TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-81/44 +263-3		

4. Title and Subtitle

An Evaluation of Work Zone Traffic Accidents Occurring on Texas Highways in 1977

5. Report Date
July 1981

6. Performing Organization Code

7. Author(s)

Stephen H. Richards and Michael J. S. Faulkner

8. Performing Organization Report No.
Research Report 263-3

9. Performing Organization Name and Address

Texas Transportation Institute
The Texas A & M University System
College Station, Texas 77843

10. Work Unit No.

11. Contract or Grant No.
Study No. 2-18-79-263

12. Sponsoring Agency Name and Address

Texas State Department of Highways and Public Transportaion; Transportation Planning Division
Austin, Texas 78763

13. Type of Report and Period Covered
Interim:
September 1978 - July 1981

14. Sponsoring Agency Code

15. Supplementary Notes

Research performed in cooperation with DOT, FHWA.
Study Title: Traffic Management During Freeway Reconstruction and in Rural Work Zones

16. Abstract

This report documents the findings of a work zone traffic accident study conducted in Texas in 1977. The study revealed that there were nearly 8,000 work zone accidents on state-maintained streets and highways during the study year. These accidents, although less severe than accidents in general, resulted in 73 deaths and nearly 2,900 injuries.

In terms of accident numbers, major freeway work zone (e.g., urban Interstate reconstruction worksites) were found to be the largest contributor to the State's work zone safety problem. Rural work zones, however, produced over one-half of the deaths and injuries.

Included in this report are discussions of the following topics with respect to the work zone accident problem in Texas:

1. Extent of Problem
2. Problem Location
3. Types of Accidents
4. Vehicle Involvement
5. Contributing Factors
6. Geometric Design
7. Traffic Control

17. Key Words	18. Distribution Statement
Work Zones, Traffic Accidents, Traffic Safety, Maintenance, Construction	No Restrictions. This document is available to the public through the National Technical Information Service Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	27	

Form DOT F 1700.7 (8-69)

AN EVALUATION OF WORK ZONE TRAFFIC ACCIDENTS OCCURRING ON TEXAS HIGHWAYS IN 1977

by

Stephen H. Richards
Engineering Research Associate

and

Michael J. S. Faulkner
Assistant Research Engineer

Research Report 263-3

Traffic Management During Freeway Reconstruction
and in Rural Work Zones
Research Study Number 2-18-79-263

Sponsored by
State Department of Highways and Public Transportation
in Cooperation with the
U. S. Department of Transportation
Federal Highway Administration

Texas Transportation Institute
The Texas A&M University System
College Station, Texas

July 1981

ACKNOWLEDGMENTS

The author would like to thank Mr. Tony Huber for his assistance in conducting the accident study. Mr. Huber, who is currently working for the Florida Department of Transportation, supervised the data gathering phase of the study.

Mr. Herman Haenel of D-18T of the Texas State Department of Highways and Public Transportation is also acknowledged for his assistance and guidance during the course of the research documented herein. Mr. Haenel served as the Department Contact for HPR Study 2-18-79-263. The contributions and guidance provided by the Technical Advisory Committee:

W. R. Brown, Supervisory Maintenance Engineer, D-18M
Walter Collier, District Maintenance Engineer, District 15
Billie E. Davis, District Maintenance Engineer, District 2
Milton Dietert, Senior Traffic Engineer, District 15
Larry Galloway, Engineer Technician IV, District 12
Hunter Garrison, District Maintenance Engineer, District 12
Henry Grann, Supervisory Traffic Engineer, District 18
Herman Haenel, Supervisory Traffic Engineer, D-18T
Bobby Hodge, Supervisory Traffic Engineer, D-18T
Blair G. Marsden, Traffic Engineer, D-18T
Tom Newbern, Senior Traffic Engineer, D-18T
Russell G. Taylor, Engineering Technician V, District 14
Milton Watkins, District Maintenance Engineer, District 18
John Wilder, District Maintenance Engineer, District 14

are also gratefully acknowledged.

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

SUMMARY

ACCIDENT STUDY

A study of work zone traffic accidents occurring on state-maintained streets and highways in Texas during 1977 was conducted to determine the extent and nature of the work zone traffic safety problem in the State. Coded accident records in the computerized Texas Master Accident file were the primary data used in the study.

EXTENT OF PROBLEM

In 1977, there were approximately 8,000 work zone traffic accidents reported in Texas. Thus, work zone traffic safety deserves special attention. The accidents resulted in 73 deaths and nearly 2,900 injuries. Work zone accidents, on the average, were less severe than total accidents.

PROBLEM LOCATION

Almost 60% of the work zone accidents in Texas occurred in five large cities. Major freeway work zones in these cities accounted for a large percentage of the accidents.

Although the number of rural work zone accidents was not high in 1977, these accidents produced over one-half of the deaths and injuries attributed to work zone accidents. The high speeds at rural work zones are blamed for the increased accident severity.

TYPES OF ACCIDENTS

Approximately 40% of the work zone accidents involved rear-end collisions. This percentage was significantly higher than the percentage of total accidents which involve rear-end collisions. Sideswipe collisions were also more common

at work zones, while angle and head-on collisions were less common (compared to total accidents).

Over 19% of the work zone accidents involved a vehicle hitting a fixed object. In one-fourth of these accidents, a temporary work zone traffic control device was hit.

Less than 1% of the work zone accidents involved a vehicle hitting a pedestrian. In the study year there were 4 pedestrians killed and 58 pedestrians injured in work zone accidents. Most of these were workers or flaggers.

VEHICLE INVOLVEMENT

Large trucks were involved in a disproportionately high percentage of the work zone accidents. The high truck involvement rate may be due to the fact that a large percentage of the accidents occurred on Interstate highways which carry more truck traffic.

From the study, work zone accidents are more likely to involve three or more vehicles compared to total accidents. The fact that rear-end and sideswipe collisions are more common at work zones may explain this finding.

CONTRIBUTING FACTORS

The large speed differential among vehicles travelling through work zones apparently contributes to the work zone accident problem. Lane changes also pose a problem.

Work zone accidents occur most frequently during daylight hours, in good weather, and during the summer months. In other words, they occur most frequently when work activities are in progress.

Speeding is the major driver violation contributing to work zone accidents. Based on the study results, DWI offenses are not a major contributor.

GEOMETRIC DESIGN

Work zone accidents are more likely to occur at curves and on grades compared to total accidents. These design elements should be considered in developing work zone Traffic Control Plans. Intersections and driveways in work zones apparently do not pose a major safety problem.

TRAFFIC CONTROL

Flaggers were involved in a very small percentage of work zone accidents in 1977 (less than 3%). No-passing zone accidents at work zones were not a major problem.

INTRODUCTION

BACKGROUND

More and more repair work (e.g., maintenance and reconstruction) is performed on our nation's highway system each year. This fact has caused increased concern over work zone traffic safety. In fact, in 1977, the Federal Highway Administration proclaimed work zone traffic safety a national emphasis area and established new policies for traffic control and safety on federal-aid highway projects (1).

Several research studies have been conducted in recent years to evaluate the extent and nature of the work zone traffic safety problem (2, 3). Most of these studies have concluded that there is a serious accident problem at some work zones, and that work zone traffic control, in general, needs to be improved. This report documents the findings of one of these studies which evaluated 1977 work zone accidents in Texas.

STUDY DESCRIPTION

A study of work zone traffic accidents occurring on state-maintained streets and highways in Texas during 1977 was conducted. The primary purpose of the study was to determine the magnitude of the work zone traffic safety problem in the State (e.g., the number and severity of work zone accidents). The study also investigated several factors which contribute to work zone accidents.

Accident Data

Accident records in the 1977 Texas Master Accident File were the primary data used in the study. The Master Accident File is a coded accident record

file stored on magnetic tape. The File is compiled by the Texas Department of Public Safety and it contains collision and roadway information for every reported accident occurring on state-maintained streets and highways in Texas. The 1977 File includes data for over 227,000 accidents.

Additional accident data were obtained from District 17 (Bryan) and the Houston Urban Office of the Texas State Department of Highways and Public Transportation. These data were used to evaluate work zone safety at rural work zones and freeway reconstruction worksites.

Identification of Work Zone Accidents

Accidents reported in the Master Accident File were identified as work zone-related if one or more of the following conditions were satisfied:

1. The accident occurred at a detour.
2. The accident occurred at a location where the road was under construction.
3. The accident occurred at a location where a maintenance or repair activity was affecting traffic.
4. The accident involved a vehicle hitting a construction or maintenance barricade, cones, warning signs, or materials.
5. The accident involved a vehicle hitting construction or maintenance machinery.
6. The accident occurred at a location where one or more lanes were closed for repair.

Data Analysis

A standardized statistical analysis program (called S.A.S.) was used to select work zone accidents from the Master Accident File. The S.A.S. program package was also used to reduce and analyze the accident data.

The analysis included a frequency evaluation of the 49 informational items shown in Appendix A (e.g., the number of accidents by District, County, Surface Conditions, etc.). In addition, work zone accidents were compared to total accidents to identify trends in work zone accidents as a group. When appropriate, the statistical significance of the trends was verified using a Test of Proportions (4).

STUDY FINDINGS

EXTENT OF PROBLEM

The study found that several thousand work zone traffic accidents occur each year on state-maintained streets and highways in Texas. Based on this finding, it may be concluded that work zone traffic safety is an apparent problem in the State and that work zone traffic control deserves the increased attention that it has received in recent years.

Number of Accidents

In 1977, there were 7,936 reported work zone accidents on state-maintained streets and highways in Texas. This number represents 3.5% of the total accidents.

Whether or not the number of work zone accidents in the State (approximately 8,000 per year) is alarmingly high may be debated, since 3-5% of the State's highway mileage is under repair or construction at any given time. (This mileage estimate is based on conversations with several Highway Department District personnel.) It is reasonable to conclude, however, that the number of work zone accidents is large enough to justify close evaluation of work zone traffic control and safety statewide.

In addition, the number of reported work zone accidents probably is less than the actual number for two reasons. First of all, many minor accidents occurring at work zones are never reported to the Department of Public Safety and consequently, there are no records of these accidents. Also, work zone-related accidents which do not occur near a work activity (e.g., a rear-end collision at the end of a work zone queue) may not be reported as work zone accidents. This latter problem has been verified through interviews with

local police officers. In conclusion, the work zone traffic safety problem is probably larger than reported.

Accident Severity

There were 63 fatal work zone accidents on Texas streets and highways in 1977. These accidents resulted in 73 deaths. In addition, there were 2,879 injuries resulting from work zone accidents during the year.

On the average, 1977 work zone accidents were less severe than total accidents as indicated by the data in Table 1. From the Table, there were approximately 90 deaths and 3,600 injuries per 10,000 work zone accidents. In comparison, there were 120 deaths and 5,300 injuries per 10,000 total accidents (total accidents include all reported accidents).

The relatively low severity of the work zone accidents probably is due to the fact that a disproportionately large percentage of these accidents involved rear-end and sideswipe collisions. Rear-end and sideswipe collisions generally speaking, are less likely to result in injuries or fatalities compared to other types of accidents (e.g., angle or head-on collisions).

TABLE 1. INJURY AND FATALITY RATES FOR WORK ZONE AND ALL TYPES OF ACCIDENTS (TEXAS 1977)

Accident Category	Approximate Number Per 10,000 Accidents	
	Injuries	Fatalities
Work Zone	3,600	90
All Types	5,300	120

PROBLEM LOCATION

The study found that work zone accidents are a statewide problem. They occur in relatively large numbers in both rural and urban areas and at all types of work zones. They occur most frequently, however, at major construction/reconstruction worksites in urban areas.

Urban-Oriented Problem

The work zone safety problem, at least in terms of accident numbers, is most critical in large cities, as indicated by the data in Table 2. From the Table, 59% of the 1977 work zone accidents occurred in the five major metropolitan areas listed. These five areas accounted for only 44% of the total accidents in the State during 1977.

TABLE 2. PERCENTAGE OF WORK ZONE AND ALL ACCIDENTS OCCURRING IN MAJOR METROPOLITAN AREAS (TEXAS 1977)

Metropolitan Area	Percent of State's Accidents	
	Work Zone	All Types
Dallas-Ft. Worth*	25	17
Houston	17	15
San Antonio	7	6
Galveston	5	2
Austin	5	4
TOTAL	59	44

*Dallas-Ft. Worth Metroplex which includes Arlington, Bedford, Grand Prairie, Euless, Irving, Huest, Mesquite, Garland, etc. Individually Ft. Worth - 4% and Dallas - 11% of the work zone accidents.

The disproportionate number of work zone accidents in large cities may be due to several factors. For example, it is likely that there is usually a large amount of roadwork performed in large metropolitan areas because of the heavy traffic volumes. In addition, the heavy traffic volumes at urban work zones, combined with the disruptive nature of roadwork activities, may interact to produce a high accident occurrence rate. Overshadowing these possible factors, however, is the presence of major freeway work zones in large cities. These work zones account for a very large percentage of work zone accidents statewide.

Major Freeway Work Zones

In 1977, the 10 freeway work zones listed in Table 3 accounted for one-fourth of the State's work zone accidents (over 2,000 accidents). All of these work zones involved major work activities such as reconstruction of the travel lanes, resurfacing, addition of lanes, etc.

To further illustrate the contribution of major freeway work zones, the I-35 reconstruction work zone in Austin produced almost 70% of all the work zone accidents in the Austin area (Travis County) during 1977. Also, three major freeway work zones in Houston produced one-half of the work zone accidents in Harris County during the study year.

It should not be surprising that major freeway work zones experience high accident frequencies. Typically, these work zones create major traffic disruptions (e.g., detours, lane closures, etc.) over long time periods. They also are exposed to heavy traffic volumes. What is surprising about major freeway work zones is the fact that they accounted for such a large percentage of all 1977 work zone accidents.

TABLE 3. MAJOR FREEWAY WORK ZONES WITH THE HIGHEST FREQUENCY OF TRAFFIC ACCIDENTS (TEXAS 1977)

Work Zone Location			Number of Work Zone Accidents	Percent of All Work Zone Accidents
Highway	Cont. - Sec.	City		
I - 35	15 - 13	Austin	270	3.4
Lp 12	581 - 1	Dallas	239	3.0
I - 45	500 - 3	Houston	237	3.0
I - 20	9 - 11	Dallas	219	2.8
I - 45	500 - 4	Houston	212	2.7
I - 10	508 - 1	Houston	206	2.6
Lp 12	581 - 2	Dallas	195	2.5
US 290	50 - 9	Houston	171	2.1
Lp 410	521 - 4	San Antonio	142	1.8
US 59	177 - 11	Houston	130	1.6
		Totals	2021	25.5

Rural Work Zones

In 1977, approximately 20% of the State's work zone accidents occurred in rural areas. The same percentage of total accidents occurred in rural areas.

Rural work zone accidents have similar characteristics to other work zone accidents with one notable exception. They are much more severe than other work zone accidents. In fact in 1977, over one-half of the deaths and injuries resulting from work zone accidents occurred at rural area worksites. The greater severity of the rural work zone accident is attributed to the higher speed characteristic of rural areas.

Construction vs. Maintenance

In 1977, 96% of the work zone accidents reportedly occurred at construction work zones and only 1% occurred at maintenance work zones. It is reasonable to assume that the majority of work zone accidents did occur at construction work zones, since construction work usually involves major traffic disruptions over long time periods. However, it is unlikely that only 1% of all work zone accidents in 1977 occurred at maintenance work zones.

Apparently, there is a problem in defining work zones by type in the reporting and/or coding of work zone accidents. It is therefore recommended that the Department attempt to define a construction work zone versus a maintenance work zone, and then inform the police community and Department of Public Safety of the definitions.

Detours

Only 21 accidents reportedly occurred at work zone detours in 1977 in Texas. This number represents less than 0.3% of all work zone accidents. In all likelihood there were more detour accidents than reported, and again there is a problem in the proper coding or reporting of the accidents.

Lane Closures

In 1977, there were 375 accidents reportedly occurring at work zone lane closures. This number represents only 4.7% of all work zone accidents.

Highway Type

Table 4 presents a breakdown of 1977 work zone accidents by highway type. From the Table, 31% of the work zone accidents occurred on Interstate highways, while only 22% of the total accidents occurred on Interstate highways. The difference (31% versus 22%) is significant and may be a result of several factors. First, the relatively high speeds and volumes which characterize Interstate highways, in combination with work zone distractions and traffic disruptions, may result in a disproportionate number of accidents. Second, there may be an abnormal amount of repair work performed on Interstate highways since they are priority facilities in the State.

TABLE 4. SUMMARY OF WORK ZONE AND TOTAL ACCIDENTS BY HIGHWAY TYPE (TEXAS 1977)

Highway Type	Percent of Work Zone Accidents	Percent of Total Accidents
Interstate	31	22
US and State	57	64
Farm-to-Market	11	14
TOTAL	100	100

TYPES OF ACCIDENTS

Table 5 categorizes 1977 work zone accidents by accident type. The data in the Table indicate that 40% of the work zone accidents involved two or more vehicles in a rear-end collision. Most of these rear-end collisions resulted when a vehicle collided with another vehicle which was slowing or stopped in response to a work activity. This suggests that the speed differentials among vehicles at work zones may be a primary contributor to work zone accidents. The study also found that the percentage of 1977 work zone accidents involving rear-end collision was significantly higher than the percentage of total accidents involving a rear-end collision (40% vs. 34%).

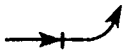
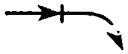
Approximately 24% of the 1977 work zone accidents were one car accidents (see Table 5). The same percentage of total accidents were one car accidents.

Angle and head-on collisions were found to be less frequent at work zones compared to total accidents. The percentage of work zone sideswipe collisions was slightly higher than the percentage of total accidents which were sideswipe collisions.

Fixed Object Accidents

Over 19% of the one-car work zone accidents in 1977 involved a vehicle striking some fixed object in or near the roadway. Table 6 presents a listing of the objects which were most frequently hit in those accidents. From the Table, temporary work zone traffic control devices (e.g., barricades, cones, and warning signs) were involved in 23% of the fixed object accidents at work zones. Construction and maintenance machinery were involved in 8% of the accidents.

TABLE 5. A SUMMARY OF WORK ZONE-RELATED ACCIDENTS BY ACCIDENT TYPE (TEXAS 1977)

Type of Accident		Percent of Statewide Work Zone Accidents	
Manner of Collision	Vehicle Movement		
One Car[a]		24	
Angle		9	15
		2	
		4	
Rear-End		34	40
		4	
		2	
Sideswipe		10	
Head-on		3	8
		5	
Other	- - -	3	
	Total	100	

[a] The "One Car" manner of collision category includes non-collision, collision with objects, and collision with pedestrian or animal accidents.

TABLE 6. FIXED OBJECTS MOST FREQUENTLY INVOLVED IN WORK ZONE ACCIDENTS (TEXAS 1977)

Fixed Object	Percent of Fixed Object Accidents
Barricades, cones, or warning signs	23
Guardpost, guardrail, or delineator	14
Construction or maintenance machinery	8
Highway sign	8
All Other objects	47
TOTAL	100

Pedestrian Accidents

In 1977, there were 53 pedestrian accidents reported at work zones. These accidents resulted in 4 deaths and 58 injuries. It is believed that most of the pedestrians killed or injured at work zones were workers or flaggers.

The percentage of work zone accidents which involved a pedestrian was the same as the percentage of total accidents which involved a pedestrian (0.7%). This fact suggests that pedestrian safety is as hazardous a problem at work zones as it is on all streets and highways in general.

VEHICLE INVOLVEMENT

The study included an evaluation of the types and numbers of vehicles involved in work zone accidents. The study results indicate that large trucks are involved in a disproportionate number of the accidents and that multi-vehicle accidents (three or more vehicles involved) are more common at work zones.

Truck Accidents

Trucks and truck-trailer combinations were involved in a disproportionately large percentage of work zone accidents. This finding is supported by the data in Table 7. From the Table, 31% (24% + 7%) of the vehicles involved in work zone accidents in 1977 were trucks or truck-trailer combinations. In comparison, only 25% (22% + 3%) of the vehicles involved in all accidents were trucks or truck-trailer combinations.

The data in Table 7 may indicate that large trucks are having difficulty in travelling safely through some work zones. This may suggest that the geometric design of these work zones were inadequate for accommodating the special operating requirement of trucks.

TABLE 7. VEHICLE INVOLVEMENT IN WORK ZONE AND TOTAL ACCIDENTS (TEXAS 1977)

Vehicle Type	Percent of Vehicles In Work Zone Accidents	Percent of Vehicles In Total Accidents
Passenger Car	67	72
Truck (pick-up & single unit)	24 } 31	22 } 25
Truck-Trailer Combination	7 }	3 }
Bus	--	--
Road Machinery	--	--
Motorcycle	1	2
Other or Unknown	1	1
All Vehicles	100	100

There is another possible explanation for the high involvement of trucks in work zone accidents, however. As noted earlier in this report, a disproportionately high percentage of work zone accidents occur on Interstate highways. These facilities generally carry more large truck traffic compared to the remainder of the highway system. It is possible that this fact results in a higher involvement of trucks in work zone accidents.

Multiple Vehicle Accidents

Approximately 79% of the 1977 work zone accidents involved two or more vehicles in collision with one another. This percentage is consistent with the percentage for total accidents. However, a slightly larger percentage of the work zone accidents involved three or more vehicles, compared to total accidents. This finding may be explained by the fact that more work zone accidents involve rear-end and sideswipe collisions. These collision-types are more likely to produce "chain-reaction" collisions involving several vehicles.

CONTRIBUTING FACTORS

Table 8 presents a list of the major factors contributing to work zone accidents. From the Table, a vehicle moving slowly or stopped in the travel lane contributed to 16% of the 1977 work zone accidents. This high percentage is consistent with the finding that rear-end collisions are more common at work zones. It again indicates that one of the major problems at work zones is the large speed differential among vehicles.

Also from Table 8, a vehicle changing lanes contributed to 7% of the work zone accidents. Lane changes are a particular problem at lane closure work zones. It is recommended that adequate sight distance be provided to all lane closures and that appropriate traffic control devices (e.g., cones, arrowboard, and advance signing) be used at lane closure work zones.

TABLE 8. FACTORS CONTRIBUTING TO WORK ZONE-RELATED ACCIDENTS AND TOTAL ACCIDENTS (TEXAS 1977)

Factor	Percent Contributing In Work Zone Accidents	Percent Contributing in Total Accidents
Vehicle moving slowly or stopped in travel lane	16	9
Vehicle changing lanes	7	6
Vehicle slowing or stopped for a traffic control device	7	9
Vehicle entering or leaving a driveway	5	8
Vehicle making a left turn	3	3
No factor	47	51
All other factors	15	14
TOTAL	100	100

Weather Conditions

A significantly high percentage of the 1977 work zone accidents (88%) occurred on dry pavement during fair weather. This finding is not surprising since most work activities are performed during good weather conditions. Many repair jobs are halted during bad weather (e.g., rain, snow, fog, dust, etc.).

Time of Accidents

Work zone accidents are more apt to occur during time periods when road work activities are being performed. In 1977, for example, a disproportionately large number of work zone accidents occurred during daylight hours on weekdays in the summer months (especially July and August).

The accident data did not indicate that there was a serious nighttime accident problem at work zones in general. Only 27% of the work zone accidents in 1977 occurred at night, while 31% of total accidents occurred at night. It should be noted, however, that during 1977 there was not a great deal of work activity performed at night around the State.

Driver Violations

The study included an evaluation of driver violations contributing to work zone accidents. It found that speed violations contributed to 27% of the work zone accidents in 1977. In comparison, speeding was cited as a contributing factor in only 15% of all accidents. These data suggest that speed control at work zones is critical to work zone traffic safety. There is a need to develop practical guidelines for speed control at work zones.

The study revealed that only 30 drivers involved in the nearly 8,000 work zone accidents were cited for being under the influence of alcohol or drugs. Based on this finding, DWI violations do not contribute to the work zone accidents more than accidents in general.

GEOMETRIC DESIGN

Using the computerized accident data, it was difficult to evaluate the effects of geometric design features on the work zone accidents. The study did reveal some interesting results concerning alinement and intersections/ driveways.

Alinement

The study revealed that work zone accidents are more likely to occur at curves and on grades than accidents in general. During 1977, for examele, 7%

of the work zone accidents occurred at curves or on grades, while only 5% of the total accidents occurred at curves or on grades. Although this difference (7% versus 5%) is not large, it suggests that poor alinement may be a contributing factor to the work zone safety problem and therefore should be considered in developing work zone Traffic Control Plans.

Intersections and Driveways

Work zone accidents are less likely to occur at intersections and driveways compared to total accidents. In 1977, 57% of all accidents occurred at intersections and driveways, while only 45% of the work zone accidents occurred at intersections and driveways.

The fact that a smaller percentage of work zone accidents occurred at intersections and driveways in 1977 suggests two possible conclusions. First, it may indicate that intersections and driveways do not pose a particular problem with respect to work zone traffic safety. On the other hand, it may suggest that there are other accident-producing elements of work zones which overshadow the effects of intersections and driveways.

TRAFFIC CONTROL

It was also difficult to evaluate the influence of traffic control features on work zone accidents using the computerized data. However, the study results did suggest that two traffic control elements common at work zones (flagger and no-passing zones) do not contribute significantly to the accident problem.

Flaggers

Only 3% of the work zone accidents in 1977 reportedly occurred at work zones where a flagger was controlling traffic.

No-Passing Zones

Only 2 work zone accidents in 1000 involved a vehicle attempting to pass illegally in a no-passing zone. Although these accidents were infrequent, they tended to be severe.

No-passing zones should be appropriately identified with temporary pavement markings and/or signs to discourage no-passing zone violations. It was not determined from the study whether or not the lack of such markings and signs contributed to the few passing accidents reported.

SUMMARY OF FINDINGS

In 1977, 80% of work zone accidents occurred on urban area roadways while the remaining 20% occurred in rural work zones. Although the urban work zone accident was predominant in occurrence, the rural work zone accident was more severe.

Rural work zone accidents accounted for more than half of the death and injuries resulting from all work zone accidents. The increased severity of the rural work zone accident can be attributed to the higher speed characteristics of the rural area.

The urban work zone accident rate was high simply because of exposure. Higher volumes of motorist were exposed to urban work zones. Sixty percent of these urban work zone accidents occurred in five metropolitan areas. Twenty-five percent occurred in 10 freeway work zones in four cities.

The work zone accident like any accident typically involved two or more vehicles (73% work zone/75% total accidents). The most predominant and significantly different multi-vehicle accident type was the rear-end accident (40% work zone/34% total accidents). This type of accident suggests that speed differential is a primary contributor at work zones. Most of these rear-end collisions resulted when a vehicle collided with another vehicle which was slowing or stopped in response to a work activity.

Trucks (pick-ups to truck-trailer combinations) were involved in a disproportionately larger percentage of work zone accidents than in total accidents (31% work zone/25% total accidents). Speed and work zone geometrics may have been primary causes of the disproportionate occurrence. Another factor in the high involvement of trucks in work zone accidents may have been roadway

type. Work zone accident occurrence was higher on Interstate highways than the normal accident occurrence. These facilities generally carry more large trucks than the remainder of the highway system.

Work zone speed appears to be the primary contributing factor in most work zone-related accidents. On the other hand, darkness, adverse weather and alcohol-related accidents varied little from the normal rate of occurrence in all accidents.

REFERENCES

1. Federal Highways Procedural Manual. Federal Highway Administration, U.S. Department of Transportation, Washington, D.C.

2. J.L. Graham, R.J. Paulsen, and J.C. Glennon. Accident and Speed Studies in Construction Zones. Report No. FHWA-RD-77-80, Federal Highway Administration, Washington, D.C., June 1977.

3. B.T. Hargroves and M.R. Martin. Vehicle Accidents in Highway Work Zones. Report No. FHWA-RD-80/063. Federal Highway Administration, Washington, D.C., June 1980.

4. R.G.D. Steel and J.H. Torre. Principles and Procedures of Statistics. McGraw-Hill Book Company, Inc., New York, New York, 1960.

APPENDIX A

Informational Items Evaluated

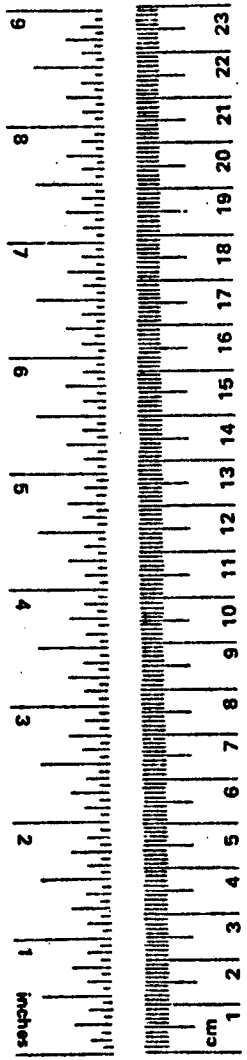
1. District
2. County
3. Control-Section
4. Surface Condition
5. Road Condition
6. Alinement
7. Traffic Control
8. Roadway Related
9. Intersection Related
10. Intersecting Road Type
11. Intersection Type/Entering Roads
12. Vehicle Movements/Manner of Collision
13. Object Struck
14. Other Factor
15. Population Group
16. Road Class
17. Month
18. Date (day of month)
19. Time
20. Light Condition
21. First Harmful Event
22. Part of Roadway Involved
23. Weather
24. Physical Features
25. Bridge Detail
26. Total Number of Vehicles Involved
27. Pedestrian Accident Type
28. Number of Pedestrians Killed
29. Number of Pedestrians Injured
30. Total Injured
31. Total Killed
32. Vehicle Type
33. Driver Contributing Factors
34. Highway System
35. Highway Number
36. Federal Aid System
37. Highway Status
38. Design Type
39. Number of Lanes
40. Degree of Curve
41. Day of Week
42. Adminstrative System
43. Reservation (location within)
44. City
45. Roadbed Width
46. Surface Width
47. Shoulder Type
48. Urban Area
49. Functional Classification

APPENDIX B

METRIC CONVERSION FACTORS

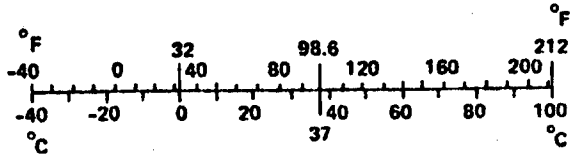
Approximate Conversions to Metric Measures

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



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



*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.