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16. Abstract

The objective of this study was to determine the magnitude and characteristics of safety problems, in terms of reported accidents, that are associated with moving vehicular traffic around and through highway work zones. This was accomplished by examining the 2,127 reported work zone accidents that occurred in 1977 in Virginia. These represented roughly 1.5% of all reported accidents. It was estimated, however, that due to the sampling procedure, only about 82% of the total number of (reported) work zone accidents were identified.

Examined were work zone accidents, general and specific locations of the accidents, time of the accidents, roadway and environmental factors, characteristics of the work zone, causes of the accidents, and accident severity. Where data were available, comparisons of accidents were made of the characteristics of the work zone accidents to those found in the literature and to those for all Virginia accidents.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (CONTINUED)

LIST OF FIGURES

PROBLEM STATEMENT

The safety of the motoring public in highway work zones is an issue of increasing importance, as additional emphasis is being placed on improving and rehabilitating in-service highways.

A number of studies have addressed various aspects of work zone safety; however, nearly all have been based on very limited data, and provide little indication of the scope of the work zone accident problem. Consequently, this study was undertaken to determine the magnitude and characteristics of motor vehicle accidents in highway work zones using cross-sectional data. The study was based on 2,127 work zone accidents reported in Virginia in 1977. The data on these accidents were taken from FR-300 reporting forms noting that the road was "Under Repair".

STUDY TASKS

To accomplish the above objective the following tasks were performed.

Task A: Literature Review

A literature review was conducted to obtain information on the causes and characteristics of highway work zone accidents and their relationship to highway work zone activity. Specific attention was placed on gathering data for use in a comparative analysis with the Virginia data.

Task B: Data Preparation

Using a computerized file of 1977 Virginia motor vehicle accident reports, all of the reports marked Under Repair were identified, the data reformatted, and a subfile produced. From each of the identified reports, additional data items were manually coded. These additional items were determined largely from the Accident Description and Accident Diagram sections of the report and deal with the relationship between the cause and characteristics of the accident and the characteristics of the work zone.

Task C: Review Instructions for Completing Accident Reports

A review was undertaken to determine the instructions and guidelines, both written and oral, that are given to police officers for using the Under Repair designation, the Accident Diagram, and the Accident Description sections of the accident report. As part of this review, training and field officers were interviewed to determine both instructions and typical interpretations. In addition, a questionnaire was used to identify field officers' interpretations of these instructions.

Task D: Accident Analysis

The data taken from the accident reports were examined to determine both the general and specific characteristics of the work zone accidents. This analysis included a breakdown of accidents by the variables regularly coded on the FR-300 (e.g., time of accident, roadway alignment, etc.) as well as the separately coded items. These latter items provided information on the location of the accident within the work zone, the specific relationship between the accident and the work zone activity, and the relationship between the accident and traffic congestion. The analysis was also used to identify interactions between selected variables (e.g., incidence of rear end accidents in advance of the actual work zone) and the significance of various data stratifications (e.g., urban versus rural).

As part of this analysis, various characteristics of the work zone accidents reported in Virginia were compared to those of accidents noted in the literature. The analysis also included an assessment of the completeness and consistency of accident reporting.

REPORT ORGANIZATION

The remainder of this report consists of three major sections. In the next section, the results of the analysis of the work zone accident data are presented.

This is followed by another major section which contains the results of the instructional review, including an analysis of the information obtained with the questionnaire employed in the study. This information, combined with the accident data, was also used to estimate the overall magnitude of the work zone accident problem.

The final section summarizes the results and findings from the earlier sections. Conclusions are stated and recommendations for future study are presented.

ANALYSIS OF DATA

An analysis was made of data from report forms covering the 2,127 accidents that occurred in work zones in Virginia in 1977. These accidents represent approximately 1.5% of the 142,270 accidents reported in the state for that year.* Of the 2,127 work zone accidents, 1,847 were associated with construction activities and 280 with shorter term maintenance and utility type work.

Table 1 lists the variables that were coded for each of the work zone accidents. As noted, some of the variables were coded directly from computerized files while others were coded manually. For the latter, information was taken from the Accident Description and Accident Diagram sections of the reports and dealt with the relationship between the accident and the work zone. This additional coding was completed for 1,628 of the 2,127 accidents; copies of the remaining 499 accident reports could not be located.

In the presentation of the results the data are organized into categories similar to those shown in Table 1. Frequency tables are presented for each variable and the results of cross classifications are provided in the appropriate sections. Where possible, comparisons were made between the characteristics of work zone accidents in Virginia and those of all reported 1977 Virginia accidents. Only significant differences are presented.

In addition, several comparisons were made between the Virginia work zone accident data and characteristics of accidents found through the literature search. These were limited, however, because of an extreme scarcity of pertinent, quality data.

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*Virginia law requires the reporting of all accidents in which persons are injured or killed or in which property damage of $250 or more occurs.

Table 1

Variables Examined For Work Zone Accidents

Location Classification

- Report Number
- Route Classification
- Political Jurisdiction
- Type of Locality
- *Type of Highway
- State/Non-State Network Route
- Filer of Report

Time

- Month of Year
- Time of Day
- Day of Week

Roadway and Environmental Factors

- Road Alignment
- Road Surface Condition
- Lighting Conditions
- Weather Conditions

Characteristics of Vehicle and Driver

- Age of Driver
- Sex of Driver
- Vehicle Speed
- Type of Vehicle
- Pedestrian Involvement

Characteristics of Work Zone

- *Indication of work zone in Accident Diagram and Description on Accident Report
- *Type of Work Activity
- *Traffic Control and Geometric Conditions
- *Accident Location in Work Zone

Causal Factors

- Principal Cause of Accident
- *Type of Collision
- Traffic Violations
- *Accident in Relation to Congestion
- Accident in Relation to Speeding
- Accident in Relation to Alcohol Use

Accident Severity

- Accident Severity
- Number of Persons Injured
- Number of Persons Killed
- Number of Property Damage Accidents Only
- *Amount of Property Damage
- Number of Pedestrians Injured
- Number of Pedestrians Killed

*Additional items were coded separately from original FR-300 forms.

RESULTS

Time of Accident

All of the work zone accidents were identified by month, day of the week, and time of day. Figure 1 shows the monthly variation. As expected, the work zone accidents were more frequent in the warmer months when regular work activity typically is scheduled than they were during the rest of the year. The number of maintenance and utility zone accidents peaked in July and October, and the average was 21.5 accidents per month from May to October. All of the work zone accidents had a wider peak centered in May. From March to August there were an average of 205.2 work zone accidents per month.

Figure 2 shows the daily distributions of accidents for work zones and all 1977 accidents.* Examination of the data shows, not unexpectedly, that the frequency of work zone accidents is high during the Monday-through-Friday workweek,whereas the all 1977 accidents exhibit a weekend peak.

The breakdown of accidents by hour of the day is shown in Figure 3. For the all 1977 accident categories, the lowest number of accidents occurred in the late evening and early morning hours. There is a small peak during the typical morning traffic peak (7-9 a.m.); the number then rises fairly steadily to late afternoon (3-5 p.m.), then drops off rapidly. Not unexpectedly, the hourly variation in the work zone accidents matches the variation in all 1977 accidents. The one notable exception is that there were relatively more work zone accidents from midmorning (10 a.m.) to midafternoon (3 p.m.). This exception is due, no doubt, to the relatively larger amount of work activity that typically occurs during this period.

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*In all figures and tables that include the All 1977 Accidents data, this information was taken from the publication entitled Virginia Crash Facts, 1977 and issued by the Virginia Department of State Police.

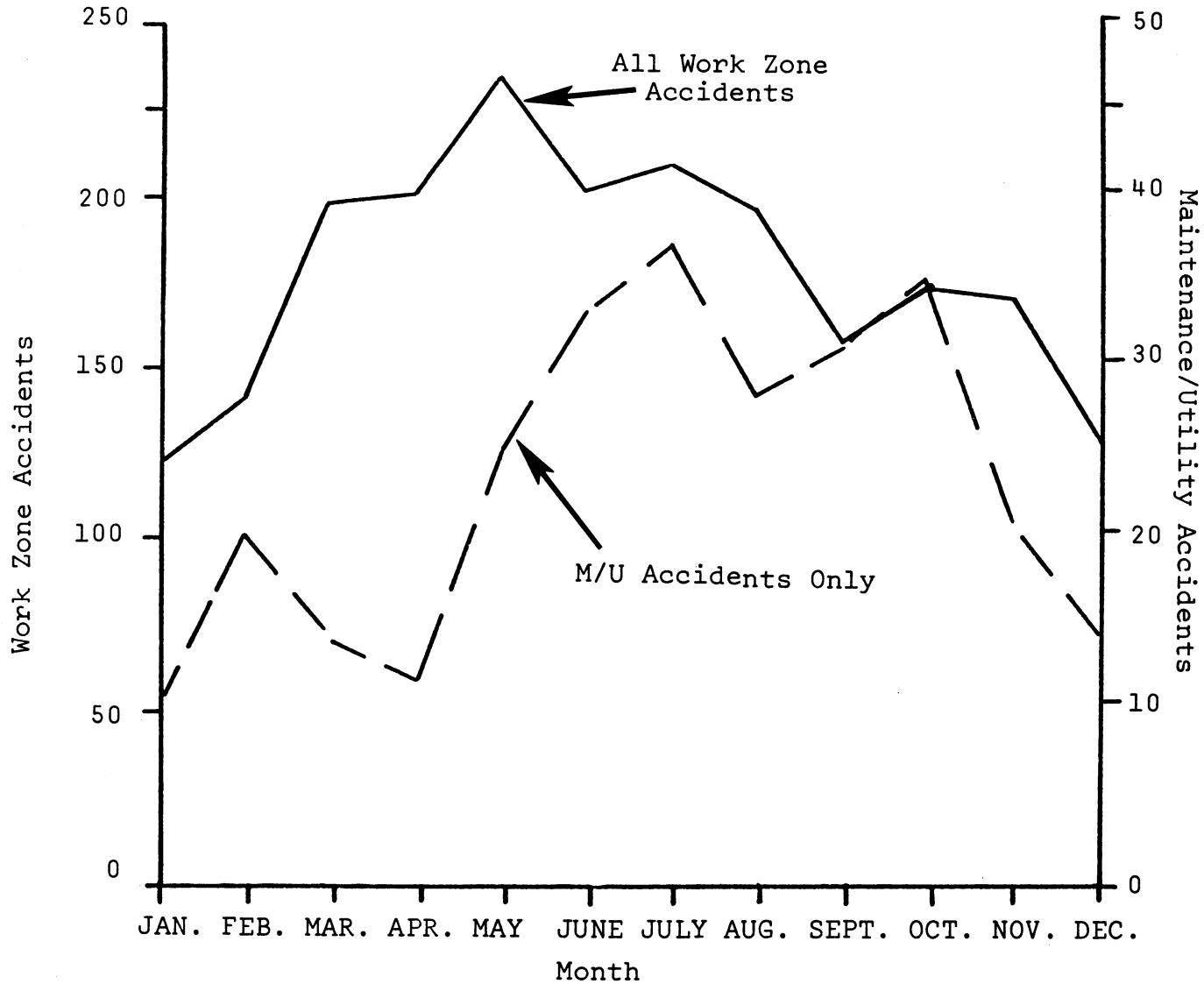


Figure 1. Accidents by month.

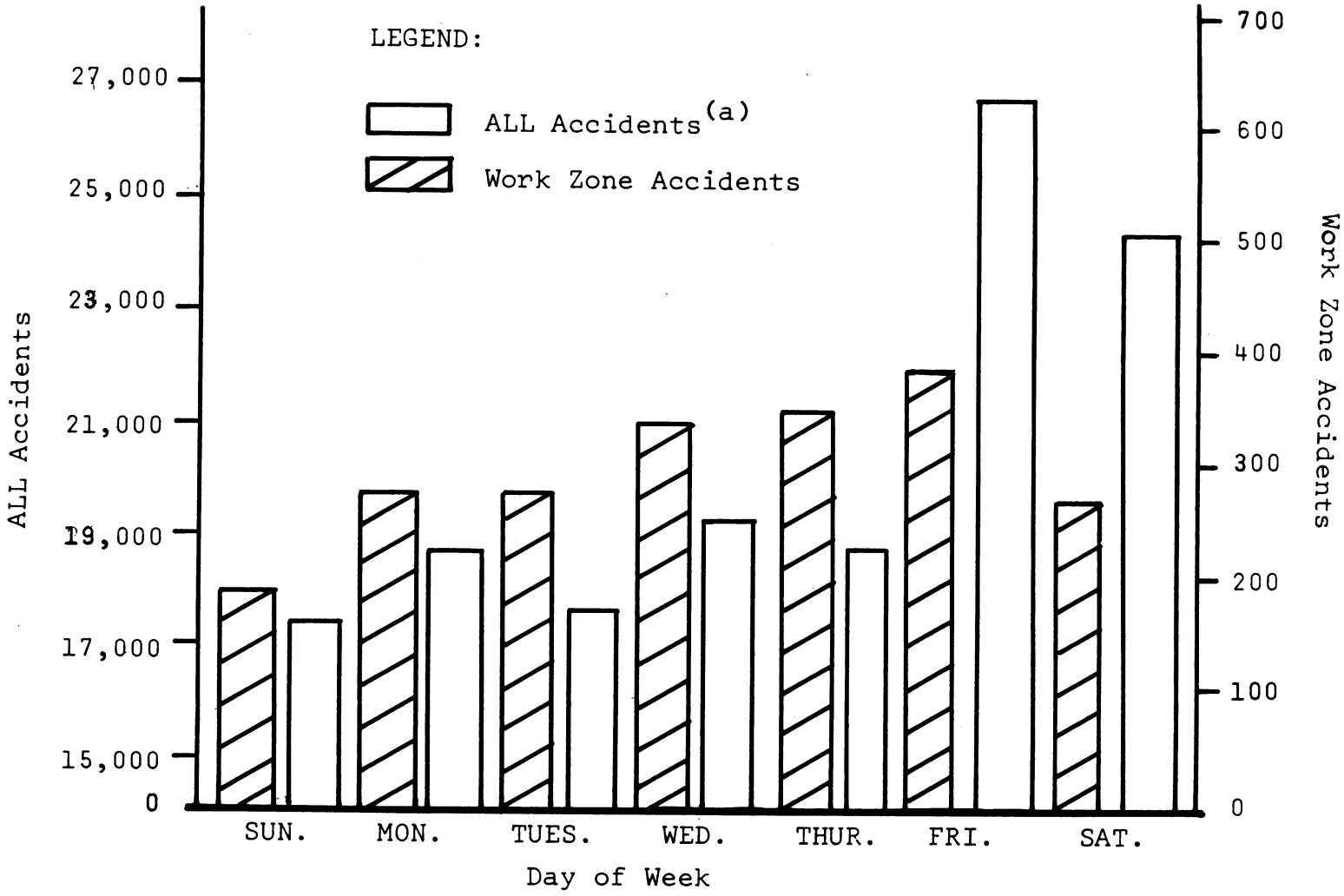


Figure 2. Accidents by day of the week.
((a)From Virginia Crash Facts 1977.)

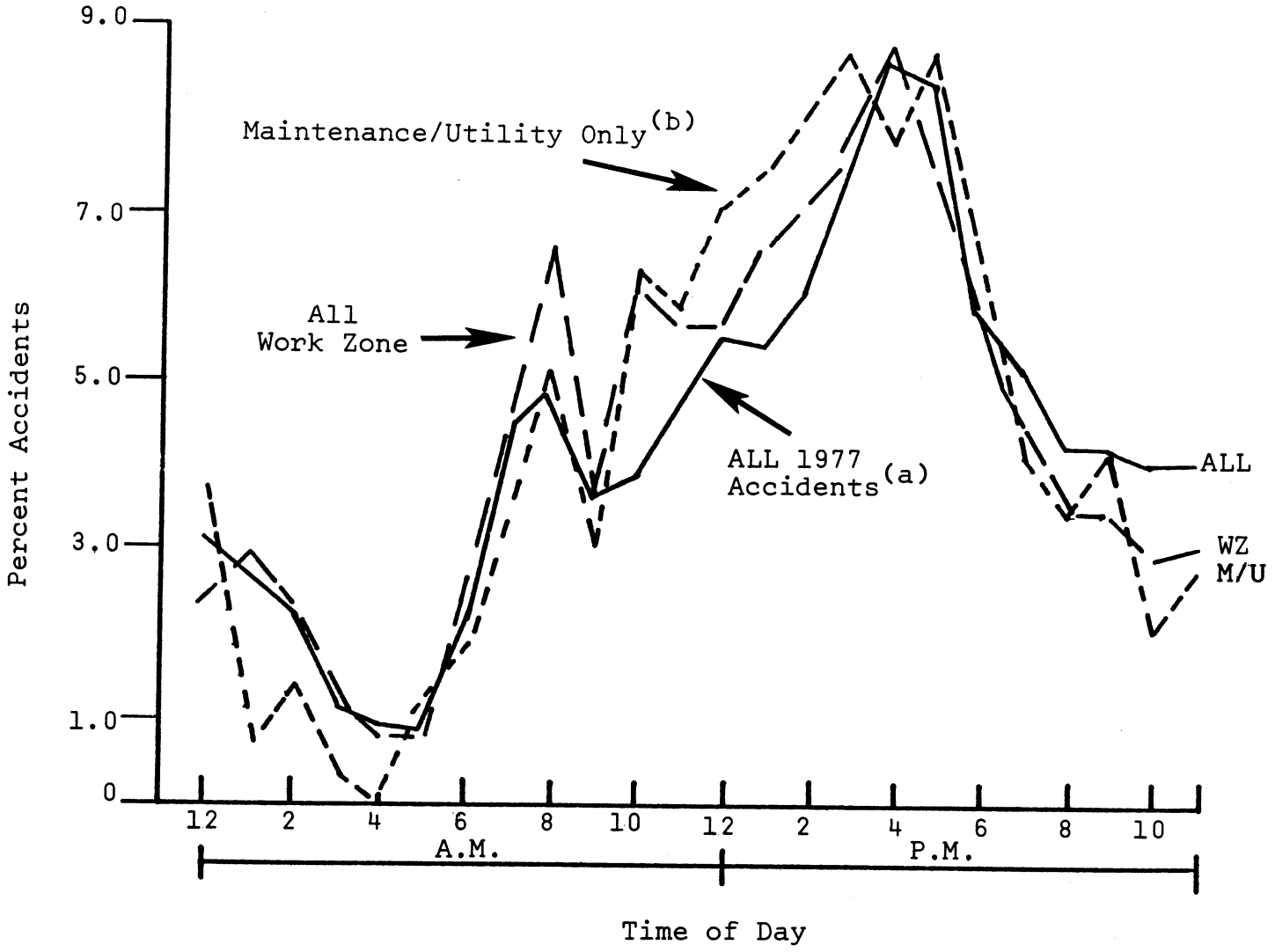


Figure 3. Accidents by time of the day.
(Source: (a) Virginia Crash Facts 1977.
(b) Hargroves 1978.)

Accident Location

Accident location was examined by identifying several general and specific characteristics of the accident sites. The numbers of urban and rural accidents are shown by degree of severity in Table 2. For both the work zone and all 1977 Virginia accidents there were more in the urban category. A comparison of these data, however, also shows that there is an overrepresentation in the number of work zone accidents in urban areas and an overrepresentation in the number of fatalities and injuries in urban work areas, which indicate that accidents in the urban work zone may constitute a considerably more serious problem than accidents in the rural work zone.

Tables 3, 4, and 5 show more specific characteristics of the accident locations. In Table 3, it is shown that the majority of the work zone accidents occur at nonintersection locations. In addition, the comparison of all 1977 accidents with those occurring in work zones shows proportionately fewer of the latter at intersections in the Street or Highway and Alley or Driveways categories. Table 4 shows that work zone accidents are most frequent in "open country" areas, but that they are underrepresented when compared to all 1977 accidents. This fact correlates well with the above findings that work zone accidents are overrepresented in urban areas.

Table 5 shows that work zone accidents occurred most commonly on 4-lane divided facilities (i.e., roads having 4 lanes separated by a barrier or median). For those cases where a positive determination could be made, 65% of the work zone accidents were identified as occurring on the state primary system.

Table 2

Accident Location By Urban/Rural Classification

Location	All 1977						Work Zone					
	Crashes		Deaths		Injuries		Crashes		Deaths		Injuries	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Urban Areas	73,859	51.9	267	23.3	26,556	46.3	1,269	60.9	8	61.5	447	59.6
Rural Areas	68,411	48.1	878	76.7	30,833	53.7	831	39.1	5	38.5	303	40.4
Total	142,270	100.0	1,145	100.0	57,389	100.0	2,127	100.0	13	100.0	750	100.0

Table 3

Accident Location by Type of Intersection

Location	All 1977		Work Zone	
	No.	%	No.	%
Street or Highway Intersection	59,144	41.6	762	35.8
Alley or Driveway Intersection	17,388	12.2	152	7.2
All Other Non-Intersections	65,738	46.2	1,213	57.0
Total	142,270	100.0	2,127	100.0

Table 4

Accident Location by Land Use

Land Use	All 1977		Work Zone	
	No.	%	No.	%
Open Country	46,292	58.2	944	44.4
Business/ Industrial	48,689	19.2	701	33.0
Residential	42,530	20.0	449	21.1
Other and Not Stated	4,759	2.6	33	1.5
Total	142,270	100.0	2,127	100.0

Table 5

Work Zone Accidents by Type of Roadway

Roadway Type	No.	%
One-way	40	2.9
2-Lane	465	33.6
3-Lane	21	1.5
4-Lane	684	49.4
Undivided	141	10.2
Divided	543	39.2
6-Lane	167	12.1
8-Lane	7	0.5
All Others and Not Stated	249	*
Total	1,628**	100.0

*Not included in percent calculation.

**Does not include 499 Road Under Repair accidents for which forms were unavailable for review.

Roadway and Environmental Factors

In this section the results of an examination of roadway alignment, surface condition, and light and weather conditions are presented. Since the information for these factors is regularly coded on all accident reports, comparisons between work zone accidents and all 1977 accidents were possible.

Table 6 shows the number of accidents that occurred on different types of roadway alignments. As can be seen, there is an extremely close agreement between the work zone accidents and all 1977 accidents. Not shown in the table is the fact that maintenance and utility work zone accidents are 55% to 60% more common in the Grade-Straight and the Grade-Curve alignment conditions as compared to all 1977 accidents.

Table 6

Accidents by Road Alignment

Alignment	All 1977		Work Zone	
	No.	%	No.	%
Level — Straight	80,266	57.2	1,180	55.7
Level — Curve	14,267	10.2	219	10.3
Grade — Straight	23,672	16.9	362	17.1
Grade — Curve	15,017	10.7	231	10.9
Hillcrest — Straight	3,975	2.8	73	3.5
Hillcrest — Curve	1,428	1.0	23	1.1
Dip — Straight	1,152	0.8	21	1.0
Dip — Curve	597	0.4	9	0.4
Not Stated	1,186	*	9	*
Total	142,270	100.0	2,127	100.0

*Not included in percent calculation.

Accidents are broken down by road surface condition in Table 7. While there was a similar pattern for the work zone accidents and all accidents, the notable difference was that work zone accidents were more common on dry pavement and less common for all other conditions. The lower percentage of work zone accidents on wet, icy, and snowy pavement suggests that motorists are more cautious under these circumstances and/or that work zone activity is typically curtailed under adverse weather conditions. Not shown in the table is the fact that 40% of the work zone accidents on muddy and oily surfaces occurred in maintenance and utility areas. A reexamination of the accident reports showed that the adverse surface conditions were often the result, directly or indirectly, of the work activity.

Table 8 shows the breakdown of accidents by light condition. Approximately 70% of the work zone accidents occurred during daylight compared to slightly over 63% for all 1977 accidents. This was due, no doubt, to the fact that more work was performed under daylight than under other conditions.

Table 7

Accidents by Road Surface Condition

Surface Condition	All 1977		Work Zone	
	No.	%	No.	%
Dry	101,877	72.7	1,728	81.5
Wet	28,625	20.4	313	14.8
Icy	6,938	5.0	33	1.6
Muddy	153	0.1	17	0.8
Snowy	2,377	1.7	15	0.7
Oily	184	0.1	13	0.6
Not Stated	2,116	*	8	*
Total	142,270	100.0	2,127	100.0

*Not included in percent calculation.

Table 8

Accidents by Light Conditions

Light Condition	All 1977		Work Zone	
	No.	%	No.	%
Daylight	88,998	63.4	1,468	69.4
Dusk	4,906	3.5	52	2.5
Dawn	1,699	1.2	33	1.6
Darkness Road Not Lighted	22,184	15.8	253	11.9
Darkness Road Lighted	22,687	16.1	309	14.6
Not Stated	1,796	*	12	*
Total	142,270	100.0	2,127	100.0

*Not included in percent calculations.

In Table 9 accidents are shown by weather condition. As can be seen, both work zone accidents and all accidents were far more prevalent in clear as compared to inclement conditions. A closer examination, however, shows that there was an overrepresentation of work zone accidents under clear conditions or, conversely, an underrepresentation under adverse conditions. This finding parallels the information above on surface conditions and once again suggests that motorists are more cautious under adverse weather conditions than under good conditions and/or that work activities are curtailed under the former.

Table 9

Accidents by Weather Conditions

Weather	All 1977		Work Zone	
	No.	%	No.	%
Clear	82,793	58.2	1,460	68.6
Cloudy	30,420	21.4	389	18.3
Raining	16,514	11.6	183	8.6
Misting	4,033	2.8	40	1.9
Sleeting	2,665	1.9	15	0.7
Fog	1,130	0.8	14	0.7
Snowing	1,969	1.4	13	0.6
Other and Not Stated	2,746	1.9	13	0.6
Total	142,270	100.0	2,127	100.0

Characteristics of the Work Zone

This section reports on several physical and operational characteristics of the work zones examined. These included the type of work activity being performed, the characteristics of the traffic control used,and the location of the accident within the

work zone. Data for this examination were taken almost entirely from the Accident Diagram and Accident Description sections of the accident reports. As a result, it was not possible to compare these characteristics for the work zone accidents and all 1977 accidents.

Of the 1,628 work zone accident reports manually reviewed, 62.7% had no information on the work zone in either the Accident Diagram or Accident Description. Information on the work zone was in one or the other section in about 20.0% of the cases and in both in 20.0% of the cases.

The type of traffic control used is shown in Table 10. For both the work zone and all 1977 accidents the rank order of the accident frequency by type of control was nearly identical. In both cases, the first two categories, "Traffic Lanes Marked" and "No Control", comprised the majority of the accidents (i.e., 55% to 60%). No Control indicates that there were no traffic control devices in the vicinity of the accident. Not unexpectedly, the work zone accidents showed an underrepresentation in the No Control category and an overrepresentation in the Slow Sign category.

The type of work activity being performed was identified in only 122 (7.5%) of the 1,628 reports examined. As shown in Table 11, roughly half of those identified were resurfacing operations. Another 40.0% were split nearly equally between trenching, bridge-deck repair, nonspecific shoulder work, and work beyond the shoulder.

Table 12 summarizes several types of traffic control used in the work zone. As shown, nearly half of the cases where a determination could be made involved a lane closure. Another quarter of the cases involved a shoulder closure.

One of the more instructive aspects of the analysis of the characteristics of the work zone concerned the location of the accident within the work zone. For this analysis the area surrounding a typical work area was divided into six overlapping areas (see Figure 4). Using the information in the Accident Diagram and the Accident Description, locations for 566 of the 1,628 accidents reviewed were determined.

As shown in Figure 4, slightly less than half of all of the accidents located (44.7%) occurred in the roadway immediately adjacent to the work area (excluding the approach and closure tapers). The region immediately before the work area, the approach taper region, was the scene of the next highest percentage, with at least 75 accidents (13.3%). An additional 26% of the accidents were identified as occurring in the general area designated as "work zone"; however, it could not be determined whether these accidents occurred in the approach taper, work area, or closure taper. Consequently, the aforementioned figures should be interpreted as minimum values.

Table 10

Accidents by Type of Traffic Control

Traffic Control	All 1977		Work Zone	
	No.	%	No.	%
Traffic Lanes Marked	43,808	30.8	732	34.4
No Control	41,581	29.2	417	19.6
Traffic Signal	19,515	13.7	273	12.8
Stop Sign	19,654	13.8	200	9.4
Slow Sign	1,363	1.0	197	9.3
All Others and Not Stated	16,349	11.5	308	14.5
Total	142,270	100.0	2,127	100.0

Table 11

Work Zone Accidents by Type of Work Zone

Type of Work Zone	Work Zone Accidents	
	No.	%
Specific Work Activity		
Resurfacing	62	50.8
Trenching	11	9.0
Bridge Deck Repair	10	8.2
Sweeping/Washing	3	2.5
Pavement Marking	1	0.8
Pothole Repair	1	0.8
Nonspecific Shoulder Work	13	10.6
Work Beyond Shoulder	13	10.6
All Others	8	6.7
Unknown	1,506	*
Total	1,628**	100.0

*Not included in percent calculations.

**Does not include 499 Road Under Repair accidents for which forms were unavailable for review.

Table 12

Work Zone Accidents by Traffic Control Characteristics

Characteristic	No.	%
Lane(s) Closed	204	47.9
Shoulder Closed	115	27.0
Flagman/Signal	51	12.0
Lane Narrowed or Partially Taken	32	7.5
Work Beyond Shoulder	13	3.0
All Others	11	2.6
Unknown	1,202	*
Total	1,628**	100.0

*Not included in percent calculations.

**Does not include 499 Road Under Repair accidents for which forms were unavailable for review.

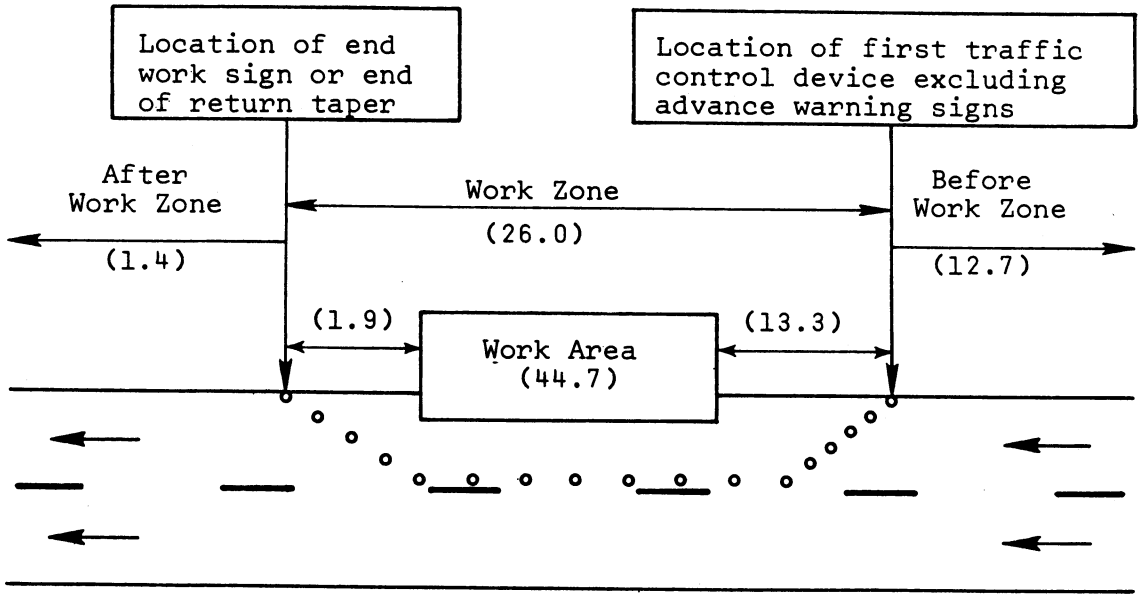


Figure 4. Accident location within the work zone. (Note: Numbers in parentheses indicate the percentages of accidents located in areas.)

Further examination of the accident locations showed that each of the general work zone regions exhibited different types of accident patterns. In terms of absolute numbers of accidents, rear end and fixed object accidents were most frequent in the area immediately adjacent to the work area. However, it was not unexpected that rear end accidents, the most prevalent type, made up a larger percentage of the accidents in the areas in advance of the actual work area. Fixed object accidents, the second largest type, occurred with nearly equal percentages throughout the entire work zone.

Similar data were generated by Nemeth and Migletz (1978) and are shown in Table 13. The region descriptions differed slightly but were generally the same as those described above. A comparison of the two data bases showed that, relative to the Ohio study, Virginia had the following:

- Fewer fixed object and rear end accidents before the work zone
- Fewer accidents in general in the approach taper region and relatively more rear end and relatively fewer fixed object accidents in the approach taper
- Fewer fixed object accidents immediately adjacent to the work area
- Fewer rear end accidents in the entire work area region

Table 13

Type of Accident by Location

Location	% of Total Accidents		Type of Accident	% of Accidents in Location	
	Va.	Ohio		Va.	Ohio
Before Work Zone	12.7	15.9	Rear End Fixed Object Other	50.0 12.5 37.5	58.3 29.2 12.5
Approach Taper	13.3	22.5	Rear End Fixed Object Other	42.7 32.0 25.3	23.5 44.1 32.4
Adjacent to Work Area	44.7	16.5	Fixed Object Rear End Side Swipe Other	28.0 27.7 18.2 26.1	37.5 24.0 12.0 26.5
Entire Work Zone Area	85.9	78.1	Fixed Object Rear End Other	40.8 28.6 30.6	44.0 42.9 13.1

Type of Accident

This section examines several variables that describe the types of accident occurring in work zones. These include vehicle type, type of crash, type of fixed object hit, and vehicle action. Where data for a particular measure were taken from information regularly coded on the accident report, comparisons were made with the entire 1977 data base. In a few cases, comparisons were possible using data from other studies.

Table 14 shows the breakdown of accidents by vehicle type for both all 1977 and work zone accidents. As can be seen, the only notable difference is the overrepresentation of larger vehicles involved in work zone accidents. An examination of the accident reports showed that this was due in part to the involvement of construction equipment in work zone accidents. In addition, there was some evidence (sparse) that large vehicles had difficulty negotiating work areas because of reduced geometric standards and/or driver inattention (e.g., driver not noticing lane closure).

Table 14

Accidents by Type of Vehicle

Type of Vehicle	All 1977		Work Zone	
	No.	%	No.	%
Passenger Car	203,423	80.3	2,978	77.0
Large Vehicles (Total)	39,668	15.7	775	20.0
Truck or Tractor-Trailer	37,066		713	
Bus	1,767		31	
Other Tractor & Combination (Not Tractor-Trailer)	835		26	
Motor Scooter and Motorcycle	3,187	1.3	34	0.9
Emergency Vehicles	1,006	0.4	12	0.3
All Others and Not Stated	5,929	2.3	70	1.8
Total	253,213	100.0	3,869	100.0

Table 15 shows that just over 70% of all crashes involved vehicles hitting other vehicles for both all 1977 and the work zone accidents. More importantly, however, these data show that relative to all 1977 crashes, work zone accidents involved fewer noncollision type accidents and more fixed object type. For the Virginia work zones, the most prevalent type of fixed object hit included work area barriers and signs; 33.7% as shown in Table 16. The category "Construction Equipment or Vehicles" accounted for another 16.2% of the fixed objects hit. It will be shown later that the majority of these were the direct result of the unsafe movement of a work vehicle.

The high incidence of fixed object type crashes and the unsafe movement of work vehicles have been documented as problems in a number of case studies; e.g. Cal. DOT (1974). More specifically, Nemeth and Migletz (1978) have shown that 37.1% of construction accidents in Ohio involved the striking of a fixed object, and that 27.8% of the total number of work zone accidents involved the striking of construction barriers or signs. While not directly comparable, Rowe (1975) has noted that 3.0% of all injury accidents in England involved the hitting of construction related objects.

Table 15

Accidents by Type of Crash

Type of Crash	All 1977		Work Zone	
	No.	%	No.	%
Other Motor Vehicle	100,232	70.5	1,508	70.9
Noncollision	32,631	22.9	348	16.3
Fixed Object	3,959	2.8	221	10.4
Pedestrian	2,052	1.4	27	1.3
All Others and Not Stated	3,396	2.4	23	1.1
Total	142,270	100.0	1,127	100.0

Table 16

Work Zone Accidents by Type of Fixed Object Hit

Type of Fixed Object	No.	%
Bank or Ledge	26	7.1
Trees	17	4.7
Utility Pole	26	7.1
Fence or Fence Post	11	3.0
Guardrail or Post	25	6.8
Highway Structure	65	17.8
Signs, Traffic Signals	13	3.6
Construction Barricades, Barriers & Signs	123	33.7
Construction Equipment or Vehicles	59	16.2
Not Stated or Not Applicable	1,263	*
Total	1,628**	100.0

*Not included in percent calculations.

**Does not include 499 Road Under Repair Accidents for which forms were unavailable for review.

Further information on the type of crash was derived by the directional analysis and is presented in Table 17. The most common work zone accident, the same-direction-intersection crashes (16.2%), were typically sideswipe accidents often caused by reduced shoulder or lane width. Compared to all 1977 accidents, there was an overrepresentation of work zone accidents in the non-intersection subcategories of Rear End, Stopped in Traffic, and Fixed Object in Road. The manual review of the accident reports showed that where a positive determination could be made, 34.5% of the accidents were rear end crashes. This is nearly double the roughly 18.0% rear end crashes reported for all 1977 accidents. Nemeth and Migletz (1978) have also shown a high incidence of rear end accidents in rural construction areas (40.4%).

Table 17

Type of Crash by Location

Vehicle Action	All 1977		Work Zone	
	No.	%	No.	%
Intersection Crashes				
Entering at Angle	22,495	15.8	231	10.9
From Same Direction	21,881	15.4	344	16.2
From Opposite Direction	6,846	4.8	74	3.5
Fixed Object in Road	690	0.5	21	1.0
Left Road	4,617	3.3	56	2.6
Non-Intersection Crashes				
Head On	1,559	1.1	18	0.9
Angle or Sideswipe	11,796	8.3	222	10.4
Rear End	4,632	3.3	176	8.3
Parked	8,373	5.9	472	2.2
Stopped in Traffic	7,553	5.3	256	12.0
At Alley or Driveway	14,589	10.2	130	6.1
Fixed Object in Road	3,273	2.3	200	9.4
Overturned	1,866	1.3	20	0.9
Left Road	24,680	17.3	240	11.3
All Others and Not Stated	7,420	5.2	92	4.3
Total	142,270	100.0	2,127	100.0

Factors Relating to the Cause of the Accident

In this section several factors relating to the causes of the work zone accidents are identified. These include the principal cause of the accident, traffic violations, driver and pedestrian actions, the relationship between the accidents and traffic congestion, excessive speed, and drinking. The data used were taken largely from the Accident Diagram and Accident Description sections of the reports. However, in some cases, information was available from items regularly coded on the accident forms. Consequently, some comparisons could be made between the work zone accidents and all 1977 accidents. In those few cases where data were available, comparisons were made with the results of other studies of work zone accidents.

Table 18 shows that the primary cause of nearly 80.0% of the work zone accidents was driver error; more specifically, over 65.0% of the accidents were listed as driver inattention. By comparison, Nemeth and Migletz (1978) found that driver error was responsible for 86.1% of construction zone accidents. Baerwald (1976) has noted that, nationwide, 89.4% of all accidents are due to "improper driving."

Table 18

Principal Cause of Work Zone Accidents

Principal Cause	No.	%
Driver Error Indicated	663	79.7
Driver Inattention	547	65.8
Driver Under Influence	54	6.5
Driver Speeding	51	6.1
Driver Failed to Obey Highway Signs	11	1.3
All Other Driver Error		
Weather Conditions Indicated	26	3.1
Weather or Visibility Conditions	26	3.1
Work Zone Activity Error Indicated	143	17.2
Unsafe Movement of Work Vehicle	33	4.0
Road Defective and Debris in Road	47	5.7
Flagman Related	21	2.5
Poor Delineation of Work Area	17	2.0
Inadequate Advance Signing, Pavement Delineation, and Advance Transition	15	1.8
Barrier Left in Unsafe Position	10	1.2
Unknown	796	*
Total	1,628 **	100.0

*Not included in percent calculations.

**Does not include 499 Road Under Repair accidents for which forms were unavailable for review.

In only 17.2% of the accidents was some particular aspect of the work zone cited as the primary cause of the accident. Over half of these (56%) were due to Unsafe Movement of Work Vehicles and Road Defective and Debris in Road. A number of other studies (e.g., Cal. DOT [1974]) have also shown that vehicles entering and leaving the work area cause a significant accident problem.

An examination of the accident reports revealed that the unexpected presence of a flagman or construction signal caused a notable problem. Often the difficulty did not involve the first vehicles but the following vehicles as the queue built up through the work area. This finding tends to indicate adequate traffic control for slowing or stopping lead vehicles, but that motorists approaching the congested area are unprepared for the situation.

Of all the drivers involved in Virginia work zone accidents, 48.2% were cited for some driving violation. In contrast, 51.7% of the drivers in all 1977 accidents were cited. The pattern of driver violations shown in Table 19 illustrates the similarity between the work zone and all 1977 accidents. The notable difference lies in the relatively high frequency of Following Too Close violations. This finding ties in well with the high incidence of rear end collisions shown earlier. In contrast, the Ohio study by Nemeth and Migletz (1978) showed only a 10.0% incidence of Following Too Close.

Table 19

Accidents by Driver Violation

Drivers' Actions	All 1977		Work Zone	
	No.	%	No.	%
Exceeded Speed Limit or Safe Speed	18,708	14.9	309	16.6
Did Not Have Right-of-Way	23,836	19.0	256	13.8
Following Too Close	16,739	13.3	417	22.4
Disregard Police Officer or Traffic Signal	3,290	2.6	38	2.0
Disregard Stop or Slow Sign	2,818	2.3	34	1.8
All Others	60,065	47.9	809	43.4
Total	125,456	100.0	1,863	100.0

In addition to the driver violations, the miscellaneous driver actions noted in Table 20 also show a very similar pattern between the work zone and all 1977 accidents. Not unexpectedly, however, the work zone accidents showed a larger percentage of

drivers Avoiding Other Vehicles. An examination of the accident reports showed that this was due, in part, to the reductions in lane width and lane closures typical in work zones.

In 1977 there were 166 pedestrian fatalities in Virginia, and 2,052 pedestrian injuries. Of these totals, work zone accidents accounted for only 1 fatality and 33 pedestrian injuries. Table 21 shows that in the majority of the cases (in excess of 55.0%), the pedestrian was physically in the roadway when the accident occurred. It is noteworthy, however, that in reviewing the accident reports it was not possible to determine with complete certainty whether or not the pedestrian was part of the work crew.

Table 20

Accidents by Driver Actions

Driver Action	All 1977		Work Zone	
	No.	%	No.	%
Skidded	50,301	70.9	756	70.8
Avoiding Other Vehicle	8,156	12.0	172	16.1
Hit and Run	7,513	10.6	90	8.4
All Others	4,601	6.5	50	4.7
Total	70,931	100.0	1,068	100.0

Table 21

Work Zone Accidents by Pedestrian Action

Pedestrian Action	No.	%
Working in Roadway	10	29.4
Walking or Standing in Roadway	9	26.5
Crossing Not at Intersection	5	14.7
Not in Roadway	4	11.8
All Others	6	17.6
Not Stated	5	*
Total	34	100.0

Note: Only 1 pedestrian was killed while working in road.

*Not included in percent calculations.

It is also noteworthy that the average number of pedestrians killed or injured per accident is nearly identical for work zones and all 1977 accidents (i.e., 0.0160 vs. 0.0156).

In contrast, Rowe (1975) estimated that nationwide roughly 700 persons are killed per year while working in the road and in excess of 2,000 are injured. In addition, Anderson (1976) has indicated that the injury rate (per man-hour worked) for road crews may be in excess of five times the average rate for all industries. All industries includes the categories of trade, manufacturing, service, government, transportation, utilities, agriculture, construction, and mining.

Compared to all 1977 accidents, younger drivers were less involved in work zone accidents than older drivers. Specifically, Table 22 shows an underrepresentation of drivers through the 20-24 years age category for work zone accidents. Above that category older drivers are overrepresented in work zone accidents. This tendency could be interpreted as an indication that younger drivers are more alert or better able to handle unusual or unexpected situations that may be found in work zone areas.

Little difference was found when the numbers for sex of the driver for work zone and all 1977 accidents were compared. For all 1977 accidents, 66.1% of the drivers were male, compared to 67.3% male drivers for the work zone accidents.

In addition to determining the principal causes of the work zone accidents, an attempt was made to identify the relationship between these accidents and several contributory factors. First, a subjective evaluation was made to determine if the cause of the accident was related to congestion. Using several pieces of information from the accident reports, it was estimated that congestion was at least a contributing factor in 18.1% of the accidents examined. While no comparative data exist, this value seems somewhat larger than that expected for all accidents; however, the value does correlate well with the relatively high incidence of work zone accidents classified as Stopped in Traffic and Rear End types. Generally, there was no way to determine if the congestion was directly caused by the work activity.

An examination was also made of the distribution of vehicle speeds for both work zone and all 1977 accidents. This comparison showed that there was an overrepresentation of work zone accidents involving slow moving vehicles (i.e., 40.1% of work zone vehicles travelling less than 15 mph [24 kph] compared to 36.4% for all 1977 accidents). It was also determined that excessive speed (i.e., speed in excess of the speed limit or safe speed) was present in 13.1% of all Virginia accidents, but in only 11.4% of the work zone accidents. This is slightly less than the nationwide average of 14.6% (Baerwald 1976) and dramatically less than the 58.3% found in the Ohio study (Nemeth and Migletz 1978). It

is noteworthy, however, that the Ohio study involved only high speed, rural locations.

Finally, an investigation of alcohol involvement showed that drinking was evident in 11.4% of the work zone accidents compared to 13.1% for all 1977 Virginia accidents. At a minimum, this finding suggests that drinking presents no more of a problem in work zones than in the ordinary highway environment.

Table 22

Accidents by Age of Driver

Age Groups	All 1977		Work Zone	
	No.	%	No.	%
17 Years & Under	10,850	8.7	183	4.7
18 - 19 Years	14,430	11.5	326	8.4
20 - 24 Years	26,359	21.0	797	20.6
25 - 34 Years	25,860	20.6	884	22.9
35 - 44 Years	12,978	10.4	551	14.2
45 - 54 Years	10,305	8.2	396	10.3
55 - 64 Years	7,700	6.1	290	7.5
65 - 74 Years	4,320	3.4	108	2.8
75 Years & Over	1,589	1.3	28	0.7
Not Stated	11,065	8.8	306	7.9
Total Drivers	125,456	100.0	3,869	100.0

Accident Severity

A variety of indicators were selected to evaluate the relative severity of the work zone accidents. As shown in Table 23, the average work zone accident was slightly less severe than the average 1977 accident when compared by the percentage of property damage only (PDO) accidents and the numbers of persons killed or injured per accident. The average work zone accident was more severe, however, than the average 1977 accident in terms of the number of vehicles involved per accident.

Table 23

Accident Severity

Severity Index	All 1977			Work Zone		
	Total	Rural	Urban	Total	Rural	Urban
Number of Accidents (Total)	412,270	68,411	73,859	2,127	831	1,296
Fatal	998	750	248	12	5	7
Injury	39,802	20,993	18,809	535	217	318
Property Damage	101,470	46,668	54,802	1,580	609	971
Percent of Accidents						
Fatal	0.7%	1.1%	0.3%	0.6%	0.6%	0.5%
Injury	28.0%	30.7%	25.4%	25.2%	26.1%	24.5%
Property Damage	71.3%	68.2%	74.3%	74.3%	73.3%	74.9%
Number of Persons						
Killed	1,145	878	267	13	5	8
Injured	57,389	30,833	26,556	750	303	447
Number of Persons Killed or Injured Per Accident	0.411	0.464	0.359	0.359	0.371	0.351
Number of Vehicles Involved Per Accident	1.78	1.61	1.95	1.82	1.79	1.84
Property Damage Per Accident	—	$1,104*	—	$1,091	$1,185	$1,047

*Summary of Accident Data, 1977

An examination of rural accidents only (work zone and all 1977) showed that the rural work zone accident exhibited the same pattern as the average work zone accident described above; that is, it involved less personal injury. In addition, the amount of property damage per accident was slightly larger for work zone accidents than for the average 1977 accident.

In the comparison of urban and rural work zone accidents, no great difference was evident. A different pattern emerged, however, when the average urban work zone accident and all 1977 urban accidents were compared. Unlike the results for the rural accidents, the injury and fatality measures for the urban work zone and average 1977 accidents showed almost no difference. Also unlike the rural pattern, the number of vehicles involved per accident was smaller for the urban work zone accident than for the average 1977 urban accident.

Outside the Virginia data base, little data have been published on work zone accident severity. Comparisons were further complicated by different reporting procedures. Nevertheless, the limited data available do show a much greater proportion of property damage only accidents in Virginia than that reported in Arizona, California, and Ohio (see Table 24). In addition, the percentage of work zone accidents involving a fatality has been consistently lower in Virginia than that reported by others.

Table 24

Summary of Work Zone Accidents By State

Study Source	Data Date	Number of Projects	Number of Work Zone Accidents (Percent)				Number of Persons	
			Total	PDO	Injury	Fatal	Injured	Killed
Arizona[a]	1969	All Rural Work Zones	278	155 (55.7)	112 (40.3)	11 (4.0)	235	18
California[b]	1965	10	745	383 (51.4)	334 (44.8)	28 (3.8)	—	35
California[c]	1970	31	4,927	2,890 (58.6)	1,954 (39.7)	83 (1.7)	—	106
Ohio[d]	1972-1974	21	151	99 (65.6)	49 (32.4)	3 (2.0)	—	—
Texas[e]	1960	All Rural Work Zones	1,724	— —	— —	60 (3.5)	—	—
	1961		1,647	— —	— —	49 (3.0)	—	—
	1962		1,500	— —	— —	50 (3.3)	—	—
	1963		1,573	— —	— —	56 (3.6)	—	—
	1964		2,184	— —	— —	53 (2.4)	—	—
	1965		2,063	— —	— —	30 (1.5)	—	—
	1966		2,394	— —	— —	53 (2.2)	—	—
	1967		2,704	— —	— —	54 (2.0)	—	—
Virginia[e]	1960	All Work Zones	574	— —	— —	4 (0.7)	—	—
	1961		881	659 (74.8)	217 (24.6)	5 (0.6)	—	—
	1962		971	709 (73.0)	247 (25.5)	15 (1.5)	—	—
	1963		1,109	830 (74.9)	272 (24.5)	7 (0.6)	—	—
	1964		1,319	1,003 (76.0)	307 (23.3)	9 (0.7)	—	—
	1965		1,814	1,415 (78.0)	383 (21.1)	16 (0.9)	—	—
	1966		1,763	1,356 (76.9)	394 (22.4)	13 (0.7)	—	—
	1967		1,734	1,308 (75.4)	447 (25.8)	9 (0.5)	—	—
Virginia[f]	1977	M/U Rural	280	196 (70.0)	83 (29.6)	1 (0.4)	122	1
Wyoming[e]	1962	All Work Zones	127	— —	— —	— —	76	3
	1963		108	— —	— —	— —	54	4
	1965		100	— —	— —	— —	91	3
	1966		118	— —	— —	— —	86	6

(a) Hatton (1970)
(b) California Highway Transportation Agency (1965)
(c) Juergens (1972)
(d) Nemeth and Migletz (1978)
(e) Munro and Huang (1968)
(f) Hargroves (1978)

INSTRUCTIONAL REVIEW

To evaluate the consistency and completeness of accident reporting in Virginia, two subtasks were performed. The first was a review of the training given state and local police on accident investigation and reporting. This was followed by an analysis of a questionnaire used to determine those specific situations in which officers were using the Road Under Repair designation. An analysis of the information obtained enabled an estimate to be made of the completeness of work zone accident reporting. The results of the analysis are presented in the succeeding sections of the report.

Police Officer Training

Training in accident investigation and reporting is given to all state and local police throughout the Commonwealth. Typically, 1½ to 2 hours are devoted to instruction for filling out the accident reports and all use the same instruction manual.

In regard to the specific instructions for completing the FR-300, three items were of interest in this investigation; namely, the Road Under Repair designation, the Accident Diagram, and the Accident Description. An examination of the training materials and interviews with training officers indicated that the written and oral instructions were identical for all officers. The pertinent features of this instruction are described below.

The investigating officer is instructed to indicate on the FR-300 any road defects which contribute to the accident by checking off the appropriate item in the Roadway Defects blocks (see Figure 5). For the case where multiple responses are possible, the officer is instructed to indicate only the one item that is considered to have contributed most to the accident or that best describes its cause. For example, if the defect could be classified as Soft or Low Shoulders and Under Repair, the officer would have to decide which best describes the cause of the accident. From noting the different items in the Road Defects block and discussions with training officers, it was assumed that some accidents that could be identified as Under Repair were, in fact, classified under a more explicit classification.

Completion of the Accident Diagram on the FR-300 consists of drawing the vehicle(s); indicating the path(s) of travel, including point(s) of impact; and noting approximate landmarks for locating the accident. For the Accident Description section, the officers are simply instructed to "write a summary of how the accident happened."

DEFECTS (CHECK ONE)

_____ Under Repair

_____ Loose Material

_____ Holes, Ruts, Bumps

_____ Soft or Low Shoulders

_____ No Defects

Figure 5. Designation of Road Under Repair on accident report.

In regard to both the Accident Diagram and Accident Description, guidelines are given by way of examples in both the training program and the instruction manual. These guidelines indicate that factors contributing to the cause of the accident should be identified or detailed in these sections.

Police Officer Questionnaire

The purpose of the police questionnaire was to determine the personal guidelines or criteria used by the investigating officers in filling out the FR-300. In particular, the responses were used to determine the specific circumstances under which the troopers checked off Road Under Repair. A total of 135 questionnaires were used in the analysis. They were completed by state and local police representing a variety of experience and areas of regular patrol — i.e., urban and rural.

In the instructions for filling out the questionnaire, the officers were advised that the questions were largely opinion type and that their personal responses, without discussion with others, were desired. The questionnaire, with a summary of results, is shown in Figure 6. To facilitate the analysis described later, the results were weighted according to the number of state and local police filers for work zone accidents.*

*Work zone accidents are filed as follows: State Police 36.4%; local police, 49.1%; and individuals, 14.5%. Compared to all 1977 Virginia accidents, the State Police fill out proportionately more work zone accident reports than do local police, probably because work zone accidents are more common on the routes they typically patrol.

TROOPER QUESTIONNAIRE

I. Assume you are the investigating officer at the scene of an accident. In the following scenarios, please mark yes, if you would classify the incident as "Road Under Repair," and no, if not.

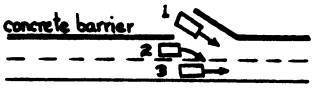
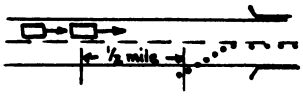
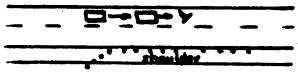
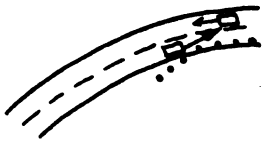
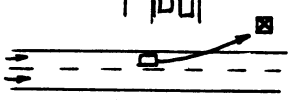
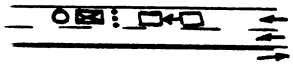
		YES	NO
1.	 Construction vehicle (1) entering through opening in concrete barrier fails to yield to oncoming vehicle (2); vehicle (2) sideswipes vehicle (3).	39.6	60.4
2.	 Temporary lane closure for bridge repairs (using cones) creates substantial congestion upstream. Rear end collision takes place upstream of work area.	71.4	28.6
3.	Driver falls asleep - vehicle runs off road and hits construction barrels on shoulder.	30.3	69.7
4.	 Rear end collision; first vehicle stopping for cone blown into roadway from road work on shoulder.	56.7	43.3
5.	 Utility trench across two-lane rural road filled in at night. Vehicle runs off road in curve due to dirt/mud left in roadway.	90.6	9.4
6.	Rear end collision with street sweeper; dust may have obscured driver vision.	11.5	88.5
7.	 Utility pole being set near edge of a two-lane rural road; poor advance sight distance of the work zone causes driver to overreact and veer into path of oncoming car.	36.7	63.3
8.	Resurfacing operation has been completed on a two-lane rural road, but has yet to be marked (with edge lines and centerlines); vehicle runs off road at night due to poor delineation in a curve.	57.8	42.2
9.	 Maintenance vehicle (X) working on overhead signal; sideswipe accident.	28.9	71.1
10.	 Vehicle runs off road at night and hits exposed storm drain (X) under construction in the middle of a 60' depressed open median; evident that no work has taken place in last few weeks.	5.0	95.0
11.	 Four-lane urban road; rear end collision due to lane closure for work in manhole.	74.9	25.1
12.	Run off road accident - skidding on loose gravel; tar and gravel treatment finished several days before but gravel still loose.	24.8	75.2

Figure 6. Police questionnaire with summary of responses.

II.1. Check the item in the list below which best describes when you check "Road Under Repair."

24.9 If there are any traffic control devices in the area (e.g., cones, barriers, signs).

22.9 If there is any physical evidence of work activity in the area (e.g., new surface without pavement markings).

41.8 Only if the work activity was a contributing factor in the accident.

6.8 Only if the work activity was the direct cause of accident.

3.6 Other, briefly describe._____

_____

2. Check any of the activities below that you would classify as "Road Under Repair" if they were the direct cause of an accident.

Work Actually in Travel-Way

Yes	No		Yes	No	
64.5	35.5	A. Painting Edge Line	69.0	31.0	F. Utility Trenching
9.0	91.0	B. Street Sweeping	96.5	3.5	G. Pothole Repair
96.3	3.7	C. Bridge Repair	24.3	75.7	H. Surveying
98.8	1.2	D. Resurfacing	84.1	15.9	I. Joint Repair
71.8	28.2	E. Manhole/Utility Work			

Work on Shoulder or Beyond

Yes	No	
69.1	30.9	J. Grading Shoulder
58.6	41.3	K. Guardrail repair
33.3	66.7	L. Sign Replacement
25.0	75.0	M. Tree Trimming
17.9	82.1	N. Mowing
20.5	79.5	Q. Landscaping

Longer Term Activities

Yes	No	
93.4	6.6	P. Lane Addition on Interstate
88.4	11.6	Q. Adding Left Turn In Median of Primary Road
91.4	8.6	R. Extending Acceleration Ramp on Interstate
79.4	20.6	S. Construction of Overpass

Figure 6. Continued.

Question I was designed to determine the proportion of officers that would check off Road Under Repair in a variety of accident scenarios. A wide variety of scenarios was selected to make the choices obvious and to limit questionnaire bias. As shown in Figure 6, the responses to this question indicated that the officers were likely to check off Road Under Repair when (1) the work activity was in or physically on the roadway, thus necessitating a lane closure; (2) when there was work related debris in the roadway; and (3) when there was a malfunction in the traffic control system. The questionnaire also showed that the officers were less likely to check off Road Under Repair when the work activity was not physical repair of the roadway and when the first event in the accident sequence was not related to the work area (e.g., vehicle runs off road and hits some component of the work area). The response patterns for state and local police were nearly identical, except that local police make slightly more frequent use of the Road Under Repair designation.

Question II. 1 was designed to examine the relationship between the work activity and the cause of the accident. As shown in Figure 6, roughly half of the officers indicated that they would check off Road Under Repair only if the work activity was a contributing factor or the direct cause of the accident. The other half said that only some indication of the work activity (i.e., traffic control devices or physical evidence of work) was necessary to warrant their checking Road Under Repair. There was a noted tendency for the local police officers to fall in this group. The few "other" responses consisted of multiple or unusable responses.

The final question (II.2) was designed to determine how the troopers interpreted "road repair"; that is, which situations or work activities do they consider to qualify as road repair and which do not. A variety of activities were chosen to reflect different work locations (i.e., on roadway, on shoulder, and beyond shoulder) and different work types (i.e., moving, less than one day, several days or long-term construction activities). The results from this question indicated that, as before, the Road Under Repair designation is not likely to be checked when the work activity is not concerned with the physical repair of the roadway surface (e.g., sweeping, tree trimming, surveying, mowing, landscaping, and sign replacement). Excluding shoulder grading, only 24.2% of the officers indicated that accidents directly caused by work activity on or beyond the shoulder would warrant checking Road Under Repair. In contrast, 83.0% indicated that work in the traveled way (excluding sweeping and surveying) would qualify. This is very close to the average response (88.2%) for the long-term construction activities listed (e.g., lane addition on interstate). The only notable difference between the state and local

police responses was that the local police were slightly more prone to use the under repair designation if the work was on or beyond the shoulder (in particular, guardrail repair, sign replacement, and tree trimming).

The combined results of these sections of the questionnaire show that police chose a highly literal interpretation of the phrase Road Under Repair. That is, if the actual roadway was not under repair, they were much less likely to check off Road Under Repair than if it was. As a result, there were a variety of cases where accidents actually occurred in a work zone and as the result of the work zone, but were not designated as Road Under Repair. Based on information on characteristics of the work zone (i.e., distribution of accidents by type of work activity) and the completeness of reporting information obtained from the questionnaire, it is estimated that there were actually 2,600 Road Under Repair accidents in Virginia in 1977. (This estimate does not take into account unreported accidents.) The difference between this number and the reported figure of 2,127 represents a weighted average completeness of reporting ratio of roughly 0.82. The results of the questionnaire also indicate a direct cause-effect relationship between the accident and the work zone in roughly half of the 2,600 accidents.

SUMMARY OF FINDINGS

This study was undertaken to determine the magnitude and characteristics of motor vehicle accidents in highway work zones. This objective was accomplished by examining all of the 1977 Virginia motor vehicle accident reports marked Under Repair (2,127 reports). As part of this analysis, comparisons were made between the Virginia data and results reported from other studies. In addition, an assessment was made of the completeness and consistency of work zone accident reporting.

The major findings of this investigation are presented below. Because the analysis is based on only those work zone accidents occurring in one state in one year, caution should be exercised in interpreting and generalizing the results.

1. The survey of prior work zone studies showed that two basic approaches have been used in analyzing work area accidents. Most of the studies used time series data for specific work sites to estimate the percentage change in accidents due to the presence of the work activity. The one common finding of these studies was that an increase in the

accident rate at a particular site was generally associated with specific work zone problems at that site. Other studies have examined work zone accidents in an attempt to identify the specific characteristics or problems of work zones that are most hazardous in terms of causing the most accidents.

In both approaches, studies have been performed that used a variety of work zone sites; none, however, have been based on truly cross-sectional data, i.e., complete accident data for an entire geographic area. In addition, a comparison of results from these studies is difficult because of different reporting formats and methodological problems. As a result, only a limited number of comparisons were possible between the Virginia data and those found in the literature.

2. In 1977 there were 2,127 accidents in Virginia that were marked Road Under Repair. These represented approximately 1.5% of the 142,270 accidents reported that year. Slightly over 85.0% of the Road Under Repair accidents were identified as having occurred in construction zones; the remainder were classified as having taken place in maintenance and utility areas.

3. When compared to all Virginia accidents, the work zone accidents occurred, as expected, more frequently during the times when work activity was most likely. That is, there was an overrepresentation of work zone accidents during the midday, from Monday to Friday, and during the warmer months; there was an underrepresentation of work zone accidents during poor weather conditions.

4. Compared to all Virginia accidents, there was an overrepresentation of work zone accidents in urban areas.

5. Slightly less than 40.0% of the work zone accident reports contained explicit information on the characteristics of the work zone or the activity under way. The specific type of work activity was identified in only 7.5% of the cases. Resurfacing accounted for roughly half of these, and roughly 40.0% was split nearly equally between trenching, bridge deck repair, nonspecific shoulder work, and work beyond the shoulder.

6. The specific location of the accident relative to the work zone was determined for 566 of the 1,628 accident reports manually reviewed. Roughly half occurred immediately adjacent to the actual work area. Another eighth occurred in the area before the general work zone (i.e., before the first traffic control device, excluding advance warning signs).

7. The most common type of accident throughout the work zone was the rear end collision (34.5%); it made up the highest relative percentage of accidents in the area in advance of the actual work zone. Other studies have shown an even higher percentage. The percentage of rear end accidents in work zones is nearly double that for all 1977 Virginia accidents. The high incidence of rear end accidents found for work zones in this study reflects the overrepresentation of Following Too Close violations, the higher involvement rate of slow vehicles, the larger number of vehicles involved per accident, and the indication of congestion as a contributing factor.

8. Fixed object type crashes are the second most prevalent type of work zone accident. They occur with nearly equal relative frequency throughout the entire work zone.

9. Roughly 80.0% of the Virginia work zone accidents were attributed to driver error (65.0% to driver inattention). This finding is very similar to that reported in other studies of work zone accidents and all accidents in general.

10. Some aspect of the work zone was cited as the cause of roughly 17.0% of all of the work zone accidents. The most common category was Road Defective or Debris in Road, followed by Unsafe Movement of Work Vehicles.

11. Excessive speed and alcohol appear to present no more of a problem in work zones than in non-work zone situations.

12. In Virginia, work zone accidents are slightly less severe than the average accident in terms of the number of persons killed or injured per accident. They are slightly more severe in terms of the number of vehicles involved per accident, particularly

in rural areas. The severity of Virginia work zone accidents tends to be less than that reported by other studies, in that the Virginia data show a larger percentage of property damage only accidents.

13. When compared to all 1977 Virginia accidents, younger drivers are slightly underinvolved in work zone accidents.

14. The numbers of pedestrians killed or injured per accident are nearly identical for work zone and non-work zone accidents in Virginia.

15. In filling out the accident reports, police chose a highly literal interpretation of the phrase Road Under Repair. That is, if the actual roadway was not under repair, they were much less likely to check off Road Under Repair than if it was. Nevertheless, because of the higher frequency of accidents involving this type of activity, it was estimated that 82.0% of all work zone accidents in Virginia carry the Road Under Repair designation.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this investigation, the following conclusions and recommendations for future research are made.

1. In Virginia the Road Under Repair designation is a reasonably effective means of identifying work zone accidents. There is room for improvement since roughly one-fifth of the work zone accidents do not carry the Under Repair designation. However, those work zone accidents not carrying the Under Repair designation are typically less frequent, involve work not actually in the travelled way, and are caused by factors not related to the work zone activity.

2. There is substantial evidence of a rear end accident problem in highway work zones. Analysis of the problem showed simply that approaching motorists are generally unprepared for the interruptions to free-flowing traffic typical in many work areas. There did not appear to be any problems related directly to the methods used to slow or stop traffic; nor could any highway capacity problems be directly

attributed to the work operations. Nevertheless, it is recommended that traffic control plans be designed for work zones, where practical, to eliminate bottlenecks, minimize speed reductions, and minimize interruptions to what would otherwise be free-flowing traffic conditions. It is also recommended that research be undertaken to determine (1) how much additional caution or awareness motorists should be expected to exercise in work areas, and (2) what methods are most effective in communicating this need for additional caution or awareness to the motorist.

3. There are accidents occurring in work zones that can be avoided without extraordinary cost by improving work zone practices and procedures. The unsafe movement of work vehicles and the presence of road defects and debris are both common and inexpensively correctable problems. In order to reduce the number of accidents caused by these, as well as other work zone problems, it is recommended that: (1) specific standards and guidelines be developed for the access and egress of work vehicles from the work area, (2) all work area personnel be trained in the fundamental principles of work zone safety, and (3) inspection procedures be included as an integral part of the work zone traffic control plan.

4. The reason for the slight overrepresentation of work zone accidents in urban areas was not apparent from the data contained on the accident reports. Consequently, it is recommended that a study be undertaken to examine the special problem of urban work zones. At a minimum, this study should consider: (1) any problem with the target value of traffic control devices in the urban environment, (2) the problems created by large information loads put on the driver, and (3) the effect of high volumes of traffic on different traffic control procedures.

5. The results of this study are unique in the level of detail presented and fact that the data represented a full year of work zone accidents for an entire state rather than those for a select group of work sites. While the results fill a critical gap in the body of knowledge concerning work zone accidents, there are insufficient data available to allow precise conclusions

on a national scale. Consequently, it is recommended that current efforts to assemble information on work zone accidents be continued. There are particular problems, however, in using historical accident data. First, typical work zone accident reports contain very little information on the characteristics of the work zones and the relationships between accidents and work zones. Also, major changes are being made in work zone practices and traffic control procedures such that the true scope of the current accident problem may be reflected only by very current data. Site specific studies using non-accident indicators (e.g. traffic conflicts) may provide a useful direction for future studies.

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