3. 0	1	19- 21
VAT06	F 2. 0	1	22- 23
VAT07	F 2. 0	1	24- 25
VAT08	F 4. 0	1	26- 29
VAT09	F 2. 0	1	30- 31
VAT10	F 2. 0	1	32- 33
VAT11	F 2. 0	1	34- 35
VAT12	F 2. 0	1	36- 37
VAT13	F 2. 0	1	38- 39
VAT14	F 4. 0	1	40- 43
VAT15	F 2. 0	1	44- 45
VAT16	F 2. 0	1	46- 47
VAT17	F 2. 0	1	48- 49
VAT18	F 2. 0	1	50- 51
VAT19	F 2. 0	1	52- 53
VAT21	F 2. 0	1	56- 57

Table 69. Example SPSS program and output (continued).

URBAN ARTERIAL STUDY 07/13/82 PAGE 2

ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

VARIABLE	FORMAT	RECORD	COLUMNS
VAT22	F 2. 0	1	58- 59
VAT23	F 2. 0	1	60- 61
VAT24	F 2. 0	1	62- 63
VAT25	F 2. 0	1	64- 65
VAT26	F 2. 0	1	66- 67
VAT27	F 2. 0	1	68- 69
VAT28	F 2. 0	1	70- 71
VAT29	F 2. 0	1	72- 73
VAT30	F 2. 0	1	74- 75
VAT31	F 2. 0	1	76- 77
VAT34	F 2. 0	1	82- 83
VAT35	F 2. 0	1	84- 85
VAT36	F 2. 0	1	86- 87
VAT37	F 2. 0	1	88- 89
VAT38	F 2. 0	1	90- 91
VAT39	F 2. 0	1	92- 93
VAT40	F 2. 0	1	94- 95
VAT41	F 2. 0	1	96- 97
VAT42	F 2. 0	1	98- 99
VAT43	F 2. 0	1	100- 101
VAT44	F 2. 0	1	102- 103
VAT45	F 2. 0	1	104- 105
VAT46	F 2. 0	1	106- 107
VAT47	F 2. 0	1	108- 109
VAT48	F 2. 0	1	110- 111
VAT49	F 2. 0	1	112- 113
VADO1	F 4. 0	2	1- 4
VADO2	F 4. 0	2	5- 8
VADO3	F 4. 0	2	9- 12
VADO4	F 4. 0	2	13- 16
VADO5	F 4. 0	2	17- 20
VADO6	F 4. 0	2	21- 24
VADO7	F 4. 0	2	25- 28
VADO8	F 4. 0	2	29- 32
VADO9	F 4. 0	2	33- 36
VACO1	F 5. 0	2	38- 42
VACO2	F 3. 0	2	43- 45
VACO3	F 2. 0	2	46- 47
VACO4	F 2. 0	2	48- 49
VACO5	F 3. 1	2	50- 52
VACO6	F 3. 0	2	53- 55

Table 69. Example SPSS program and output (continued).


```
                    ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

                    VARIABLE  FORMAT  RECORD     COLUMNS

                    VAC07     F 2. 0     2      56-   57
                    VAC08     F 2. 0     2      59-   60
                    VAC09     F 3. 0     2      61-   63
                    VAC10     F 3. 0     2      64-   66
                    VAC11     F 4. 1     2      67-   70
                    VAC12     F 4. 1     2      71-   74
                    VAC13     F 2. 0     2      75-   76
                    VAC15     F 5. 0     2      80-   84
                    VAC16     F 7. 3     3       1-    7
                    VAC17     F 7. 3     3       9-   15
                    VAC18     F 7. 3     3      17-   23
                    VAC19     F 7. 3     3      25-   31
                    VAC20     F 7. 3     3      33-   39

THE INPUT FORMAT PROVIDES FOR   74 VARIABLES.   74 WILL BE READ
IT PROVIDES FOR    3 RECORDS ('CARDS') PER CASE.  A MAXIMUM OF   113 'COLUMNS' ARE USED ON A RECORD.

                   9 ALLOCATE        TRANSPACE=15000

SPECIFIED SPACE ALLOCATION..   ALLOWS FOR..   150 TRANSFORMATIONS
WORKSPACE      66920 BYTES                    600 RECODE VALUES + LAG VARIABLES
TRANSPACE      15000 BYTES                   2400 IF/COMPUTE OPERATIONS

                  10 N OF CASES      UNKNOWN
                  11 VAR LABELS      VAT01,ROUTE NUMBER/
                  12                 VAT02,STREET ID/
                  13                 VAT03,TRAFFIC FLOW/
                  14                 VAT04,NO. OF TRAFFIC SIGNS/
                  15                 VAT05,LARGE OBSTACLES/
                  16                 VAT06,SMALL OBSTACLES/
                  17                 VAT07,NO. OF THRU LANES/
                  18                 VAT08,MEDIAN WIDTH/
                  19                 VAT09,MED TYPE CURB/
                  20                 VAT10,MED TYPE PAVED/
                  21                 VAT11,CURB TYPE RT/
                  22                 VAT12,CURB TYPE LT/
                  23                 VAT13,AVG SHOULDER WIDTH/
                  24                 VAT14,PERCENT GUARDRAIL/
                  25                 VAT15,VERT ALIGN/
                  26                 VAT16,HORZ ALIGN/
                  27                 VAT17,NO. OF DRIVEWAYS/
                  28                 VAT18,NO. OF INTER SIG/
                  29                 VAT19,NO. OF INTER NSIG/
                  30                 VAT21,POSTED SPEED/
                  31                 VAT22,LIGHTING/
                  32                 VAT23,SURFACE TYPE/
                  33                 VAT24,LAND USE/
```

Table 69. Example SPSS program and output (continued).


```
                        VAT25,CURB LANE USAGE/
                        VAT26,NO. BUS STOPS/
                        VAT27,BUS STOP TYP CURB/
                        VAT28,BUS STOP PULLOUT/
                        VAT29,SECTIONS PER CITY/
                        VAT30,CITY SIZE/
                        VAT31,ROADWAY CLASS/
                        VAT34,REGULATORY SIGNS/
                        VAT35,WARNING  SIGNS/
                        VAT36,GUIDE SIGNS/
                        VAT37,TREES/
                        VAT38,UTILITY POLES/
                        VAT39,LTLANE 1 DIR/
                        VAT40,LTLANE 2 DIR/
                        VAT41,RTLANE MID/
                        VAT42,PARKING LANE RT/
                        VAT43,PARKING LANE LT/
                        VAT44,RTBAY INT/
                        VAT45,LTBAY INT/
                        VAT46,RTBAY MID/
                        VAT47,BUS STOP NEAR/
                        VAT48,BUS STOP FAR/
                        VAT49,BUS STOP MID/
                        VADO1,ACCIDENT FREQUENCY/
                        VADO2,FATAL ACCIDENTS/
                        VADO3,INJURY ACCIDENTS/
                        VADO4,PROPERTY DAMAGE/
                        VADO5,HEAD ON/
                        VADO6,REAR ENDS/
                        VADO7,SIDESWIPE/
                        VADO8,ANGLE/
                        VADO9,ALL OTHERS/
                        VACO1,ADT/
                        VACO2,PHF/
                        VACO3,VEH MIX CARS/
                        VACO4,VEH MIX COMM/
                        VACO5,PKNG TNOVER RATE/
                        VACO6,LOCAL BUS PER HR/
                        VACO7,LANE WIDTH/
                        VACO8,AVG CYCLE LENGTH/
                        VACO9,LOC FACTOR/
                        VAC10,CITY POPULATION/
                        VAC11,RAINFALL/
                        VAC12,SNOWFALL/
                        VAC13,OPER SPEED/
                        VAC15,CAPACITY/
                        VAC16,VC RATIO/
                        VAC17,TOT ACCIDENT RATE/
                        VAC18,FATAL RATE/
                        VAC19,INJURY RATE/
                        VAC20,PD RATE/
    MISSING VALUES      VAT03,VATO8 TO VAT10,VAT15,VAT16,VAT21,VAT23,
                        VAT24,VACO1 TO VAC15(0)/VAT13,VAT39,VAT40(99)/
```

Table 69. Example SPSS program and output (continued).

```
URBAN ARTERIAL STUDY                                                    07/13/82        PAGE    5

             VAD01 TO VAD09(9999)/VAC16 TO VAC20(999.999)/
COMPUTE      VAD10=VAD01/3
VAR LABELS   VAD10,AVG ACCIDENT FREQ/
VALUE LABELS VAT03 (0)UNKNOWN(1)ONE WAY(2)TWO WAY(3)1WY DIVIDED
             (4)2WY DIVIDED/
             VAT22 VAT41 (0)NONE(1)YES(2)NO/
             VAT42 VAT43 (0)NONE(1)PARTIAL(2)CONTINUOUS /
             VAT09 (1)CURB(2)NO CURB/
             VAT10 (1)PAVED(2)UNPAVED/
             VAT11 VAT12 (0)NONE(1)VERTICAL(2) MOUNTABLE/
             VAT15 (1)LEVEL(2)MODERATE(3)STEEP/
             VAT16 (1)STRAIGHT(2)CURVE/
             VAT27 VAT28 (0)NO(1)YES/
             VAT23 (1)BITUMINOUS(2)CONCRETE(3)DIRT/
             VAT24 (1)COMMERICAL(2)RESIDENTIAL(3)VACANT
             (4)OTHER/
             VAT25 (0)OTHER(1)THRU(2)BIKE(3)BUS(4)RESTRICTED
             (5)UNRESTRICTED(6)LIMITED/
             VAT29 (0)UNKNOWN
             (1)BIG RAPIDS(2)KALAMAZOO(3)LANSING(4)SAGINAW(5)BIRMINGHAM
             (6)FARMINGTON(7)FARMINGTON HILLS(8)NOVI(9)OAK PARK
             (10)ROYAL OAK(11)SOUTHFIELD(12)TROY(13)TOPEKA(14)NEW ORLEANS
             (15)MILWAUKEE(16)SAN FRANCISCO(17)FORT WAYNE(18)SEATTLE
             (19)MINNEAPOLIS/
             VAT30 (0)UNKNOWN(1)SMALL(2)MEDIUM(3)LARGE/
             VAT31 (0)UNKNOWN(1)ONE WAY(2)TWO WAY,TWO LANE
             (3)MULTLANE DIV(4)MULTLANE UNDIV/
ANOVA        VAD10,VAC17 BY VAT31(1,4),VAT30(1,3)
               WITH VAC01/
STATISTICS   ALL

'ANOVA' PROBLEM REQUIRES     1776 BYTES OF SPACE.

READ INPUT DATA

AFTER READING   8678 CASES FROM SUBFILE URBAN.A ,  END OF DATA WA  ENCOUNTERED ON LOG  \L UNIT # 8
```

Table 69. Example SPSS program and output (continued).

```
URBAN ARTERIAL STUDY                                                   07/13/82        PAGE    6

FILE   URBAN.A  (CREATION DATE = 07/13/82)

* * * * * * * * * * * * * * *   C E L L   M E A N S   * * * * * * * * * * * * * *
                VAD10     AVG ACCIDENT FREQ
             BY VAT31     ROADWAY CLASS
                VAT30     CITY SIZE
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TOTAL POPULATION

      3.66
  (  8678)

VAT31
         1          2          3          4

      3.72       2.50       4.73       4.37
  (   726)  (  3459)  (  1897)  (  2496)

VAT30
         1          2          3

      2.15       3.89       3.60
  (   446)  (  3806)  (  4424)


             VAT30
                    1          2          3
VAT31
         1       1.10       4.28       2.73
             (    16)  (   481)  (   229)

         2       1.61       2.64       2.53
             (   310)  (  1602)  (  1547)

         3       4.01       5.54       4.45
             (    38)  (   531)  (  1428)

         4       3.52       4.69       4.13
             (    84)  (  1192)  (  1220)
```

Table 69. Example SPSS program and output (continued).

URBAN ARTERIAL STUDY 07/13/82 PAGE 7

FILE URBAN.A (CREATION DATE = 07/13/82)

* * * * * * * * * * * * * * C E L L M E A N S * * * * * * * * * * * * * *

	VAC17	TOT ACCIDENT RATE
BY	VAT31	ROADWAY CLASS
	VAT30	CITY SIZE

* *

TOTAL POPULATION

8.32
(8678)

VAT31

1	2	3	4
10.07	8.06	7.82	8.59
(726)	(3458)	(1997)	(2496)

VAT30

1	2	3
5.60	9.21	7.84
(448)	(3806)	(4424)

VAT31 \ VAT30	1	2	3
1	8.44	10.85	8.54
	(16)	(481)	(229)
2	5.36	8.76	7.88
	(310)	(1602)	(1547)
3	6.15	9.76	7.14
	(38)	(531)	(1428)
4	5.69	8.90	8.47
	(84)	(1192)	(1220)

Table 69. Example SPSS program and output (continued).

```
URBAN ARTERIAL STUDY                                                                          07/13/82       PAGE    8

FILE   URBAN.A  (CREATION DATE = 07/13/82)

* * * * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * * * *
                VAD10     AVG ACCIDENT FREQ
             BY VAT31     ROADWAY CLASS
                VAT30     CITY SIZE
           WITH VAC01     ADT
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	25371.473	1	25371.473	1048.545	0.000
VAC01	25371.473	1	25371.473	1048.545	0.000
MAIN EFFECTS	1813.945	5	362.789	14.993	0.000
VAT31	667.739	3	222.580	9.199	0.000
VAT30	962.671	2	481.336	19.893	0.000
2-WAY INTERACTIONS	693.215	6	115.536	4.775	0.000
VAT31 VAT30	693.215	6	115.536	4.775	0.000
EXPLAINED	27878.688	12	2323.224	96.014	0.0
RESIDUAL	209665.500	8665	24.197		
TOTAL	237544.188	8677	27.376		

```
COVARIATE   RAW REGRESSION COEFFICIENT

VAC01            0.000

   8678 CASES WERE PROCESSED.
      0 CASES (  0.0 PCT) WERE MISSING.
```

Table 69. Example SPSS program and output (continued).

URBAN ARTERIAL STUDY 07/13/82 PAGE 9

FILE URBAN.A (CREATION DATE = 07/13/82)

* * * M U L T I P L E C L A S S I F I C A T I O N A N A L Y S I S * * *

	VAD10	AVG ACCIDENT FREQ
BY	VAT31	ROADWAY CLASS
	VAT30	CITY SIZE
WITH	VAC01	ADT

* *

GRAND MEAN = 3.66

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS DEV'N	ADJUSTED FOR INDEPENDENTS BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
VAT31							
1 ONE WAY	726	0.07				0.38	
2 TWO WAY,TWO LANE	3459	-1.15				-0.35	
3 MULTLANE DIV	1997	1.08				0.10	
4 MULTLANE UNDIV	2496	0.72				0.29	
			0.19				0.06
VAT30							
1 SMALL	448	-1.50				-0.97	
2 MEDIUM	3806	0.24				0.33	
3 LARGE	4424	-0.05				-0.18	
			0.07				0.06

MULTIPLE R SQUARED	0.114
MULTIPLE R	0.338

Table 69. Example SPSS program and output (continued).

URBAN ARTERIAL STUDY 07/13/82 PAGE 10

FILE URBAN.A (CREATION DATE = 07/13/82)

```
* * * * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * * * *
              VAC17     TOT ACCIDENT RATE
           BY VAT31     ROADWAY CLASS
              VAT30     CITY SIZE
         WITH VAC01     ADT
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	7134.504	1	7134.504	62.198	0.0
VAC01	7134.504	1	7134.504	62.198	0.0
MAIN EFFECTS	10352.480	5	2070.496	18.050	0.000
VAT31	3115.461	3	1038.487	9.053	0.000
VAT30	6194.121	2	3097.061	27.000	0.000
2-WAY INTERACTIONS	1499.699	6	249.950	2.179	0.042
VAT31 VAT30	1499.700	6	249.950	2.179	0.042
EXPLAINED	18986.688	12	1582.224	13.794	0.0
RESIDUAL	993932.563	8665	114.707		
TOTAL	1012919.250	8677	116.736		

COVARIATE	RAW REGRESSION COEFFICIENT
VAC01	-0.000

8678 CASES WERE PROCESSED.
0 CASES (0.0 PCT) WERE MISSING.

Table 69. Example SPSS program and output (continued).

URBAN ARTERIAL STUDY 07/13/82 PAGE 11

FILE URBAN.^ (CREATION DATE = 07/13/82)

* * * M U L T I P L E   C L A S S I F I C A T I O N   A N A L Y S I S * * *

	VAC17	TOT ACCIDENT RATE
BY	VAT31	ROADWAY CLASS
	VAT30	CITY SIZE
WITH	VAC01	ADT

* *

GRAND MEAN = 8.32

VARIABLE + CATEGORY	N	UNADJUSTED DEV'N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS DEV'N	ADJUSTED FOR INDEPENDENTS BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV'N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
VAT31							
1 ONE WAY	726	1.74				1.10	
2 TWO WAY,TWO LANE	3459	-0.26				-0.74	
3 MULTLANE DIV	1997	-0.50				0.34	
4 MULTLANE UNDIV	2496	0.26				0.44	
			0.06				0.06
VAT30							
1 SMALL	448	-2.73				-2.61	
2 MEDIUM	3806	0.88				0.81	
3 LARGE	4424	-0.48				-0.43	
			0.09				0.08
MULTIPLE R SQUARED							0.017
MULTIPLE R							0.131

Table 69. Example SPSS program and output (continued).

```
URBAN ARTERIAL STUDY                                              07/13/82        PAGE   12

TRANSPACE REQUIRED..        100 BYTES
      1 TRANSFORMATIONS
      O RECODE VALUES + LAG VARIABLES
      3 IF/COMPUTE OPERATIONS

CPU TIME REQUIRED..    20.96 SECONDS

                118 FINISH

          NORMAL END OF JOB.
            118 CONTROL CARDS WERE PROCESSED.
              O ERRORS WERE DETECTED.
```

Table 70. Example OSIRIS V program and output.

```
R *OSIRIS4 SPRINT=-6
&DICT DICTOUT=-DIC2 SOURCE=DIC1 PRINT=OUTC
&RECODE SOURCE=RCODE
&TRANS DICTIN=-DIC2 DATAIN=-GEOM(LR=113) DICTOUT=DIC2 DATAOUT=-DATA
CREATE NEW VARIABLES
RECODE=1 PRINT=CODEBK VARS=V1-V49,V101-V124,V201-V210,R50-R71
&END
$EMPTY -6
&SEARCH DICTIN=DIC2 DATAIN=-DATA
INCLUDE V31=3
BRANCHING ANALYSIS FOR URBAN ARTERIAL STUDY
RECODE=1 DEPV=R70 MAX=30 MIN=25 EXPL=.25
VAR=R67 M CODES=(1-7)
VAR=R54 CODES=(1-6)
VAR=V25,R52 CODES=(0-6)
VAR=R51,R55 CODES=(1-5)
VAR=V24,V31,R53,R62,R68 CODES=(1-4)
VAR=V19,R58,R59,R65,R66 CODES=(0-4)
VAR=V18,R57,R63,R64 CODES=(0-3)
VAR=V15,V23,V30,R60,R69 CODES=(1-3)
VAR=V11,V12,V22,V42,V43,R61 CODES=(0-2)
VAR=V16,V9 CODES=(1-2) END
&END
$COP -6(1,30)
&SEARCH DICTIN=DIC2 DATAIN=-DATA
INCLUDE V31=3
BRANCHING ANALYSIS FOR URBAN ARTERIAL STUDY
RECODE=1 DEPV=R50 MAX=30 MIN=25 EXPL=.25
VAR=R54 CODES=(1-6)
VAR=R67 M CODES=(1-7)
VAR=V25,R52 CODES=(0-6)
VAR=R51,R55 CODES=(1-5)
VAR=V24,V31,R53,R62,R68 CODES=(1-4)
VAR=V19,R58,R59,R65,R66 CODES=(0-4)
VAR=V18,R57,R63,R64 CODFS=(0-3)
VAR=V15,V23,V30,R60,R69 CODES=(1-3)
VAR=V11,V12,V22,V42,V43,R61 CODES=(0-2)
VAR=V16,V9 CODES=(1-2) END
&END
STOP
CON *PRINT* ROUTE=EAPC
COP -6 *PRINT*
REL *PRINT*
End of file
```

Table 70. Example OSIRIS V program and output (continued).

```
DICTIONARY FOR URBAN ARTERIAL STUDY
NRECORDS=3 LRECL=113
V=1 G=1 NAME='STREET ID' REC=1 COL=1 WID=6 TYPE=C MD1=NONE L=NONE
V=2 NAME='CITY CODE' COL=8 WID=6 MD1=0 L=NONE
V=3 NAME='TRAFFIC FLOW' COL=15 WID=1 MD1=0 L=NONE
V=4 NAME=SIGNS COL=17 WID=2 MD1=NONE L=NONE
V=5 NAME='LARGE OBSTACLES' COL=19 WID=3 L=NONE
V=6 NAME='SMALL OBSTACLES' COL=22 WID=2 L=NONE
V=7 NAME='NO OF THRU LANES' COL=24 WID=2 L=NONE
V=8 NAME='MEDIAN WIDTH' COL=26 WID=4 MD1=0 L=NONE
V=9 NAME='MED TYPE CURB' COL=30 WID=2 L='1=CURB,2=NO CURB'
V=10 NAME='MED TYPE PAVED' COL=32 L='1=PAVED,2=UNPAVED'
V=11 NAME='CURB TYPE RS' COL=34 MD1=NONE L='0=NONE,1=VERTICAL,2=MOUNTABLE'
V=12 NAME='CURB TYPE LS' COL=36 MD1=NONE L='0=NONE,1=VERTICAL,2=MOUNTABLE'
V=13 NAME='SHOULDER WIDTH' COL=38 MD1=99 L=NONE
V=14 NAME='GUARDRAILS' COL=40 WID=4 MD1=NONE L=NONE
V=15 NAME='VERTICAL ALIGN' COL=44 WID=2 MD1=0 L='1=LEVEL,-
 2=MODERATE,3=STEEP'
V=16 NAME='HORIZONTAL ALIGN' COL=46 L='1=STRAIGHT,2=CURVE'
V=17 NAME='DRIVEWAYS' COL=48 MD1=NONE L=NONE
V=18 NAME='SIGNALIZED INTER' COL=50 MD1=NONE L=NONE
V=19 NAME='NONSIGNALIZED INTER' COL=52 L=NONE
V=20 NAME='LANES ON CROSS ST' COL=54 L=NONE
V=21 NAME='POSTED SPEED' COL=56 L=NONE
V=22 NAME='LIGHTING' COL=58 MD1=NONE L='0=NONE,1=YES'
V=23 NAME='SURFACE TYPE' COL=60 MD1=0 L='1=BITUMINOUS,2=CONCRETE,3=DIRT'
V=24 NAME='LAND USE' COL=62 L='1=COMMERICAL,2=RESIDENTAL,3=VACANT,4=OTHER'
V=25 NAME='CURB LANE USAGE' COL=64 MD1=NONE L='0=OTHER,1=THRU,2=BIKE,3=BUS,-
 4=RESTRICTED,5=UNRESTRICTED,6=LIMITED'
V=26 NAME='BUS STOP' COL=66 L=NONE
V=27 NAME='BUS STOP CURB' COL=68 L=NONE
V=28 NAME='BUS STOP PULLOUT' COL=70 L=NONE
V=29 NAME='SECTIONS BY CITY' COL=72 MD1=0 L=NONE
V=30 NAME='CITY SIZE' COL=74 MD1=NONE L='1=SMALL,2=MEDIUM,3=LARGE'
V=31 NAME='ROADWAY CLASS' COL=76 L='1=ONEWAY,2=2WAY 2LANE,3=DIVIDED,4=UNDIVIDED'
V=32 NAME='SHOULDER TYPE RS' COL=78 L='1=PAVED,2=UNPAVED'
V=33 NAME='SHOULDER TYPE LS' COL=80 L='1=PAVED,2=UNPAVED'
V=34 NAME='REGULATORY SIGNS' COL=82 MD1=NONE L=NONE
V=35 NAME='WARNING SIGNS' COL=84 L=NONE
V=36 NAME='GUIDE SIGNS' COL=86 L=NONE
V=37 NAME='TREES' COL=88 MD1=NONE L=NONE
V=38 NAME='UTILITY POLES' COL=90
V=39 NAME=:LTLANE 1DIR' COL=92
V=40 NAME='LTLANE 2DIR' COL=94
V=41 NAME='RTLANE MIDBLK' COL=96 L='0=NONE,1=YES,2=NO'
V=42 NAME='PARKING RS' COL=98 L='0=NONE,1=PARTIAL,2=CONT'
V=43 NAME='PARKING LS' COL=100 L='0=NONE,1=PARTIAL,2=CONT'
V=44 NAME='RTBAY INTER' COL=102 L=NONE
V=45 NAME='LTBAY INTER' COL=104
V=46 NAME='RTBAY MIDBLK' COL=106
V=47 NAME='BUS STOP NEAR' COL=108
V=48 NAME='BUS STOP FAR' COL=110
V=49 NAME='BUS STOP MIDBLK' COL=112
V=101 G=2 NAME='ACCIDENT FREQ' REC=2 COL=1 WID=4  MD1=9999
V=102 NAME='FATAL ACCIDENTS' COL=5
V=103 NAME='INJURY ACCIDENTS' COL=9
V=104 NAME='PDO ACCIDENTS' COL=13
V=105 NAME='HEAD ON ACC' COL=17
V=106 NAME='REAR END ACC' COL=21
V=107 NAME='SIDESWIPE ACC' COL=25
```

Table 70. Example OSIRIS V program and output (continued).

```
V=108 NAME='ANGLE ACC' COL=29
V=109 NAME='OTHER ACC' COL=29
V=110 NAME='ADT' COL=38 WID=5 MD1=0
V=111 NAME='PHF' COL=43 WID=3
V=112 NAME='VEH MIX CARS' COL=46 WID=2
V=113 NAME='VEH MIX COMM' COL=48
V=114 NAME='PARKING TURNOVER' COL=50 WID=3 NDEC=1
V=115 NAME='BUSES PER HOUR' COL=53 TYPE=C WID=3 NDEC=0
V=116 NAME='LANE WIDTH' COL=56 WID=2
V=117 NAME='AVG CYCLE LENGTH' COL=59
V=118 NAME='LOC FACTOR' COL=61 WID=3
V=119 NAME='POPULATION' COL=64
V=120 NAME='RAINFALL' COL=67 WID=4 NDEC=1
V=121 NAME='SNOWFALL' COL=71
V=122 NAME='OPERATOR SPEED' COL=75 TYPE=C WID=2 NDEC=0
V=123 NAME='POPULATION LEVEL' COL=78 WID=1
V=124 NAME='CAPACITY' COL=80 WID=5
V=201 G=3 NAME='VC RATIO' REC=3 COL=1 WID=7 NDEC=3 MD1=999.999
V=202 NAME='ACCIDENT RATE' COL=9
V=203 NAME='FATAL RATE' COL=17
V=204 NAME='INJURY RATE' COL=25
V=205 NAME='PDO RATE' COL=33
V=206 NAME='HEAD ON RATE' COL=41
V=207 NAME='REAR END RATE' COL=49
V=208 NAME='SIDESWIPE RATE' COL=57
V=209 NAME='ANGLE RATE' COL=65
V=210 NAME='OTHER RATE' COL=73
&END
End of file
```

Table 70. Example OSIRIS V program and output (continued).

```
OSIRIS IV MONITOR SYSTEM
16:33:21 JUL 12. 1982

&RECODE SOURCE=RCODE
 RECODE=1 FLOATING POINT
 R50=0
 IF V101 GT 0 THEN R50=V101/3
 R51=0
 IF V4 IN(0-4) THEN R51=1
 IF V4 IN(5-7) THEN R51=2
 IF V4 IN(8-10) THEN R51=3
 IF V4 IN(11-15) THEN R51=4
 IF V4 GE 16 THEN R51=5
 MDATA R51(0)
 R52=0
 IF V5 IN(0-4) THEN R52=1
 IF V5 IN(5-10) THEN R52=2
 IF V5 IN(11-15) THEN R52=3
 IF V5 IN(16-20) THEN R52=4
 IF V5 IN(21-24) THEN R52=5
 IF V5 GE 25 THEN R52=6
 MDATA R52(0)
 R53=4
 IF V6 EQ 0 THEN R53=0
 IF V6 IN(1-2) THEN R53=1
 IF V6 IN(3-6) THEN R53=2
 IF V6 GE 7 THEN R53=3
 MDATA R53(4)
 R54=0
 IF V7 GT 0 THEN R54=V7
 IF V7 GE 7 THEN R54=7
 MDATA R54(0)
 R55=0
 IF V8 IN(1-4) THEN R55=1
 IF V8 IN(5-10) THEN R55=2
 IF V8 IN(11-20) THEN R55=3
 IF V8 IN(21-35) THEN R55=4
 IF V8 GE 36 THEN R55=5
 MDATA R55(0)
 R56=0
 IF V13 IN(1-5) THEN R56=1
 IF V13 IN(6-10) THEN R56=2
 IF V13 GE 11 THEN R56=3
 MDATA R56(0)
 R57=4
 IF V14 EQ 0 THEN R57=0
 IF V14 IN(1-25) THEN R57=1
 IF V14 IN(26-50) THEN R57=2
 IF V14 GE 51 THEN R57=3
 MDATA R57(4)
 R58=5
 IF V17 EQ 0 THEN R58=0
 IF V17 IN(1-2) THEN R58=1
 IF V17 IN(3-5) THEN R58=2
 IF V17 IN(6-9) THEN R58=3
 IF V17 GE 10 THEN R58=4
 MDATA R58(5)
 R59=0
 IF V2 EQ 60610 THEN R59=1
 IF V2 EQ 80820 THEN R59=2
```

Table 70. Example OSIRIS V program and output (continued).

```
IF V2 EQ 90910 THEN R59=3
IF V2 EQ 101010 THEN R59=4
IF V2 EQ 121230 THEN R59=5
IF V2 EQ 131310 THEN R59=6
IF V2 EQ 141310 THEN R59=7
IF V2 EQ 151310 THEN R59=8
IF V2 EQ 161420 THEN R59=9
IF V2 EQ 171520 THEN R59=10
IF V2 EQ 181310 THEN R59=11
IF V2 EQ 191310 THEN R59=12
IF V2 EQ 201310 THEN R59=13
IF V2 EQ 211620 THEN R59=14
IF V2 EQ 221310 THEN R59=15
IF V2 EQ 231310 THEN R59=16
IF V2 EQ 241710 THEN R59=17
IF V2 EQ 241711 THEN R59=18
IF V2 EQ 251710 THEN R59=18
IF V2 EQ 312410 THEN R59=18
IF V2 EQ 322510 THEN R59=19
MDATA R59(0)
R60=0
IF V21 IN(15-25) THEN R60=1
IF V21 IN(26-35) THEN R60=2
IF V21 GE 36 THEN R60=3
MDATA R60(0)
R61=V26
IF V26 GE 2 THEN R61=2
R62=0
IF V34 IN(0-1) THEN R62=1
IF V34 IN(2-5) THEN R62=2
IF V34 IN(6-10) THEN R62=3
IF V34 GE 11 THEN R62=4
MDATA R62(0)
R63=V35
IF V35 GE 3 THEN R63=3
R64=4
IF V36 EQ 0 THEN R64=0
IF V36 IN(1-2) THEN R64=1
IF V36 IN(3-4) THEN R64=2
IF V36 GE 5 THEN R64=3
MDATA R64(4)
R65=5
IF V37 EQ 0 THEN R65=0
IF V37 IN(1-2) THEN R65=1
IF V37 IN(3-6) THEN R65=2
IF V37 IN(7-9) THEN R65=3
IF V37 GE 10 THEN R65=4
MDATA R65(5)
R66=5
IF V38 EQ 0 THEN R66=0
IF V38 IN(1-2) THEN R66=1
IF V38 IN(3-7) THEN R66=2
IF V38 IN(8-10) THEN R66=3
IF V38 GE 11 THEN R66=4
MDATA R66(5)
R67=0
IF V110 IN(0-4999) THEN R67=1
IF V110 IN(5000-9999) THEN R67=2
IF V110 IN(10000-14999) THEN R67=3
IF V110 IN(15000-19999) THEN R67=4
```

Table 70. Example OSIRIS V program and output (continued).

```
IF V110 IN(20000-24999) THEN R67=5
IF V110 GE 25000 THEN R67=6
MDATA R67(0)
R68=0
IF V116 IN(7-9) THEN R68=1
IF V116 IN(10-12) THEN R68=2
IF V116 IN(13-14) THEN R68=3
IF V116 GE 15 THEN R68=4
MDATA R68(0)
R69=0
IF V124 IN(1650-4950) THEN R69=1
IF V124 IN(5000-8250) THEN R69=2
IF V124 GE 8300 THEN R69=3
MDATA R69(0)
R70=0
IF V202 LT 999.999 THEN R70=V202
R71=0
IF V119 IN(0-49) THEN R71=1
IF V119 IN(50-249) THEN R71=2
IF V119 GE 250 THEN R71=3
NAME R50 'AVG ACC FREQ', R51 'SIGNS',R52 'LARGE OBSTACLES',R53 'SMALL OBSTACLES'
NAME R54 'THRU LANES',R55 'MDEIAN WIDTH',R56 'SHOULDER WIDTH',R57 'PCT GUARDRAIL'
NAME R58 'DRIVEWAYS',R59 'CITY',R60 'POSTED SPEED'
NAME R61 'BUS STOPS',R62 'REGULATORY SIGNS',R63 'WARNING SIGNS'
NAME R64 'GUIDE SIGNS',R65 'TREES',R66 'UTILITY POLES'
NAME R67 'ADT',R68 'LANE WIDTH',R69 'CAPACITY',R70 'ACC RATE'
NAME R71 'POPULATION'

*****NORMAL TERMINATION OF RECODE   $ 0.17    0.73 SECS
```

Table 70. Example OSIRIS V program and output (continued).

```
OSIRIS IV MONITOR SYSTEM
16:33:43 JUL 12, 1982

$SEARCH DICTIN=DIC2 DATAIN=-OSDATA
BRANCHING ANALYSIS FOR URBAN ARTERIAL STUDY
RECODE=1 DEPV=R70 MAX=30 MIN=50 EXPL=.25
VAR=R59 F CODES=(1-19)
VAR=V24,V31 F CODES=(1-4)
VAR=V25 F CODES=(0-6)
VAR=R54 M CODES=(1-7)
VAR=R52,R67 CODES=(1-6)
VAR=R51 CODES=(1-5)
VAR=R71 CODES=(1-4)
VAR=V19,R58 CODES=(0-4)
VAR=V18,V44,R53,R57 CODES=(0-3)
VAR=V15,V30,R60 CODES=(1-3)
VAR=V11,V12,V42,V43,V46,R61 CODES=(0-2)
VAR=V16,V23 CODES=(1-2)
VAR=V22,V27,V28 CODES=(0-1) END
```

Table 70. Example OSIRIS V program and output (continued).

```
*** SEARCH - OSIRIS SEARCHING FOR STRUCTURE

JUL 12, 1982  BRANCHING ANALYSIS FOR URBAN ARTERIAL STUDY                                  SEARCH     1

THE NUMBER OF VARIABLES IS  30

ILLEGAL CHARACTERS IN THE DATA WILL
BE TREATED AS MISSING DATA

THE DATA ARE NOT WEIGHTED

THE DATA WERE TRANSFORMED BY RECODE  1

THE NUMBER OF CASES IS  8437
```

Table 70. Example OSIRIS V program and output (continued).

```
*** SEARCH - OSIRIS SEARCHING FOR STRUCTURE

JUL 12, 1982  BRANCHING ANALYSIS FOR URBAN ARTERIAL STUDY                              SEARCH    1

THE NUMBER OF VARIABLES IS  30

ILLEGAL CHARACTERS IN THE DATA WILL
BE TREATED AS MISSING DATA

THE DATA ARE NOT WEIGHTED

THE DATA WERE TRANSFORMED BY RECODE  1

THE NUMBER OF CASES IS  8437
```

Table 70. Example OSIRIS V program and output (continued).

```
THE PARTITIONING ENDS WITH  17  FINAL GROUPS
                                                                                    SEARCH     2
THE VARIATION EXPLAINED IS 12.8%

ONE-WAY ANALYSIS OF FINAL GROUPS

        SOURCE          VARIATION          DF

        EXPLAINED    0.1263888E+06         16
        ERROR        0.8591648E+06       8420
        TOTAL        0.9855536E+06       8436

SPLIT SUMMARY TABLE

GROUP   1       8437 CASES    SUM(WT)=  0.8437000E+04

   MEAN(Y)=  0.8335917E+01     VAR(Y)=  0.1168271E+03  VARIATION=  0.9855536E+06

    SPLIT ON R59      CITY                             VAR EXPL=  0.4193937E+05
    INTO GROUP    2     CODES  12  8  6 11 15 16 17  3 13  4 18  5  7
     AND GROUP    3     CODES   1  9 19 10 14  2

GROUP   3       3929 CASES    SUM(WT)=  0.3929000E+04

   MEAN(Y)=  0.1072410E+02     VAR(Y)=  0.1403403E+03  VARIATION=  0.5512566E+06

    SPLIT ON R51      SIGNS                            VAR EXPL=  0.1542032E+05
    INTO GROUP    4     CODES   1  2
     AND GROUP    5     CODES   3  4  5

GROUP   2       4508 CASES    SUM(WT)=  0.4508000E+04

   MEAN(Y)=  0.6254468E+01     VAR(Y)=  0.8705515E+02  VARIATION=  0.3923575E+06

    SPLIT ON V18      SIGNALIZED INTER                 VAR EXPL=  0.1070308E+05
    INTO GROUP    6     CODES   0
     AND GROUP    7     CODES   1  2  3

GROUP   5       2283 CASES    SUM(WT)=  0.2283000E+04

   MEAN(Y)=  0.1240627E+02     VAR(Y)=  0.1546504E+03  VARIATION=  0.3529122E+06

    SPLIT ON R67      ADT                              VAR EXPL=  0.5147621E+04
    INTO GROUP    8     CODES   1  2  3  4
     AND GROUP    9     CODES  -5  6

GROUP   8       1760 CASES    SUM(WT)=  0.1760000E+04

   MEAN(Y)=  0.1322482E+02     VAR(Y)=  0.1682939E+03  VARIATION=  0.2960290E+06

    SPLIT ON R59      CITY                             VAR EXPL=  0.4847602E+04
    INTO GROUP   10     CODES   1 14 10
     AND GROUP   11     CODES  19  9  2
```

Table 70. Example OSIRIS V program and output (continued).

```
THE PARTITIONING ENDS WITH  17  FINAL GROUPS
                                                                                                   SEARCH     2
THE VARIATION EXPLAINED IS 12.8%

ONE-WAY ANALYSIS OF FINAL GROUPS

      SOURCE          VARIATION          DF

      EXPLAINED    0.1263888E+06         16
      ERROR        0.8591648E+06       8420
      TOTAL        0.9855536E+06       8436

SPLIT SUMMARY TABLE

GROUP    1        8437 CASES     SUM(WT)=  0.8437000E+04

  MEAN(Y)=  0.8335917E+01      VAR(Y)=  0.1168271E+03  VARIATION=  0.9855536E+06

   SPLIT ON R59      CITY                                VAR EXPL=  0.4193937E+05
   INTO GROUP    2      CODES   12  8  6 11 15 16 17  3 13  4 18  5  7
    AND GROUP    3      CODES    1  9 19 10 14  2

GROUP    3        3929 CASES     SUM(WT)=  0.3929000E+04

  MEAN(Y)=  0.1072410E+02      VAR(Y)=  0.1403403E+03  VARIATION=  0.5512566E+06

   SPLIT ON R51      SIGNS                               VAR EXPL=  0.1542032E+05
   INTO GROUP    4      CODES    1  2
    AND GROUP    5      CODES    3  4  5

GROUP    2        4508 CASES     SUM(WT)=  0.4508000E+04

  MEAN(Y)=  0.6254468E+01      VAR(Y)=  0.8705515E+02  VARIATION=  0.3923575E+06

   SPLIT ON V18      SIGNALIZED INTER                    VAR EXPL=  0.1070308E+05
   INTO GROUP    6      CODES    0
    AND GROUP    7      CODES    1  2  3

GROUP    5        2283 CASES     SUM(WT)=  0.2283000E+04

  MEAN(Y)=  0.1240627E+02      VAR(Y)=  0.1546504E+03  VARIATION=  0.3529122E+06

   SPLIT ON R67      ADT                                 VAR EXPL=  0.5147621E+04
   INTO GROUP    8      CODES    1  2  3  4
    AND GROUP    9      CODES    5  6

GROUP    6        1760 CASES     SUM(WT)=  0.1760000E+04

  MEAN(Y)=  0.1322482E+02      VAR(Y)=  0.1682939E+03  VARIATION=  0.2960290E+06

   SPLIT ON R59      CITY                                VAR EXPL=  0.4847602E+04
   INTO GROUP   10      CODES    1 14 10
    AND GROUP   11      CODES   19  9  2
```

Table 70. Example OSIRIS V program and output (continued).

```
GROUP   6        3413 CASES     SUM(WT)=  0.3413000E+04                                                          SEARCH     3

  MEAN(Y)=  0.5381693E+01     VAR(Y)=  0.6797601E+02  VARIATION=  0.2319342E+06

   SPLIT ON V24      LAND USE                            VAR EXPL=  0.3167242E+04
   INTO GROUP  12      CODES   3  2  4
    AND GROUP  13      CODES   1

GROUP   4        1646 CASES     SUM(WT)=  0.1646000E+04

  MEAN(Y)=  0.8390944E+01     VAR(Y)=  0.1112001E+03  VARIATION=  0.1829241E+06

   SPLIT ON R67      ADT                                 VAR EXPL=  0.4686848E+04
   INTO GROUP  14      CODES   1
    AND GROUP  15      CODES   2  3  4  5  6

GROUP  11         798 CASES     SUM(WT)=  0.7980000E+03

  MEAN(Y)=  0.1504701E+02     VAR(Y)=  0.1981004E+03  VARIATION=  0.1578860E+06

   SPLIT ON V25      CURB LANE USAGE                     VAR EXPL=  0.5339828E+04
   INTO GROUP  16      CODES   5  0
    AND GROUP  17      CODES   1  4

GROUP   7        1095 CASES     SUM(WT)=  0.1095000E+04

  MEAN(Y)=  0.8974815E+01     VAR(Y)=  0.1368558E+03  VARIATION=  0.1497202E+06

   SPLIT ON R67      ADT                                 VAR EXPL=  0.4718734E+04
   INTO GROUP  18      CODES   1  2
    AND GROUP  19      CODES   3  4  5  6

GROUP  15        1476 CASES     SUM(WT)=  0.1476000E+04

  MEAN(Y)=  0.7818269E+01     VAR(Y)=  0.1002926E+03  VARIATION=  0.1479316E+06

   SPLIT ON V24      LAND USE                            VAR EXPL=  0.3952220E+04
   INTO GROUP  20      CODES   3  2  4
    AND GROUP  21      CODES   1

GROUP  17         649 CASES     SUM(WT)=  0.6490000E+03

  MEAN(Y)=  0.1628647E+02     VAR(Y)=  0.2066929E+03  VARIATION=  0.1339370E+06

   SPLIT ON R53      SMALL OBSTACLES                     VAR EXPL=  0.3441502E+04
   INTO GROUP  22      CODES   0
    AND GROUP  23      CODES   1  2  3

GROUP  10         962 CASES     SUM(WT)=  0.9620000E+03

  MEAN(Y)=  0.1171327E+02     VAR(Y)=  0.1387048E+03  VARIATION=  0.1332953E+06

   SPLIT ON R67      ADT                                 VAR EXPL=  0.3411872E+04
   INTO GROUP  24      CODES   1
    AND GROUP  25      CODES   2  3  4
```

Table 70. Example OSIRIS V program and output (continued).

```
GROUP  18          368 CASES    SUM(WT)=  0.3680000E+03                                                          SEARCH     4

   MEAN(Y)=  0.1189258E+02     VAR(Y)=  0.2229207E+03  VARIATION=  0.8181188E+05

    SPLIT ON R58      CITY                              VAR EXPL=  0.6627934E+04
    INTO GROUP  26      CODES   15 17  3
     AND GROUP  27      CODES    4 18 13  7

GROUP  27          216 CASES    SUM(WT)=  0.2160000E+03

   MEAN(Y)=  0.1545267E+02     VAR(Y)=  0.2738745E+03  VARIATION=  0.5888303E+05

    SPLIT ON V31      ROADWAY CLASS                     VAR EXPL=  0.6588176E+04
    INTO GROUP  28      CODES    2  3
     AND GROUP  29      CODES    1  4

GROUP   9          523 CASES    SUM(WT)=  0.5230000E+03

   MEAN(Y)=  0.9651679E+01     VAR(Y)=  0.9911023E+02  VARIATION=  0.5173554E+05

    SPLIT ON R58      CITY                              VAR EXPL=  0.2623204E+04
    INTO GROUP  30      CODES    9 19  1 10
     AND GROUP  31      CODES    2 14

GROUP  31          278 CASES    SUM(WT)=  0.2780000E+03

   MEAN(Y)=  0.1175413E+02     VAR(Y)=  0.1241995E+03  VARIATION=  0.3440325E+05

    SPLIT ON V18      SIGNALIZED INTER                  VAR EXPL=  0.3773719E+04
    INTO GROUP  32      CODES    0
     AND GROUP  33      CODES    1  2  3


FINAL GROUP SUMMARY TABLE

GROUP  12         2639 CASES    SUM(WT)=  0.2639000E+04

   MEAN(Y)=  0.4859988E+01     VAR(Y)=  0.6201608E+02  VARIATION=  0.1635984E+06   SHR EXPL= -0.4458056E+05

GROUP  13          774 CASES    SUM(WT)=  0.7740000E+03

   MEAN(Y)=  0.7160477E+01     VAR(Y)=  0.8430594E+02  VARIATION=  0.6516850E+05   SHR EXPL= -0.6514535E+04

GROUP  14          170 CASES    SUM(WT)=  0.1700000E+03

   MEAN(Y)=  0.1356312E+02     VAR(Y)=  0.1783228E+03  VARIATION=  0.3030556E+05   SHR EXPL=  0.1142045E+05

GROUP  16          149 CASES    SUM(WT)=  0.1490000E+03

   MEAN(Y)=  0.8648252E+01     VAR(Y)=  0.1257374E+03  VARIATION=  0.1860913E+05   SHR EXPL=  0.1886600E+04

GROUP  19          727 CASES    SUM(WT)=  0.7270000E+03

   MEAN(Y)=  0.7497873E+01     VAR(Y)=  0.8703792E+02  VARIATION=  0.6318953E+05   SHR EXPL= -0.4568137E+04
```

Table 70. Example OSIRIS V program and output (continued).

```
GROUP  20        1103 CASES     SUM(WT)=  0.1103000E+04                                                              SEARCH     5
   MEAN(Y)=  0.6866689E+01      VAR(Y)=  0.8764972E+02   VARIATION=  0.9658994E+05   SHR EXPL= -0.1112788E+05
GROUP  21         373 CASES     SUM(WT)=  0.3730000E+03
   MEAN(Y)=  0.1063219E+02      VAR(Y)=  0.1273909E+03   VARIATION=  0.4738941E+05   SHR EXPL=  0.9106578E+04
GROUP  22         358 CASES     SUM(WT)=  0.3580000E+03
   MEAN(Y)=  0.1836263E+02      VAR(Y)=  0.2078742E+03   VARIATION=  0.7421106E+05   SHR EXPL=  0.6591375E+05
GROUP  23         291 CASES     SUM(WT)=  0.2910000E+03
   MEAN(Y)=  0.1373231E+02      VAR(Y)=  0.1940841E+03   VARIATION=  0.5628439E+05   SHR EXPL=  0.2156454E+05
GROUP  24         238 CASES     SUM(WT)=  0.2380000E+03
   MEAN(Y)=  0.1499793E+02      VAR(Y)=  0.2051456E+03   VARIATION=  0.4861950E+05   SHR EXPL=  0.2378012E+05
GROUP  25         724 CASES     SUM(WT)=  0.7240000E+03
   MEAN(Y)=  0.1063350E+02      VAR(Y)=  0.1123982E+03   VARIATION=  0.8126388E+05   SHR EXPL=  0.1768830E+05
GROUP  26         152 CASES     SUM(WT)=  0.1520000E+03
   MEAN(Y)=  0.6833498E+01      VAR(Y)=  0.1079530E+03   VARIATION=  0.1630091E+05   SHR EXPL= -0.1560550E+04
GROUP  28         146 CASES     SUM(WT)=  0.1460000E+03
   MEAN(Y)=  0.1162858E+02      VAR(Y)=  0.1718256E+03   VARIATION=  0.2491471E+05   SHR EXPL=  0.5590191E+04
GROUP  29          70 CASES     SUM(WT)=  0.7000000E+02
   MEAN(Y)=  0.2342863E+02      VAR(Y)=  0.3968135E+03   VARIATION=  0.2738014E+05   SHR EXPL=  0.2475213E+05
GROUP  30         ?45 CASES     SUM(WT)=  0.2450000E+03
   MEAN(Y)=  0.7266039E+01      VAR(Y)   0.6028313E+02   VARIATION=  0.1470908E+05   SHR EXPL= -0.1904575E+04
GROUP  32         171 CASES     SUM(WT)=  0.1710000E+03
   MEAN(Y)=  0.8839683E+01      VAR(Y)=  0.9240211E+02   VARIATION=  0.1570836E+05   SHR EXPL=  0.7614846E+03
GROUP  33         107 CASES     SUM(WT)=  0.1070000E+03
   MEAN(Y)=  0.1641179E+02      VAR(Y)=  0.1407657E+03   VARIATION=  0.1492117E+05   SHR EXPL=  0.1418175E+05
```

Table 70. Example OSIRIS V program and output (continued).

% VARIATION EXPL. BY BEST SPLIT(* FOR FINAL GRPS.) SEARCH 6

	1	2	3	4	5	6	7	8	9	10	11	12*	13*
R59	4.26	0.32	0.50	0.21	0.41	0.08	0.47	0.49	0.27	0.06	0.18	0.07	0.05
V24	1.72	0.75	0.81	0.26	0.26	0.32	0.09	0.22	0.14	0.05	0.19	0.03	0.00
V31	0.21	0.13	0.38	0.08	0.38	0.02	0.02	0.24	0.03	0.04	0.23	0.02	0.05
V25	1.62	0.48	0.86	0.23	0.37	0.10	0.11	0.24	0.03	0.06	0.54	0.02	0.01
R54	0.10	0.08	0.24	0.02	0.39	0.02	0.02	0.22	0.03	0.12	0.11	0.04	0.01
R52	1.16	0.18	0.76	0.23	0.32	0.04	0.14	0.36	0.02	0.04	0.27	0.02	0.01
R67	0.55	0.25	0.66	0.48	0.52	0.25	0.48	0.11	0.01	0.35	0.03	0.22	0.14
R51	2.88	0.38	1.56	0.23	0.11	0.15	.64E-02	0.14	0.02	0.07	0.17	0.05	0.02
R71	0.38	0.19	0.24	0.07	0.01	0.01	0.11	0.01	0.09	0.03	0.09	.95E-02	0.01
V19	0.25	0.03	0.07	0.08	0.03	0.05	0.03	0.04	0.04	0.03	0.03	0.04	0.01
R58	0.63	0.05	0.89	0.39	0.25	0.02	0.16	0.14	0.06	0.01	0.20	.74E-02	0.01
V18	2.44	1.09	0.99	0.25	0.46	0.00	.52E-02	0.35	0.21	0.09	0.26	0.00	0.00
V44	0.10	0.02	0.04	.92E-02	0.01	0.02	0.01	0.01	0.19	0.03	0.00	0.03	0.00
R53	0.06	0.04	0.14	0.01	0.33	0.01	0.04	0.41	0.06	0.01	0.34	0.01	0.01
R57	0.02	0.01	0.01	0.01	0.01	0.01	0.00	.50E-02	0.08	0.00	0.00	.90E-02	0.00
V15	0.02	0.02	0.21	0.01	0.23	0.01	.61E-02	0.06	0.21	0.02	0.04	.69E-02	0.03
V30	0.38	0.19	0.24	0.07	0.01	0.01	0.11	0.01	0.09	0.03	0.09	.95E-02	0.01
R60	0.96	0.18	0.60	0.32	0.22	0.05	0.08	0.08	0.03	0.09	0.02	0.04	0.01
V11	0.82	0.27	0.23	0.09	0.03	0.13	.67E-02	0.05	0.02	0.08	0.11	0.05	0.03
V12	0.69	0.18	0.21	0.09	0.09	0.07	.53E-02	0.11	0.01	0.16	0.01	0.04	0.04
V42	0.13	0.09	0.04	0.07	0.03	0.01	0.09	0.03	0.01	0.02	0.20	.78E-02	0.01
V43	0.10	0.11	0.08	0.01	0.03	0.03	0.06	0.03	0.04	.84E-02	0.25	0.02	0.01
V46	.89E-02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R61	0.33	0.21	0.07	0.04	0.03	0.05	0.02	0.02	0.03	0.01	0.05	0.01	0.01
V16	0.01	.52E-02	0.08	0.05	.52E-02	0.01	0.01	0.01	0.05	.96E-02	0.01	0.01	0.01
V23	0.03	.65E-02	.91E-02	0.01	0.01	.70E-02	0.01	0.07	0.00	0.01	0.08	0.01	.57E-02
V22	1.42	0.31	0.22	0.07	0.00	0.08	0.12	0.00	0.00	0.00	0.00	0.06	.50E-02

Table 70. Example OSIRIS V program and output (continued).

% VARIATION EXPL. BY BEST SPLIT(* FOR FINAL GRPS.) - continued SEARCH 7

	1	2	3	4	5	6	7	8	9	10	11	12*	13*
V27	0.32	0.19	0.08	.69E-02	0.04	0.05	0.01	0.03	0.01	0.02	0.05	0.01	0.01
V28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

% VARIATION EXPL. BY BEST SPLIT(* FOR FINAL GRPS.) - continued

	14*	15	16*	17	18	19*	20*	21*	22*	23*	24*	25*	26*
R59	0.00	0.08	0.00	0.07	0.67	0.09	0.05	0.05	0.01	0.06	0.00	0.13	0.00
V24	0.12	0.40	0.01	0.15	0.18	0.08	0.07	0.00	0.20	.98E-02	0.07	0.17	0.03
V31	0.12	0.09	0.01	0.08	0.52	0.04	0.03	0.03	0.01	0.02	0.03	0.02	0.01
V25	0.00	0.27	0.00	0.04	0.18	.10E-01	0.03	0.11	0.01	0.02	0.02	0.03	0.06
R54	0.00	0.04	0.02	0.05	0.52	0.01	0.05	.82E-02	.94E-02	0.01	0.00	0.06	0.00
R52	.64E-02	0.19	0.01	0.18	0.16	0.08	0.14	0.02	0.01	0.03	.97E-02	0.09	0.03
R67	0.00	0.13	0.02	0.05	0.02	0.02	0.17	0.14	0.04	0.02	0.00	0.01	0.00
R51	.60E-02	0.30	0.03	0.08	0.01	0.04	0.15	0.08	0.03	0.04	0.02	0.03	0.01
R71	0.00	0.01	0.00	.56E-02	0.08	0.01	0.02	0.01	0.01	0.06	0.00	0.00	.53E-02
V19	0.03	0.05	0.00	0.01	0.01	0.06	0.10	0.01	0.01	0.02	0.08	0.06	0.00
R58	0.11	0.27	.80E-02	0.02	0.08	0.02	0.14	0.07	0.06	0.03	.77E-02	0.01	0.01
V18	0.00	0.24	0.00	0.18	0.00	0.01	0.10	0.01	0.21	.51E-02	0.00	0.11	0.00
V44	0.00	0.01	0.00	0.01	0.00	.52E-02	0.03	0.00	0.00	0.00	0.00	0.01	0.00
R53	0.02	0.02	.72E-02	0.35	0.08	.87E-02	0.02	0.02	0.00	0.02	0.01	0.02	0.00
R57	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
V15	.87E-02	0.04	0.00	0.16	0.09	0.02	0.03	0.07	0.03	0.03	0.00	0.06	0.00
V30	0.00	0.01	0.00	.56E-02	0.08	0.01	0.02	0.01	0.01	0.06	0.00	0.00	.53E-02
R60	0.14	0.11	0.00	0.05	0.00	0.06	0.07	0.04	0.00	.86E-02	0.07	0.04	0.00
V11	0.00	0.13	0.00	.50E-02	0.00	0.05	0.13	0.00	0.01	0.00	0.11	0.04	0.00
V12	0.00	0.15	0.00	0.04	0.00	0.01	0.18	0.00	0.11	0.00	0.18	0.10	0.00
V42	0.03	0.10	0.00	0.04	0.01	0.01	0.05	0.03	0.02	0.03	0.01	.78E-02	0.05
V43	0.01	0.04	0.00	0.01	0.02	0.01	0.02	0.01	.67E-02	0.01	.91E-02	0.02	0.05
V46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 70. Example OSIRIS V program and output (continued).

SEARCH 8

R61	0.00	0.01	0.05	0.01	0.06	0.01	0.01	0.04	0.04	0.01	0.00	0.09	.50E-02
V16	0.00	0.03	0.00	0.01	0.00	0.01	0.04	0.00	0.00	0.00	0.00	.57E-02	0.00
V23	0.00	.60E-02	0.01	.50E-02	0.02	.50E-02	0.01	0.01	.51E-02	0.00	0.06	0.02	0.00
V22	0.00	0.04	0.00	0.00	0.00	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
V27	0.00	.68E-02	0.00	.50E-02	0.04	.52E-02	.87E-02	0.04	0.03	0.01	0.00	0.10	.50E-02
V28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

% VARIATION EXPL. BY BEST SPLIT(* FOR FINAL GRPS.) - continued

	27	28*	29*	30*	31	32*	33*
R59	0.00	0.00	0.00	0.01	0.00	0.00	0.00
V24	0.11	0.02	0.00	0.09	0.23	0.08	0.08
V31	0.67	0.00	0.00	0.01	.96E-02	.55E-02	0.00
V25	0.23	0.02	0.00	0.07	0.00	0.00	0.00
R64	0.44	0.00	0.00	.72E-02	.97E-02	.72E-02	0.00
R52	0.11	0.10	0.00	0.02	0.01	0.03	0.00
R67	.51E-02	0.00	0.00	.51E-02	0.03	.61E-02	0.00
R51	0.01	0.01	0.00	.57E-02	0.01	.50E-02	0.00
R71	0.00	0.00	0.00	.55E-02	0.00	0.00	0.00
V19	0.03	0.04	0.00	0.01	0.07	0.01	0.00
R66	0.01	0.01	0.00	.58E-02	.71E-02	0.02	.70E-02
V18	0.00	0.00	0.00	0.01	0.38	0.00	0.00
V44	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R63	0.03	.62E-02	0.00	.70E-02	.78E-02	0.00	0.00
R57	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V15	0.02	0.00	0.00	0.09	0.08	0.04	0.02
V30	0.00	0.00	0.00	.55E-02	0.00	0.00	0.00
R60	0.00	0.00	0.00	0.02	0.01	0.00	0.00
V11	0.00	0.00	0.00	0.00	.51E-02	0.01	0.00
V12	0.00	0.00	0.00	0.00	.57E-02	0.01	0.00

Table 70. Example OSIRIS V program and output (continued).

% VARIATION EXPL. BY BEST SPLIT(* FOR FINAL GRPS.) - continued . SEARCH 9

	27	28*	29*	30*	31	32*	33*
V42	0.09	0.00	0.00	0.02	0.00	0.00	0.00
V43	0.18	0.00	0.00	0.02	0.00	0.00	0.00
V46	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R61	0.07	0.03	0.00	.51E-02	0.02	0.01	0.00
V16	0.00	0.00	0.00	0.00	0.07	0.00	0.00
V23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
V27	0.05	0.02	0.00	.50E-02	0.01	0.01	0.00
V28	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*****NORMAL TERMINATION OF SEARCH $ 9.07 36.42 SECS

FEDERALLY COORDINATED PROGRAM (FCP) OF HIGHWAY RESEARCH AND DEVELOPMENT

The Offices of Research and Development (R&D) of the Federal Highway Administration (FHWA) are responsible for a broad program of staff and contract research and development and a Federal-aid program, conducted by or through the State highway transportation agencies, that includes the Highway Planning and Research (HP&R) program and the National Cooperative Highway Research Program (NCHRP) managed by the Transportation Research Board. The FCP is a carefully selected group of projects that uses research and development resources to obtain timely solutions to urgent national highway engineering problems.*

The diagonal double stripe on the cover of this report represents a highway and is color-coded to identify the FCP category that the report falls under. A red stripe is used for category 1, dark blue for category 2, light blue for category 3, brown for category 4, gray for category 5, green for categories 6 and 7, and an orange stripe identifies category 0.

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems associated with the responsibilities of the FHWA under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion, and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by balancing the demand-capacity relationship through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements that affect the quality of the human environment. The goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge and technology of materials properties, using available natural materials, improving structural foundation materials, recycling highway materials, converting industrial wastes into useful highway products, developing extender or substitute materials for those in short supply, and developing more rapid and reliable testing procedures. The goals are lower highway construction costs and extended maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural and hydraulic designs, fabrication processes, and construction techniques to provide safe, efficient highways at reasonable costs.

6. Improved Technology for Highway Construction

This category is concerned with the research, development, and implementation of highway construction technology to increase productivity, reduce energy consumption, conserve dwindling resources, and reduce costs while improving the quality and methods of construction.

7. Improved Technology for Highway Maintenance

This category addresses problems in preserving the Nation's highways and includes activities in physical maintenance, traffic services, management, and equipment. The goal is to maximize operational efficiency and safety to the traveling public while conserving resources.

0. Other New Studies

This category, not included in the seven-volume official statement of the FCP, is concerned with HP&R and NCHRP studies not specifically related to FCP projects. These studies involve R&D support of other FHWA program office research.

* The complete seven-volume official statement of the FCP is available from the National Technical Information Service, Springfield, Va. 22161. Single copies of the introductory volume are available without charge from Program Analysis (HRD-3), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.