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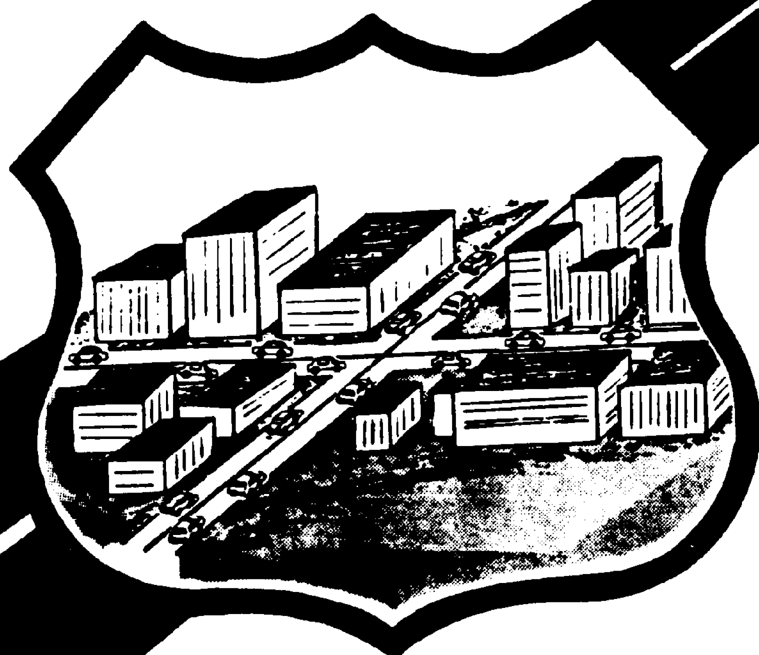
ANALYSIS OF URBAN ARTERIAL ROAD AND STREET ACCIDENT EXPERIENCE

September 1982

Vol. I. Executive Summary



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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 first 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
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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

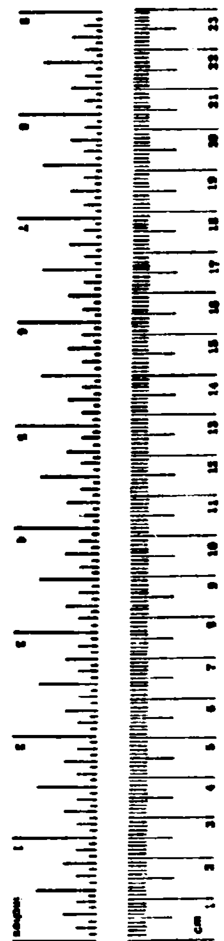
NOTICE

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

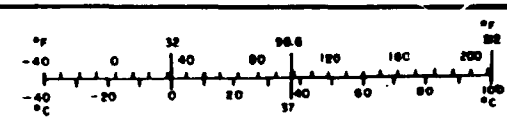
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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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INTRODUCTION

Many studies have been conducted to examine relationships between traffic accidents and specific geometric, environmental, and traffic conditions. A majority of these studies pertain to rural highway situations or a combination of rural and urban highway situations. A detailed study of accidents pertaining to urban roadway characteristics is important because the urban arterial road network is being taxed by several recent developments. The curtailment of urban freeway programs has contributed to high traffic volumes on many urban arterial roadways which has resulted in increases in congestion and traffic accidents. Additional demands on the urban arterial roadway network have occurred as a result of continued land development.

Urban arterial roads have experienced and are still experiencing significant safety problems. It has been estimated that one-third of all fatal motor vehicle accidents and over one-half of all other motor vehicle accidents occur on the urban arterial road network. As the urban arterial network represents only three percent of all highway mileage, it appears that a large safety problem exists on a relatively small system.

The operational and environmental characteristics of the urban arterial road network are varied and so are the attendant safety problems. Factors widely believed to influence traffic safety on urban arterial roadways include on-street parking conditions, traffic volume, access control, land use, and type of traffic control device. An assessment of previous research studies as well as a determination of the magnitude of existing traffic safety problems indicated the need for a detailed analysis of accident data on roads and streets functionally classified as urban arterials. This assessment would permit traffic safety and design engineers to identify accident problems and to select and evaluate potentially more cost-effective roadway treatments than is possible with existing practices.

This executive summary provides a brief overview of the study of traffic accidents and roadway features conducted for the Federal Highway Administration. Only the principal topics are discussed in the summary. For further details, the reader should consult Volume II, the final report or Volumes III and IV, the Appendixes.

OBJECTIVES AND SCOPE

This study was conducted in response to the need to identify safety problems on urban arterial roadways. The specific objectives of the study were to:

- identify the general dimensions of the urban arterial accident problem relative to the overall motor vehicle accident problem;

- determine the distribution and specific characteristics of urban arterial accidents and identify causal elements, i.e., geometrics, operational, and environmental characteristics; and

- identify appropriate countermeasures that can be implemented to reduce the rate and severity of accidents occurring on urban arterials.

The study is viewed as a benchmark in the determination and analysis of the motor vehicle traffic accident problem in the urban environment. In addition to the discovery nature of the study, a computerized data base was developed to promote continued in-depth analysis and study. The data base is of a sufficient size to allow the designer, researcher, and traffic engineer to conduct statistical analyses for a variety of urban arterial roadway characteristics.

A significant effort was devoted to the development of the comprehensive accident and roadway features data base. A large number of accident and roadway variables were collected and analyzed. Because a variety of combinations exist for analyzing the effects of the variables on accidents, only a limited number of combinations were included in this study.

METHODOLOGY

The study consisted of two phases: data collection and data analysis. The data collection phase consisted of an extensive literature review; development of a sampling plan; selection of data items to be collected; development of the data collection plan; training of data collection personnel; collection of data; input of data into computerized files; and checking of data files. Data analysis consisted of the determination of the general dimensions of the urban arterial accident problem; determination of the distribution of accident characteristics; development of causal factors; and identification of countermeasures.

Data Collection

After completing an analysis of the literature, a comprehensive sampling plan was developed. The purpose of the sampling plan was to develop a computerized data base that would be representative of the accident and roadway characteristics of urban arterial highways in the United States. Several constraints prevent the true unbiased modeling of the system. Foremost among these constraints was the need to develop the data base from computerized accident records. Due to the large number of accidents desired (greater than 100,000), 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 computerized accident records; 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 accidents to be used for the proposed analyses.

Based on data availability and sampling requirements, the following urban areas were selected for data collection and analysis.

- Big Rapids, Michigan
- Kalamazoo, Michigan
- Lansing, Michigan
- Saginaw, Michigan
- Birmingham, Michigan
- Farmington, Michigan
- Farmington Hills, Michigan
- Novi, Michigan
- Oak Park, Michigan
- Royal Oak, Michigan
- Southfield, Michigan
- Troy, Michigan
- Topeka, Kansas
- New Orleans, Louisiana
- Milwaukee, Wisconsin
- San Francisco, California
- Fort Wayne, Indiana
- Seattle, Washington
- Minneapolis, Minnesota

A roadway segment length of 0.1 mile (0.16 km) was selected as the unit for data collection and analysis. Data describing the characteristics of the 0.1-mile (0.16-km) roadway segments were either collected in the field or extracted from data files, maps, or other sources provided by city highway officials. Accident data were also obtained on computer tapes and coded for each 0.1-mile (0.16-km) segment.

A sampling plan was developed which defined the amount of data to be collected in each of the selected cities. An analysis plan defining the analysis techniques and the order in which these techniques were to be used was also developed prior to data collection. A complete discussion of the sampling plan and the data collection procedure utilized for the study is contained in Appendix C.

A major activity in this project was the identification of geometric, environmental, and traffic factors which are associated with urban arterial traffic accidents. The initial process of identification of roadway factors included a literature search and input based on the research experience of the study team members. Final selection of the factors included consideration of the following items: previously determined relationships between the factor and urban arterial accidents; availability of the element in the existing data files; suitability of the factor for collection in the field; and the amount of processing necessary to put the factor in a form for analysis.

Based upon this work, the list of factors shown in Table 1 were identified. The factors are classified according to three major categories -- geometric, environmental, and operational. For analysis purposes, these elements represent independent variables which are included in the computerized data base.

Data Analysis

The first task in the analysis was to determine the basic distributional characteristics for each of the roadway and accident variables. After the distributional characteristics were identified, a systematic analysis plan utilizing branching analysis, analysis of variance and covariance, and multiple linear regression was developed.

The branching analysis, analysis of variance and covariance, and regression analysis were utilized in a sequential manner where the application of each successive technique drew upon the results of the previous analysis. At each point, a review of the data and analysis findings was conducted to insure that all areas of concern were investigated and that the findings were reasonable.

MAJOR FINDINGS

Accident Characteristics

The mean accident frequencies and rates for the 0.1-mile (0.16-km) segments included in the sample are given in Table 2. As shown in Table 2, multilane divided roadways had the highest annual accident frequency and the lowest accident rate. Two-lane, two-way streets had the lowest annual accident frequency while one-way streets had the highest accident rates.

Table 1. Roadway factors selected for data collection.

Geometric Factors	
Lane width	Number of far-side bus stops per segment
Number of through lanes	Number of midblock bus stops per segment
Average shoulder width	Number of driveways per segment
Roadway classification	Curb lane usage
Pavement surface	Parking lane - right side
Median width	Parking lane - left side
Median curb	Number of right-turn bays at intersections
Median type	Number of left-turn bays at intersections
Curb type - right side	Number of right-turn bays at midblock driveways
Curb type - left side	Vertical alinement
Percent guardrail	Horizontal alinement
Number of signalized intersections per segment	Number of large obstacles per segment
Number of non-signalized intersections per segment	Number of small obstacles per segment
Number of bus stops per segment	Number of trees per segment
Bus stop type - curb	Number of utility poles per segment
Bus stop type - pullout	Land use
Number of near-side bus stops per segment	Midblock right-turn lanes
Environmental Factors	
Roadway lighting	Amount of rainfall
City size	Amount of snowfall
Operational Factors	
Average daily traffic (ADT)	Average cycle length
Roadway capacity	Posted speed limit
Location factor	Operating speed
Peak hour factor	Number of traffic sign faces per segment
Vehicle mix-percent commercial	Number of regulatory sign faces per segment
Vehicle mix-percent cars	Number of warning sign faces per segment
Parking turnover rate	Number of guide sign faces per segment
Number of local buses per hour	

Table 2. **Mean accident frequencies and rates for the 0.1-mile (0.16-km) urban roadway segments.**

Roadway Classification	Annual Accident Frequency*		Accident Rate**	
	Mean	Std. Dev.	Mean	Std. Dev.
One-way	3.71	5.11	10.06	11.49
Two-lane, two-way	2.50	3.98	8.06	10.93
Multilane divided	4.73	6.21	7.82	10.32
Multilane undivided	4.38	5.62	8.59	10.76
All segments	3.66	5.24	8.33	10.81

* Accidents per 0.1-mile (0.16-km) segment per year
** Accidents per million-vehicle miles
Note: 1 mile = 1.6 km

While total accident frequencies and rates can be used to describe general accident problems, an analysis of the data by severity and accident type is needed to identify specific causal factors and countermeasures. The distribution of accidents by severity and accident type is shown in Figures 1 and 2. The percentage of fatal accidents on arterial streets (0.24 percent) appears to be higher than the estimated 0.12 percent of fatal accidents that are annually reported in urban areas.

A summary of severity and accident type data stratified by functional roadway classification is given in Tables 3 and 4. As shown in Table 5, accident severity was also summarized by city size.

Examination of the data reveals that there is little difference in the severity of accidents by roadway type with the exception that one-way streets appear to have a lower percentage of injury accidents as compared to the percentage of injury accidents reported on the other roadway types. As shown in Table 5, the percentage of injury accident data for large size cities appears to be significantly higher than the percentage of injury accidents reported in smaller and medium size cities. However, a review of the accident reporting procedures in the large cities contained in the sample revealed that property damage accidents are not routinely investigated, thus, it is doubtful if there is a real difference in the percentage of injury accidents.

Primary Accident Relationships

One of the primary objectives of this study was to determine factors that significantly affect accident frequency and rate on the urban arterial street network. Specifically, the objective was to identify factors that would result in fewer accidents if controlled during design or by

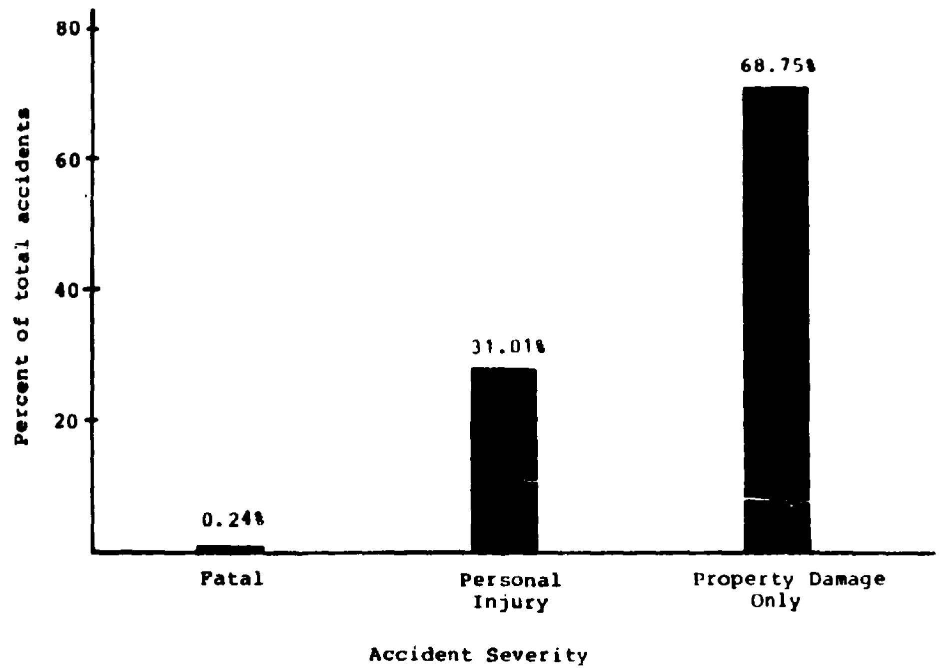

Figure 1. Distribution of accidents by severity.

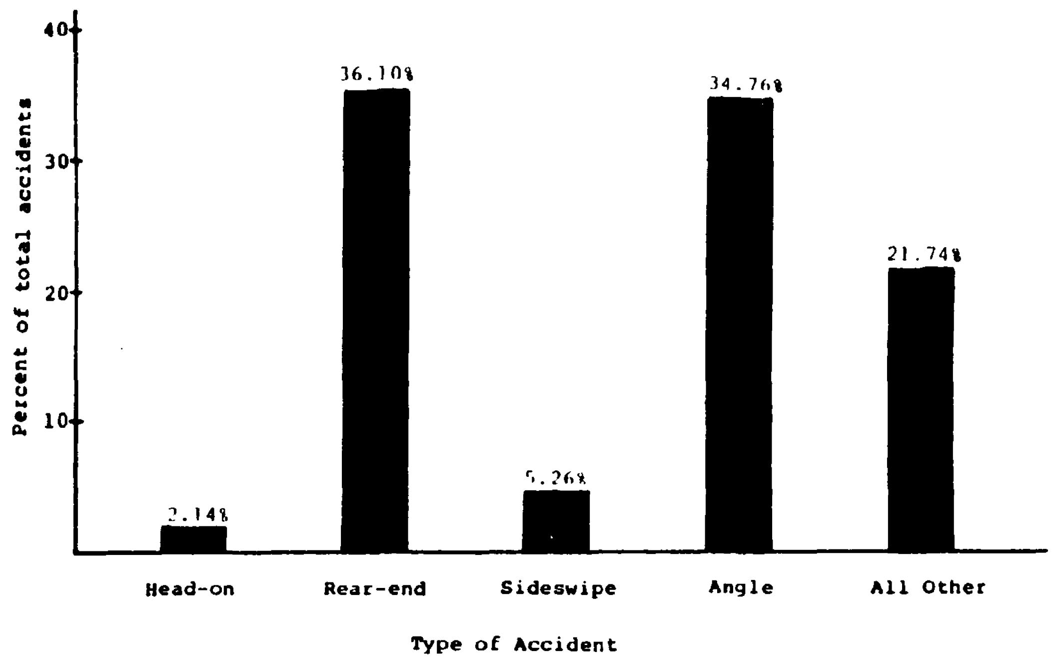

Figure 2. Distribution of accidents by accident type.

Table 3. Summary of severity by roadway classification.

Accident Severity	Roadway Classification			
	One-Way	Two-Way, Two-Lane	Multilane Divided	Multilane Undivided
Fatal	8 (0.1%)	56 (0.2%)	33 (0.2%)	56 (0.2%)
PI	1,630 (24.9%)	6,840 (29.9%)	6,198 (29.7%)	6,617 (29.3%)
PDO	4,920 (75.0%)	16,152 (69.9%)	14,618 (70.1%)	15,877 (70.5%)
Total	6,558 (100.0%)	23,048 (100.0%)	20,849 (100.0%)	22,550 (100.0%)

Table 4. Summary of accident type by roadway classification.

Accident Type	Roadway Classification			
	One-Way	Two-Way, Two-Lane	Multilane Divided	Multilane Undivided
Head-on	42 (0.6%)	490 (3.0%)	188 (1.7%)	491 (2.1%)
Rear-end	3,190 (48.9%)	4,692 (29.2%)	4,275 (38.5%)	8,382 (36.2%)
Sideswipe	306 (4.7%)	543 (3.4%)	700 (6.3%)	1,440 (6.2%)
Angle	2,038 (31.3%)	5,982 (37.2%)	3,672 (33.1%)	8,080 (34.9%)
All Other	942 (14.5%)	4,382 (27.2%)	2,271 (20.4%)	4,774 (20.6%)
Total	6,518 (100.0%)	16,089 (100.0%)	11,106 (100.0%)	23,617 (100.0%)

Table 5. Summary of severity by city size.

Accident Severity	City Size		
	Small	Medium	Large
Fatal	8 (0.3%)	74 (0.2%)	143 (0.3%)
PI	805 (27.9%)	11,415 (25.7%)	17,299 (36.2%)
PDO	2,072 (71.8%)	32,978 (74.1%)	30,386 (63.5%)
Total	2,885 (100.0%)	44,467 (100.0%)	47,828 (100.0%)

the traffic operations engineer. Using the results of the literature review and the previous analyses, the research team prepared the list of accident related factors shown in Table 6.

Extensive analyses of the data base were also conducted using multivariate statistical techniques to identify primary roadway elements which are associated with urban arterial accidents. A list of the roadway factors which have a significant effect on accidents is presented in Table 7.

Causal Factors

Based upon the results of the various tests, conclusions were drawn concerning relationships between the independent variables and accident rates and frequencies. Independent variables with a previously defined relationship were specifically reviewed to determine if the data base supports causal factor relationships with urban arterial accidents.

It is important that the nature and purpose of the summaries and analyses described in this study be recognized. Any given traffic accident involves an interactive set of several geometric, environmental, and operational circumstances. Therefore, it is difficult to describe the contribution of any single factor on any single accident and even more difficult to describe the contribution of a single factor on the total accident experience (even categorized by accident type) for a segment of roadway 0.1 mile (0.16 km) in length. However, while the cause-effect relationship may be difficult to quantify, it is also clear that the accidents are influenced by certain geometric, environmental, and operational characteristics. The data base accumulated for this study will be useful in determining the likely causes of certain types of accidents on roadway type, but only if the influence of several other critical variables are identified and controlled in the investigation. Knowledge of these causes will be useful in the selection of effective countermeasures.

The following observations are products of the accident characterization conducted within this study. As mentioned above, cause-effect relationships should not be inferred.

- Segments with medians narrower than 4 feet (1.2 m) have higher accident frequencies (i.e., accidents per segment) than those with wider medians.
- Segments bounded by commercial development have higher accident frequencies than those bounded by other types of land use.

Table 6. Factors with a possible relationship to accidents.

Roadway Feature	Literature Review	Macroscopic Analysis	Branching Analysis	Regression Analysis
Geometric Factors				
Lane width	●	●		
Number of through lanes		●	●	●
Average shoulder width		●		
Roadway classification	●	●	●	
Pavement surface		●		
Median width	●	●	●	
Median type	●	●		
Curb type - right and left		●	●	
Percent guardrail		●		
Number of signalized intersections	●	●	●	●
Number of nonsignalized intersections	●	●	●	
Number of bus stops		●	●	
Type of bus stop		●		
Number of driveways	●	●		
Curb lane usage		●	●	
Parking	●	●	●	
Turn lanes at intersections	●	●		
Vertical alinement	●		●	
Horizontal alinement	●			
Number of obstacles	●	●	●	
Number of trees	●	●		
Number of utility poles	●	●		●
Type of land use	●	●	●	●
Environmental Factors				
Roadway lighting	●	●		
City size	●	●	●	
Amount of rainfall	●	●		
Amount of snowfall		●		
Operational Factors				
Average daily traffic	●	●	●	●
Roadway capacity	●	●		
Location factor		●		
Peak hour factor		●		
Vehicle mix		●		
Parking turnover rate	●	●		
Number of local buses per hour		●		
Average cycle length	●	●		
Posted speed limit	●	●		
Operating speed		●		
Number of traffic sign faces	●	●	●	●

Table 7. Summary of roadway factors significantly affecting accident rates and frequencies on urban arterial streets.

Factors	Roadway Classification			
	One-Way	Two-Way, Two-Lane	Multilane Divided	Multilane Undivided
Geometric Factors				
Number of through lanes	•			
Number of small obstacles		•		
Number of signalized intersections	•	•		•
Number of utility poles	•	•	•	•
Number of driveways		•		
Operational Factors				
Average daily traffic	•	•	•	•
Number of traffic sign faces		•	•	

- Accident frequency increases as the number of large obstacles in the segment increases. Accident frequency seems to be independent of the number of small obstacles in the segment.

- Accident frequencies are higher in segments where there are 3 or more utility poles.

- Accident frequency increases as the number of traffic sign faces increases.

- Accident frequency, i.e., the annual number of accidents per segment, increases with traffic volume (as would be expected) but accident rates, i.e., accidents per million vehicle-miles, are lower on those segments with higher traffic volumes -- with the exception of one-way streets, where the rate increases with increasing volume.

- Segments containing signalized intersections have higher accident frequencies and rates than segments without signalized intersections.

- Segments where left-turn and/or right-turn bays are present have higher accident rates than those where there are no auxiliary lanes.

- Segments where parking is not allowed have lower accident frequencies than those segments where full or part-time parking is permitted.

Most of these observations are consistent with what might be expected. It is clear, however, that a number of confounding variables must be accounted for before cause-effect relationships can be inferred. The fact that the cited pseudo-relationships are readily observable indicates that these factors should be addressed when making use of the data base.

ACCIDENT COUNTERMEASURES

Potential countermeasures for reducing urban arterial accidents were selected based on the literature review and the results of the data analysis. The literature review provided a comprehensive list of geometric, environmental, and operational variables which had been previously found to be associated with accidents on urban arterial streets.

The second source of countermeasure development was the results of a series of branching analyses conducted for each of the four functional roadway classifications. For each of these roadway types, a separate branching analysis was made for rear-end accidents, angle accidents, sideswipe accidents, and head-on accidents. These analyses were used to determine which variables or combination of variables were associated with a significantly larger number of accidents for a particular roadway type and accident type.

Using the literature results and the branching analyses, countermeasures were developed for each accident type as shown in Tables 8 through 11. For each possible accident cause, an L denotes that the information was based on the literature results and an A denotes that analysis of the study data was used to determine the possible accident cause. In many cases, the accident cause was based on input from both the literature review and the data analysis.

Tables 8 through 11 can be used by safety engineers to select countermeasures for any of the four specific accident types for the four roadway classifications. These are general countermeasures and are intended to be a guide for selection of the most appropriate countermeasure for a given accident problem on an urban arterial road or street.

RECOMMENDED USE OF THE DATA BASE

The data base collected for this study and the extensive testing conducted on individual variables and combinations of variables have produced a valuable resource for design and traffic operations engineers. While it is not possible to display all possible combinations of dependent and independent variables, several useful safety engineering products for the operations engineer were developed. The scope and magnitude of the data files compiled in this study allows for a variety of safety related analyses. Examples of the types of analyses which can be conducted with these data are described below.

Relationships between accidents and roadway features can be plotted and used by traffic engineers to evaluate the effects of countermeasures. For example, the relationship between angle accidents, traffic volume, and parking condition is shown in Figure 3. Numerous other useful relationships can be developed by properly partitioning the data file.

The data base can also be employed to compare the accident experience in terms of frequency, rate, or accident type of a given segment or segments of an urban arterial to the accident experience of similar segments contained in the data file. This comparison, which determines whether or not the segment under investigation has an abnormal accident experience, is useful in prioritizing arterial segments for safety improvements.

The data base can also be used to evaluate proposed design and/or operational changes to a system of urban arterial streets. For example, two parallel arterials can be compared to determine which street would be least affected (in terms of accidents) by a proposed bus route. For this

Table 8. Countermeasures for angle accidents.

Possible Accident Cause	Possible Countermeasures	Applicable Roadway Classification
1. Lack of progressive movement (L,A)	1. Provide signal progression	All classes
2. Restricted sight distance to traffic on intersecting streets or signals (due to horizontal alinement, roadside sight obstructions, or parked vehicles) (L,A)	1. Remove sight obstructions 2. Restrict parking near intersections 3. Install or improve advance warning signs 4. Install 12 inch signal lenses	All classes (particularly two-lane, two-way)
3. Inadequate signal timing (L,A)	1. Adjust amber time 2. Provide all-red clearance 3 Retime signals 4. Install signal actuation 5. Add multidial controller	All classes
4. Inadequate gaps in traffic (L,A)	1. Install traffic signals (if warranted by MUTCD)	All classes
5. Excessive speed on arterial (L)	1. Reduce speed limit and initiate speed enforcement	All classes
6. Excessive commercial driveways combined with traffic volume of 10,000 to 15,000 (increased level of commercial development) (A,L)	1. Consolidate driveways 2. Prohibit left-turns into and out of driveways	Multilane undivided, and two-lane, two-way
7. High intersection street traffic volumes at unsignalized intersections (i.e., minor cross streets, commercial driveways, and high density residential driveways.	1. Consolidate commercial driveways 2. Prohibit left-turns from driveways 3. Install traffic signals (if warranted by MUTCD)	All classes

Note: L denotes that the cause is based on the results of the literature review.
A denotes that the cause is based on the results of the data analysis.
1 inch = 2.5 cm

Table 9. Countermeasures for rear-end accidents.

Possible Accident Cause	Possible Countermeasures	Applicable Roadway Classification
1. Poor signal visibility or sight distance (L,A)	Relocate or add additional signal heads 2. Install or improve advance warning signs 3. Install 12 inch signal lenses 4. Reduce speed limit on approaches and initiated speed enforcement	All classes
2. Slippery pavement surface (L)	1. Overlay pavement with skid resistant surface treatment 2. Improve drainage 3. Reduce speed limit and initiate speed enforcement	All classes
3. Inadequate storage area for vehicles turning into driveways (L)	1. Construct separate left-turn and/or right-turn lanes 2. Install a continuous median left-turn lane 3. Increase turning radii at driveways or intersections	Two-lane, two-way and multilane undivided
4. Inadequate signal timing (L,A)	1. Adjust amber time 2. Provide all-red clearance 3. Provide signal progression 4. Retime signals	All classes
5. Unnecessary signals (L,A)	1. Remove unwarranted signals (as per MUTCD)	All classes
6. Restrictions to through traffic due to on-street parking (combined with moderate to high traffic volume) (L)	1. Restrict or prohibit on-street parking 2. Widen roadway	All classes

Note: L denotes that the cause is based on the results of the literature review.
A denotes that the cause is based on the results of the data analysis.
1 inch = 2.5 cm

Table 9. Countermeasures for rear-end accidents (continued).

Possible Accident Cause	Possible Countermeasures	Applicable Roadway Classification
7. Congested traffic flow due to inadequate roadway capacity (L)	1. Convert to one-way street network	Two-lane, two-way, multilane and undivided
8. Excessive commercial driveways combined with high ADT's (about 15,000 for multilane roads and 10,000 to 15,000 for two-lane roads) due to increased commercial development (L,A)	1. Consolidate driveways 2. Prohibit left-turns into and out of driveways 3. Provide continuous left-turn median lane	Two-lane, two-way Multilane undivided and multilane divided

Note: L denotes that the cause is based on the results of the literature review.
A denotes that the cause is based on the results of the data analysis.

Table 10. Countermeasures for sideswipe accidents.

Possible Accident Cause	Possible Countermeasures	Applicable Roadway Classification
1. Restricted and/or congested traffic flow due to inadequate roadway capacity (ADT of ≤25,000 for multilane divided, and ADT of ≥15,000 for other roadway classes) (L,A)	1. Convert to one-way street network 2. Widen street	All classes
2. Narrow lanes or surface width (L)	1. Widen lanes 2. Install channelization at intersections 3. Create a network of one-way streets 4. Install median divider	All classes
3. On-street parking and/or bus stops allowed on curb lane (L,A)	1. Restrict or remove on-street parking 2. Modify near-side bus stops to far-side	All classes
4. Restricted horizontal curvature (L,A)	1. Reconstruct section to modify horizontal alinement	All classes

Note: L denotes that the cause is based on the results of the literature review.
A denotes that the cause is based on the results of the data analysis.

Table 11. Countermeasures for head-on accidents.

Possible Accident Cause	Possible Countermeasures	Applicable Roadway Classification
1. Narrow lanes or surface width (L,A)	1. Install median divider 2. Widen pavement surface 3. Provide improved roadway delineation	Two-lane, two-way Multilane undivided
2. Poor roadway design (offset lanes or restrictive horizontal or vertical alinement (A,L)	1. Reconstruct roadway to improve alinement 2. Provide improved roadway delineation	All classes
3. Inadequate information regarding one-way street designation	1. Improve location of ONE-WAY signs and/or increase the number or size of signs 2. Channelize and/or stripe side street approaches to more clearly indicate a one-way street	One-way streets only

Note: L denotes that the cause is based on the results of the literature review.
A denotes that the cause is based on the results of the data analysis.

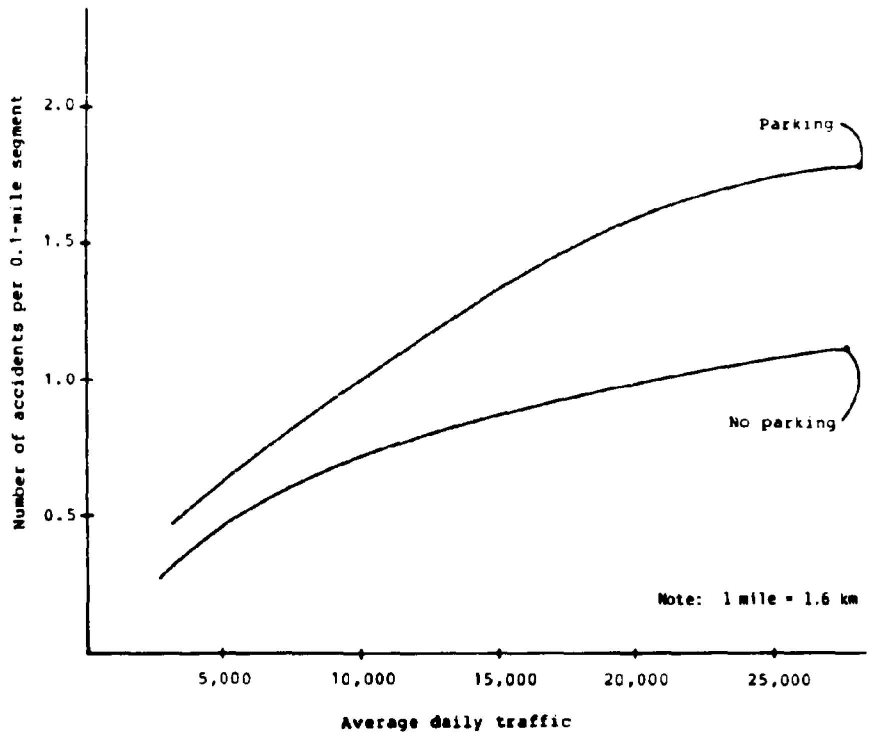

Figure 3. Number of angle accidents during a three-year period as a function of average daily traffic and parking conditions.

analysis the accident experience for each arterial being investigated is determined from the data file, first without the bus route and then with the bus route using variables such as local buses per hour, number of bus stops per segment, etc.

These examples represent only a fraction of the possible uses of the data base. The impact of changing roadside development (adding driveways, changing land use, etc.) or changes in traffic volume can also be projected and used to evaluate policy and/or design changes.

RECOMMENDED RESEARCH

Detailed analyses were conducted only on the variables that maximized the explained variance in the mean accident frequency or rate. For example, if the presence of roadway lighting did not explain a significant portion of the variance in the accident frequency or rate, no further analysis was conducted for lighting. Even though a variable did not explain a significant part of the variance in the accident data set, it cannot be concluded that the variable has no influence on accidents or that there is no interactive effect between that variable and other variables. Where such interactions were considered likely, analysis of covariance tests were conducted to determine the extent of these interactions. However, only a limited number of variable combinations are included in this study. The complete analysis of interactions, comparison of individual group differences, and future similar analyses is left for other researchers.

It may also be hypothesized that much of the analysis, especially the branching, may simply be a comparison of intersections and segments without intersections. Preliminary analysis of intersection and non-intersection segments indicates that this hypothesis is not entirely tenable but further study is encouraged.

Another factor worth consideration is the effect of the segment length used for analysis. In the initial stages of the project, it was determined that data collection and analysis should be conducted based on 0.1-mile (0.16-km) roadway segments. Thus, all accident and roadway data were collected and analyzed for 0.1-mile (0.16-km) segments. One problem with using a short length for analysis is that the range of some variables (such as number of signalized intersections, driveways, etc.) is limited by these short lengths. For example, in a 0.1-mile (0.16-km) segment, the number of signalized intersections only range from 0 to 3. Other researchers have found that signal densities with a range from 0 to 10 per mile are related to accidents. Although this trend was also found in this study, the limitations on the number of signals per segment resulted in testing relatively large discrete differences between 0,1,2 and 3 signals per segment. Using the variable number of signalized intersections per segment (and other similar variables) in a regression equation makes the explained variance appear smaller and the standard error of the estimate appear much larger than it is for longer segment lengths or for less discrete data sets.

Another problem with using 0.1-mile (0.16-km) segments is that, in many cases, it is not possible to accurately locate accidents within 0.1 mile (0.16 km). For this study, care was taken to place accidents in the nearest 0.1-mile (0.16-km) segment as indicated on the computer file. However, in such a short segment any difficulty in locating accidents accurately is magnified by the fact that the ratio of the end conditions to total segment length is high. To minimize this effect, analyses should be conducted on longer segment lengths.

It is appropriate to note that future study into the urban arterial accident problem can utilize these results as a springboard for more in-depth controlled analyses. Controlled experiments using such techniques as before and after accident studies can be designed utilizing these results to define critical variables. The results of such experiments can aid in the further definition of accident causal factors and their corresponding countermeasures.

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.