Development of a Short Course for Enhancements to the Design of Work Zones

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UTCA Theme: Management and Safety of Transportation Systems

Prepared by

UTCA

University Transportation Center for Alabama
The University of Alabama, The University of Alabama at Birmingham, and
The University of Alabama in Huntsville

UTCA Report 00107
March, 2000

University Transportation Center for Alabama

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16. Abstract

The issue of work zone safety cannot be properly addressed without attempting to understand fully the problems associated with work zones. The purpose of this research project was to investigate the current status of work zone safety in Alabama and other states and to recommend safety-enhancement measures.

A database of crash report information was mined through the use of the Critical Analysis Reporting Environment (CARE) to identify characteristics of crashes that occurred in Alabama, Michigan, and Tennessee. Characteristics of work zone crashes were compared to those of crashes in all three states. It was found that the 'typical' work zone crash involves a male driver, age 25 to 34, who, while driving during mid-afternoon on a U.S. highway or Interstate roadway, comes upon slow or stopped traffic due to construction and crashes vehicle. While most characteristics are common to all three states, fatal crashes were more likely to have occurred in Alabama than other states.

A similar analysis was then performed focusing on fatal crashes in Alabama work zones. Fatal work zone crashes were compared to non-fatal work zone crashes. Fatal crashes in work zones in Alabama were found to be more likely than other work zone crashes to involve driving under the influence of alcohol, drivers not wearing seat belts, driver not in control, and to occur on Sunday, off the roadway, and in the dark where there are no streetlights. Additional data were collected on sections in Alabama that had a high frequency of crashes. This data suggested that most fatal work zone crashes occur when the work zone

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Executive Summary

Injuries and fatalities from crashes in work zones continue to be a problem around the U.S. While much has been done to reduce the number of such crashes, there is continued interest among contractors and highway agencies in making work zones safer for workers and for the traveling public. The issue of work zone safety cannot be properly addressed without attempting to understand fully the problems associated with work zones. The purpose of this research project was to investigate the current status of work zone safety in Alabama and other states and to recommend possible safety-enhancement measures.

A database of crash report information was mined through the use of the Critical Analysis Reporting Environment (CARE) to identify characteristics of crashes that occurred in Alabama, Michigan, and Tennessee. Characteristics of work zone crashes were compared to those of non-work zone crashes in all three states. It was found that the 'typical' work zone crash involves an on-the-job male driver, age 25 to 34, who, while driving in clear weather during mid-afternoon on a U.S. highway or Interstate roadway, comes upon slow or stopped traffic due to construction and crashes into another vehicle. While most characteristics are common to all three states, fatal crashes were more likely to have occurred in Alabama work zones than in other states.

A similar analysis was then performed on fatal crashes in Alabama work zones. Fatal work zone crashes were compared to non-fatal work zone crashes and to fatal non-work zone crashes. Fatal crashes in work zones in Alabama were found to be more likely than other fatal crashes to occur on State, U.S., and Interstate highways. Causal drivers in work zone fatal crashes were significantly more likely to be more than 25 miles from home. Work zone fatalities and non-work zone fatalities were similar in the rate of DUI, in the rate of pedestrian deaths, and in the most frequent "primary contributing circumstance" (driver not in control). Additional data were collected on specific work zones in Alabama that had a high frequency of crashes, which suggested that most fatal work zone crashes occur in inactive work zones.

Alabama Department of Transportation (ALDOT) personnel were interviewed concerning current practices in Alabama, and literature on national work zone safety trends was reviewed. While Alabama has incorporated several practices aimed at reducing crashes and improving safety in work zones, the researchers recommend that ALDOT consider more frequent independent inspections of work zones. The researchers also recommend focusing safety efforts on State, U.S., and Interstate highways, paying increased attention to inactive work zones, limiting vehicle speeds, increasing time headway between vehicles, and warning vehicles of queues ahead. Recommendations for further research are also presented.

The findings from this study have been summarized in a PowerPoint presentation, which has been sent to Auburn University for possible inclusion in Auburn's existing Work Zone Traffic Control short course.

Section 1

Introduction

Increasing traffic on our aging roadways usually requires maintenance and construction work to take place without completely interrupting travel on the roadway. The work must be done in the presence of traffic, which is often traveling at high speeds. While much has been done to reduce the number of crashes in work zones, there is continued interest among contractors and highway agencies in making work zones safer for workers and for the traveling public.

Injuries and fatalities from crashes in work zones continue to be a problem around the country. The Federal Highway Administration (FHWA) reports that although the number of work zone fatalities across the country has remained fairly constant throughout the 1980s and 1990s, the number of work zones has increased. As the number of work zones continues to increase, the potential exists for increased fatalities (FHWA, 1998). The issue of work zone safety cannot be properly addressed without attempting to understand fully the problems associated with work zones.

The research presented herein provides the following results:

- A characterization and comparison of work zone crashes in Alabama, Michigan, and Tennessee
- A characterization of fatal work zone crashes in Alabama
- A review of traffic control design and inspection procedures used in Alabama
- A review of efforts in various states to enhance safety in work zones
- Recommendations for improving safety in Alabama work zones.

The research is summarized in a PowerPoint presentation that has been forwarded to Auburn University for potential inclusion in their Local Technical Assistance Program short course on Work Zone Traffic Control.

It must be noted that because analysis of crashes depends on police accident reports for data and because there are no nationally recognized definitions of work zones or work zone-related crashes (Turner, 1999), it is likely that work zone crashes have been substantially under-reported (Raub and Sawaya, 2000). There is much discrepancy in reported work zone statistics. According to the FHWA, many states disagree with the Fatal Accident Reporting System (FARS) database, claiming that the actual numbers of work zone fatalities are greater than those reported in FARS (FHWA, 1998). So that officers can clearly know where the work zone is located, Turner reports that the FHWA and several other groups have proposed standard definitions for work zone and work zone crash (Turner, 1999). Until there is more consistency in the reporting of work zone-related crashes, it is impossible to determine precisely the nationwide impact of work zones on safety.

Section 2

Analysis of Crashes in Alabama, Michigan, and Tennessee

The project analyzed computerized crash data from three states:

- Alabama, 1994-1998
- Michigan, 1996-1998
- Tennessee, 1996-1997

The data is available through the Critical Analysis Reporting Environment (CARE) software developed at the University of Alabama. CARE is a software system designed to provide direct access to crash and incident information for individual decision-makers within the traffic and aviation safety communities. Because the available variables differ for the three data sets, it was not possible to compare all of the characteristics found for any particular state with those for the other two states. Although only two years of data are common to all three states, this study analyzed all of the data available on CARE for each state.

Table 2-1 shows the number of crashes that occurred in work zone and non-work zone locations for all the available years in each state. It must be noted that differences in numbers of crashes for the different states could be due to differences in the amount of vehicle miles of travel. Table 2-2 shows the average annual vehicle miles of travel for each state.

Table 2-1. Total Number of Crashes

	Alabama 1994-1998		Michigan 1996-1998		Tennessee 1996-1997	
	WZ	NWZ	WZ	NWZ	WZ	NWZ
1994	2,230	128,112	-	-	-	-
1995	2,462	130,928	-	-	-	-
1996	2,461	134,004	5,811	429,666	1,160	166,509
1997	2,764	136,580	7,049	418,744	1,395	167,798
1998	2,548	134,960	7,408	396,355	-	-
Annual Average	2,493	132,917	6,756	414,922	1,278	167,154

- Data not available.

The above information came from the Bureau of Transportation Statistics.

Table 2-2. Average Annual Vehicle Miles of Travel, 1994 - 1997 (in Millions)

	Rural		Urban		Total	
	All Roads	Interstate	All Roads	Interstate	All Roads	Interstate
Alabama	25,787.75	5,168	25,331	5,018	51,118.75	10,186
Michigan	32,969.25	6,354.50	55,244.75	12,829.75	88,214	19,184.25
Tennessee	25,818.75	7,824.75	31,606	7,654.75	57,424.75	15,497.50

The above information came from the Bureau of Transportation Statistics.

The study was greatly facilitated by using the Information Mining for Producing Accident Countermeasure Technology (IMPACT) module of CARE. IMPACT compares a test subset (crashes in work zones) with a control subset (crashes outside of work zones) and calculates the over- or under-representation of any code within any given variable. In Alabama, for example, 35% of work zone crashes occur in rural areas, a higher percentage than the 28% of non-work zone crashes occurring in rural areas (see Table 2-3). Although rural crashes do not constitute a majority of work zone crashes, because the proportion of rural crashes is much higher in work zones than outside of work zones, rural crashes are said to be over-represented in work zones.

Table 2-3. Crashes in Rural and Urban Locations

	Percent of Rural Crashes		Percent of Urban Crashes		Percent of Total Crashes	
	WZ[a]	NWZ[b]	WZ[a]	NWZ[b]	WZ[c]	NWZ[c]
Alabama						
1994 - 1998	* 35	28	65	* 72	1.8	98
Michigan						
1996 - 1998	-	-	-	-	1.6	98
Tennessee						
1996 - 1997	* 45	29	55	* 71	0.76	99

** Indicates significant over-representation.*

[a] Percent is of State Total Work Zone Crashes.

[b] Percent is of State Total Non-Work Zone Crashes.

[c] Percent is of State Total Crashes.

- Data not available.

The Institute of Transportation Engineers (ITE) (1999) states that while some reduction in levels of service may be unavoidable, it is reasonable to expect that well-designed traffic control plans can result in no measurable increases in accident severity or frequency during the highway construction period. If work zones presented no additional causes for crashes, the proportions of accidents, injuries, and fatalities should be roughly the same for work zone crashes and for non-work zone crashes. Determining which variables are over-represented in work zones will help to

define the problems associated with work zones that should be the focus of safety enhancement efforts.

In the data tables in this paper, an asterisk (*) indicates a clear over-representation to a statistically significant alpha of at least 99% confidence. Over-representation in the non-work zone category is equivalent to under-representation in the work zone category. For data mentioned in the text, but not presented in tables, an over-representation (O-R) factor is given, which is calculated by dividing the percent of work zone crashes by the percent of non-work zone crashes. If the factor is greater than 1, then the characteristic is over-represented in work zones. If the factor is less than 1, then the characteristic is under-represented in work zones. An asterisk (*) by the O-R factor indicates a statistically significant difference.

General Characteristics of Work Zone Crashes

This study found the "typical" work zone crash includes the following factors: a male driver, age 25 to 34, while driving in clear weather during mid-afternoon on a U.S. highway or interstate roadway comes upon slow or stopped traffic due to construction and crashes into another vehicle; or else in the process of avoiding such, crashes into a barrier or construction equipment. The characteristics used to describe the "typical" crash do not necessarily happen in over 50% of work zone crashes. They represent "most frequently found" characteristics, not necessarily "majority" characteristics.

Fatalities were significantly over-represented in work zones crashes in Alabama, but not in Michigan or Tennessee. In all three states, it was found that the likelihood for a work zone crash to involve subsequent vehicles was relatively large. In all three states, work zone crashes are more likely to involve speeding and large trucks, which justifies the continued efforts toward reducing speeds in work zones and suggests the need for increased attention to the maneuverability requirements of large trucks when designing traffic control plans for work zones.

Information in the following sections elaborates on these trends by breaking information into who, what, where, when, and why work zone crashes occur.

Where Crashes Occur

Table 2-3 on page 3 shows that in Alabama and Tennessee, work zone crashes occur most often in urban areas, as do non-work zone crashes. Rural work zone crashes, however, are significantly over-represented in both of those states, as shown by the asterisks in the first data column. Although Alabama and Tennessee have nearly the same average annual vehicle miles of travel on rural roads (Table 2-2 on page 3), a higher percentage of Tennessee's work zone crashes occur in rural areas than do Alabama's work zone crashes. And while Tennessee has more annual vehicle miles of travel on urban roads, Alabama has a higher percentage of work zone crashes in urban areas. Michigan data was not available for rural and urban comparisons. The Institute for Transportation Engineers (1999) reports that nationally 55% of work zone fatalities occur in rural areas and that the amount of rural fatalities is disproportionately greater than the amount of rural travel.

Table 2-4 summarizes the percentage of crashes by highway classification. While non-work zone crashes occur frequently on municipal roads in all three states, work zone crashes occur less frequently there. The largest number of work zone crashes occurs on U.S. highways in Alabama, on county or city roads in Michigan, and on Interstates in Tennessee. Work zone crashes are significantly over-represented on Interstates and U.S. highways in all three states. State roads are significantly over-represented in Alabama and Michigan, but significantly under-represented in Tennessee.

Table 2-4. Crashes by Highway Classification

	Alabama 1994-1998		Michigan 1996-1998		Tennessee 1996-1997	
	Percentage of Crashes		Percentage of Crashes		Percentage of Crashes	
	WZ	NWZ	WZ	NWZ	WZ	NWZ
Interstate	* 23	6.7	* 23	6.8	* 57	8.0
U.S.	* 27	17	* 9.2	7.1	* 13	10
State	* 24	22	* 21	17	15	* 21
County	10	* 17	34	* 58[a]	4.2	* 16
Municipal	16	* 37	-	-	9.5	* 42
Other	0.040	0.060	13	11	0.75	2.8

** Indicates significant over-representation.*

- Data not available.

[a] Michigan combines County and Municipal roads into a single category.

The speed limit at a crash site is most frequently between 41 and 55 miles per hour (mph) as shown in Table 2-5. In Alabama and Tennessee, speed limits greater than 40 mph are over-represented in work zones and those lower than 40 mph are under-represented. In Michigan, speed limits greater than 25 mph are over-represented. This coincides with the highway classification and rural/urban findings described above.

Table 2-6 summarizes the percentage of crashes according to total number of traffic lanes. In all three states, crashes occur most often on two-lane roadways, but crashes on two-lane roads are under-represented in work zones. Four-lane highways and those with six or more lanes are over-represented in work zones in Alabama.

Table 2-5. Speed Limit at Crash Site

	Alabama 1994 - 1998		Michigan 1996 - 1998		Tennessee 1996-1997	
	Percentage of Crashes		Percentage of Crashes		Percentage of Crashes	
Mph	WZ	NWZ	WZ	NWZ	WZ	NWZ
0 to 5	1.3	2.2	0.11	0.29	5.2	* 13
6 to 10	0.04	0.16	0.05	0.080	-	-
11 to 15	0.54	0.71	0.34	0.41	0.08	0.50
16 to 20	0.48	0.93	0.05	0.13	0.27	0.94
21 to 25	5.3	* 12	12	* 18	0.67	1.7
26 to 30	6.4	* 12	* 7.0	6.3	4.6	* 19
31 to 35	11	* 16	* 17	14	8.9	* 15
36 to 40	11	* 11	* 8.6	7.2	6.3	* 16
41 to 45	* 27	16	* 25	14	* 20	15
46 to 50	6.2	5.9	* 4.3	3.2	* 6.0	2.7
51 to 55	* 24	17	12	* 28	* 37	13
56 to 60	* 1.5	0.73	* 4.4	0.020	0.080	0.010
61 to 65	* 3.5	2.3	3.0	3.0	* 10	3.0
66 to 70.	* 2.6	2.22	0.00	0.00	-	-
Uncoded	0.00	0.46	5.6	* 6.1	0.00	0.080

** Indicates significant over-representation.*

- Data not available.

Table 2-6. Number of Traffic Lanes

	Alabama 1994-1998		Michigan 1996-1998		Tennessee 1996-1997	
	Percentage of Crashes		Percentage of Crashes		Percentage of Crashes	
Number Of Lanes	WZ	NWZ	WZ	NWZ	WZ	NWZ
1	2.6	2.8	* 7.8	2.7	-	-
2	45	* 53	43	* 55	33	52
3	3.4	* 4.7	* 18	9.4	-	-
4	* 36	27	16	16	31	23
5	2.9	* 4.0	11	* 12	-	-
6 or more	* 9.0	6.9	3.7	4.5	-	-
Other/Error	1.0	1.6	0.20	0.32	36	26

** Indicates significant over-representation.*

- Data not available.

Temporal Characteristics of Crashes

Table 2-7 shows that work zone crashes most frequently occur during August in Alabama and Tennessee and during October in Michigan. The summer and early fall months are significantly over-represented, when traffic volumes are increased and work zone presence is likely at a peak. December, January, and February are significantly under-represented. Even though traffic volumes rise during the winter holiday season, there are not as many construction or maintenance operations at that time.

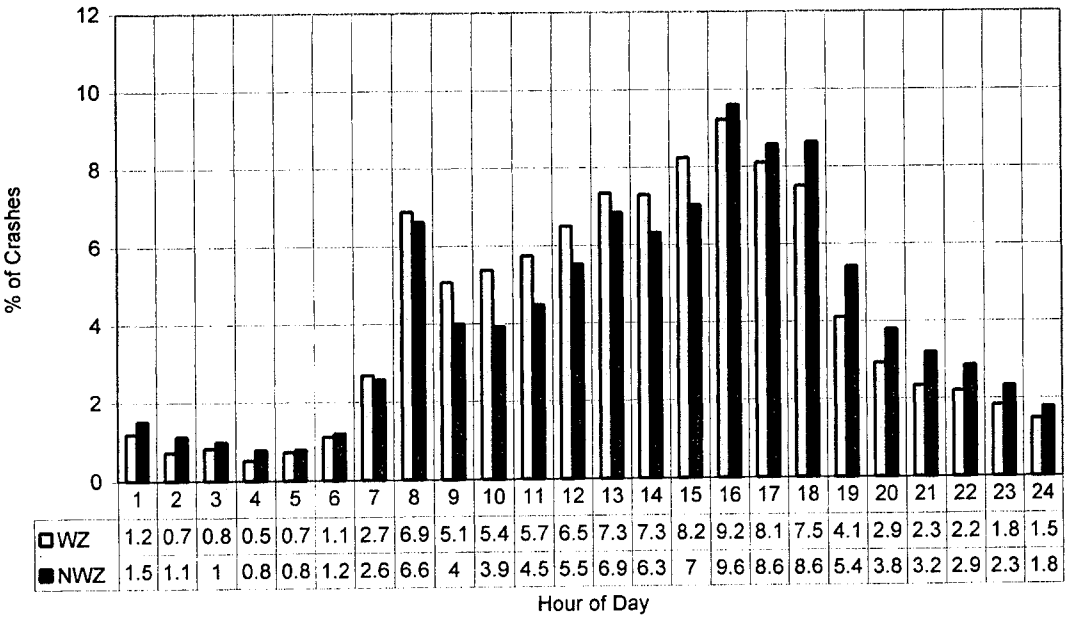
Table 2-7. Month of Crash

	Alabama 1994-1998		Michigan 1996-1998		Tennessee 1996-1997	
	Percentage of Crashes		Percentage of Crashes		Percentage of Crashes	
	WZ	NWZ	WZ	NWZ	WZ	NWZ
Jan	6.2	* 8.0	2.5	* 9.9	5.1	* 8.0
Feb	6.2	* 7.8	2.3	* 7.2	4.0	* 7.1
Mar	8.0	8.3	3.2	* 8.0	6.1	* 8.0
Apr	8.0	8.4	6.6	6.9	8.1	8.3
May	* 9.1	8.5	* 10	7.9	8.6	8.8
Jun	* 9.4	8.1	* 12	8.0	* 9.5	8.2
Jul	* 9.7	8.3	* 13	7.4	* 10	8.4
Aug	* 10	8.1	* 13	7.3	* 12	8.3
Sep	* 9.0	8.0	* 14	7.6	* 10	8.2
Oct	8.8	9.0	* 14	9.5	* 11	9.2
Nov	8.0	8.5	6.6	* 10	8.9	8.9
Dec	7.5	* 9.1	3.0	* 10	6.5	* 8.7

** Indicates significant over-representation.*

Figure 2-1 summarizes the Alabama data by time-of-day of crash. The Alabama data is representative of the data for all three states, and data for Tennessee and Michigan are not included in the figure for clarity purposes. The majority of both work zone and non-work zone crashes happen during the afternoon hours between noon and 5:00 p.m., with the peak hours being from 3:00 to 4:00 p.m. for work zones and from 5:00 to 6:00 p.m. for non-work zones. Work zone crashes are significantly over-represented during daylight hours, when it is more likely that work is being done and there is more traffic. Nighttime hours are significantly under-represented.

Percentages of crashes sorted by day of week are given in Table 2-8. Fridays have the highest frequency of crashes both in and out of work zones, but Tuesday, Wednesday, and Thursday are over-represented in work zones. A majority of work zone and non-work zone crashes occur in clear weather; however, clear-weather crashes are significantly over-represented in work zones (O-R: AL-1.1*, MI-1.2*, TN-1.1*). Again, this is probably when more work zone activity and more traffic are present.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
WZ	1.2	0.7	0.8	0.5	0.7	1.1	2.7	6.9	5.1	5.4	5.7	6.5	7.3	7.3	8.2	9.2	8.1	7.5	4.1	2.9	2.3	2.2	1.8	1.5
NWZ	1.5	1.1	1	0.8	0.8	1.2	2.6	6.6	4	3.9	4.5	5.5	6.9	6.3	7	9.6	8.6	8.6	5.4	3.8	3.2	2.9	2.3	1.8

Figure 2-1. Time-of-day of crash in Alabama, 1994 - 1998

Table 2-8. Day of Week

	Alabama 1994-1998		Michigan 1996-1998		Tennessee 1996-1997	
	Percentage of Crashes		Percentage of Crashes		Percentage of Crashes	
	WZ	NWZ	WZ	NWZ	WZ	NWZ
Monday	15	15	* 15	14	14	15
Tuesday	15	14	* 16	15	15	15
Wednesday	* 15	14	* 16	15	* 16	14
Thursday	* 17	15	* 16	15	16	15
Friday	19	19	17	17	18	18
Saturday	11	* 14	12	* 14	12	* 0.88
Sunday	7.4	* 9.5	7.4	* 10	10	9.9

** Indicates significant over-representation.*

Driver Demographics In Crashes

Age of the causal driver is shown in Table 2-9. In all three states, drivers involved in all crashes are most frequently 25 to 34 years old. Younger drivers, aged 16 to 20, are significantly under-represented in work zone crashes.

Table 2-9. Age of Driver of Causal Vehicle

	Alabama 1994-1998		Michigan 1996-1998		Tennessee 1996-1997	
	Percentage of Crashes		Percentage of Crashes		Percentage of Crashes	
Years of Age	WZ	NWZ	WZ	NWZ	WZ	NWZ
15 or Under	0.34	0.72	0.24	0.59	0.16	0.38
16	3.2	* 4.4	2.2	* 3.5	1.5	* 4.2
17	3.4	* 4.4	2.7	* 3.7	1.9	* 4.2
18	3.6	* 4.3	2.9	* 3.7	3.2	* 4.4
19	3.7	4.0	2.8	* 3.2	2.9	* 4.0
20	3.3	3.5	2.6	2.8	2.5	* 3.4
21	3.0	3.3	2.5	2.5	2.8	3.0
22 to 24	8.1	8.5	7.1	6.8	8.3	7.9
25 to 34	* 22	21	* 22	20	24	21
35 to 44	* 18	16	18	18	18	16
45 to 54	* 12	9.9	* 12	11	14	9.9
55 to 64	* 7.0	6.2	6.3	5.8	6.9	5.6
65 to 74	5.4	5.1	4.8	4.0	4.5	4.2
75 or Over	3.8	3.8	3.4	3.0	2.5	2.9
Uncoded/Error	3.4	4.8	11	* 12	6.6	8.9

** Indicates significantly over-representation.*

More than 99% of crashes overall (either in or out of work zones) do not involve pedestrians. In all three states, there were no significant differences between work zone and non-work zone crashes for any pedestrian variables when all crashes are considered. Section 3 will show that this statement does not hold if only fatal crashes are considered.

Though tables of these data are not included in this report, drivers involved in crashes were found most likely to be male (WZ: AL-62%, MI-61%, TN-62%) and to be wearing lap and shoulder belts (WZ: MI-80%, TN-81%). While most crashes involve drivers who live in the state less than 25 miles from the crash site (WZ: AL-70%, TN-56%), out-of-state drivers are over-represented in work zone crashes (O-R: AL-1.0, MI-1.6*, TN-2.9*).

Vehicle Characteristics Involved in Crashes

All crashes most frequently involve two vehicles, as shown in Table 2-10, but crashes in work zones are more likely (than non-work zone crashes) to involve more than two vehicles. Crashes involving only one vehicle are significantly under-represented in work zones in Michigan and Tennessee. Crashes involving only two vehicles are significantly over-represented in work zones in Alabama and Tennessee, but are significantly under-represented in work zones in Michigan.

Table 2-10. Number of Vehicles Involved in Work Zone Crash

Number of Vehicles	Alabama 1994-1998 Percentage of Crashes WZ	Alabama 1994-1998 Percentage of Crashes NWZ	Michigan 1996-1998 Percentage of Crashes WZ	Michigan 1996-1998 Percentage of Crashes NWZ	Tennessee 1996-1997 Percentage of Crashes WZ	Tennessee 1996-1997 Percentage of Crashes NWZ
1	22	22	19	* 32	20	* 26
2	68	* 72	* 71	63	66	* 68
3	* 8.5	5.0	* 8.4	4.6	* 11	5.8
4	* 1.6	0.69	* 1.8	0.69	* 2.4	0.86
5	* 0.22	0.10	* 0.25	0.11	0.74	0.15
6 or more	0.12	0.030	0.070	0.040	0.36	0.050

** Indicates significant over-representation.*

Though passenger cars and station wagons are involved most often, they are under-represented in work zone crashes as shown in Table 2-11. Large trucks pulling trailers and other heavy trucks are over-represented in all three states. Data on vehicle usage was available only for Alabama and Michigan. Though all of those data are not comparable, the available data indicate that vehicles in work zone crashes are more likely than those in non-work zone crashes to be in use for transporting property (O-R: AL-2.1*), for construction, or for other business rather than for personal use. This indicates that work zone crashes are more likely than non-work zone crashes to involve on-the-job drivers.

Table 2-11. Causal Vehicle Characteristics

	Alabama 1994-1998 Percent of Crashes WZ	Alabama 1994-1998 Percent of Crashes NWZ	Michigan 1996-1998 Percent of Crashes WZ	Michigan 1996-1998 Percent of Crashes NWZ	Tennessee 1996-1997 Percent of Crashes WZ	Tennessee 1996-1997 Percent of Crashes NWZ
Type:						
Cycle	0.51	0.64	0.61	0.50	0.39	0.65
Passenger/Station Wagon	64	70	69	* 71	64	73
Pickup	24	23	14	* 15	20	19
Van/Motor Home	* 0.16	0.070	* 7.9	7.3	0.67	0.25
Truck under 10,000lb	* 3.5	1.9	1.8	1.6	2.7	1.6
CDL Truck/Bus	5.9	2.8	* 5.1	2.2	9.9	2.6
Construction/Road/Farm Equipment	0.80	0.070	0.98	0.14	0.39	0.030
Other/Uncoded	1.3	1.4	0.82	1.8	2.0	2.9
Attachment:						
Pulling Trailer	8.1	3.8	* 1.1	0.64	* 13	3.2
Use:						
Construction	* 3.8	0.83	* 0.72	0.040	-	-
Commercial	* 10	6.1	* 8.8	4.7	-	-
Private	83	* 90	86	* 91	-	-
Other	3.0	3.1	4.8	4.6	-	-

** Indicates significant over-representation.*

- Data not available.

Benekohal and Shim (1999) report that in terms of vehicle miles traveled, the fatal crash rates for large trucks have been consistently higher than the rates for passenger cars and that the semitrailer trucks are under-represented in the property-damage-only and injury crashes, but over-represented in fatal crashes. Analysis of truck drivers' assessment of work zone safety revealed that a vast majority of truck drivers considered work zones to be more hazardous than non-work zone areas. Issues that were found to make truck drivers uncomfortable in work zones include visibility, clarity of the flagger's message, pavement drop-off, loose construction materials, lack of shoulder, and lane width.

Causation Characteristics For Crashes

Table 2-12 shows the actions of drivers in work zone crashes. Most frequently in work zone crashes, a driver is going straight ahead, slowing, stopping, merging, or changing lanes and runs into the back of another vehicle that is slowing, stopping, or stopped in traffic. Though the data are not presented in a table in this report, it was discovered that in Alabama, causal vehicles are more likely to be traveling at higher speeds (36 to more than 70 mph) in work zone crashes than in non-work zone crashes (O-R: AL-1.3*).

Table 2-12. Vehicle Maneuver in Work Zone

	Alabama 1994-1998		Tennessee 1996-1997	
	Percentage of Crashes		Percentage of Crashes	
	WZ	NWZ	WZ	NWZ
Causal Driver:				
Going Straight Ahead	* 55	52	67	50
Slowing, Stopping	* 12	8.4	7.3	4.1
Merging	* 2.2	1.4	-	-
Changing Lanes	* 5.0	3.4	-	-
Avoiding Object in Road	* 1.8	1.4	-	-
Other	25	34	25	45
Driver 2:				
Going Straight Ahead	32	* 38	50	45
Slowing, Stopping	* 11	6.3	17	9.8
Stopped in Traffic	* 23	18	4.1	2.7
Unit Does Not Exist	-	-	20	25
Other	33	37	9.4	17

** Indicates significant over-representation.*

- Data not available.

Michigan data not available.

As shown in Table 2-13, the primary contributing circumstance in work zone crashes is misjudging stopping distance as opposed to failure to yield right of way, which is most often cited in non-work zone crashes. Over-representation of misjudging stopping distance, following too closely, improper lane change, road defects, and vision obstruction are not surprising in work

zones. Failure to yield right of way, failure to heed sign, and weather are significantly under-represented as contributing circumstances in work zone crashes. DUI is significantly under-represented in work zones in Alabama, probably because the crashes most likely occur during daylight hours on weekdays.

Table 2-13. Primary Contributing Circumstance

Alabama	Percentage of Crashes	
1994 - 1998	WZ	NWZ
Follow Too Close	* 12	7.9
Misjudge Stopping Distance	* 15	11
Improper Lane Change	* 4.5	3.0
Road Defect	* 0.92	0.089
Vision Obstructed	* 0.81	0.64
Failure to Yield Row	11	* 17
Failure to Heed Sign	3.4	* 5.3
Parts, Cargo Fell	* 0.72	0.51
Inoperable Traffic Control	* 0.19	0.053
Load Shift	* 0.21	0.11
DUI	2.7	* 3.6
Other	48	51

Michigan	Percentage of Crashes	
1996 - 1998	WZ	NWZ
Clear Distance	* 30	18
Improper Lane Usage	* 6.4	3.6
Improper Passing	1.3	1.2
Wrong Way	* 0.21	0.15
Speed Too Slow	0.27	0.28
Disregard Traffic Control	3.2	* 3.7
Fail to Yield	13	* 16
Speed Too Fast	6.0	* 9.4
Other	39	48

Tennessee	Percentage of Crashes	
1996 - 1997	WZ	NWZ
Following Too Close	* 27	13
Improper Passing	1.6	1.4
Vision Obstructed	0.82	0.87
Reckless Driving	1.2	1.4
Drinking	4.3	4.7
Speeding	2.2	2.9
Disregard Signal or Sign	1.4	* 3.4
Weather	3.3	* 5.6
Failure to Yield	13	24
Other	45	43

** Indicates significant over-representation.*

Other contributing driver conditions such as fatigue and illness are also under-represented in work zones in Tennessee (O-R: TN-0.3). Vehicle defects are rarely contributing factors in work zone crashes, but road defects such as holes/bumps (O-R: AL-12*, TN-5.2) and shoulders too low (O-R: AL-6.0*) are over-represented, as might be expected.

Though not shown in a table, in Michigan, drivers of causal vehicles are significantly more likely to receive a traffic citation stemming from involvement in a work zone crash than in a non-work zone crash (O-R: MI-1.2*). Drivers are less likely to receive a citation in work zone crashes in Alabama and Tennessee (O-R: AL-0.76, TN-0.95). While speeding was slightly over-represented as a contributing factor in work zone crashes in Alabama (O-R: 1.2), it was significantly under-represented in Michigan (O-R: 0.64*). There were no significant differences in speeding in work zone and non-work zone crashes in Tennessee.

Severity of Crashes

Vehicles are most often not disabled in work zone crashes. Table 2-14 shows the point of impact is most often on the front end of the causal vehicle and on the rear of the second vehicle. Damage to the undercarriage, attachment, and top of the causal vehicle are over-represented (O-R: AL-1.5*, MI-2.9*). On vehicle 2, damage to the rear or to an attachment is over-represented (O-R: AL-1.4*, MI-1.5*).

Table 2-14. Point of Vehicle Impact

	Alabama 1994-1998 Percentage of Crashes		Michigan 1996-1998 Percentage of Crashes		Tennessee 1996-1997 Percentage of Crashes	
	WZ	NWZ	WZ	NWZ	WZ	NWZ
Causal Vehicle:						
Front Left Angle	9.2	* 11	-	-	7.6	* 10
Front Center	* 57	53	* 36	33	* 54	50
Front Right Angle	9.6	* 10	-	-	7.5	* 9.4
Rear Left Angle	3.1	* 3.6	-	-	4.0	3.5
Rear Center	4.5	* 5.1	* 8.0	5.5	* 10	5.9
Rear Right Angle	3.3	* 4.3	-	-	3.1	3.9
Other	13	13	56	62	14	17
Vehicle 2:						
Front Left Angle	5.7	* 7.8	-	-	4.6	* 7.5
Front Center	15	* 19	* 12	12	11	* 20
Front Right Angle	5.2	* 6.3	-	-	5.7	6.2
Rear Left Angle	3.3	* 4.3	-	-	3.5	4.1
Rear Center	* 39	29	* 26	15	* 44	24
Rear Right Angle	2.4	* 3.3	-	-	2.0	* 2.9
Attachment	* 1.6	0.67	-	-	-	-
Under Carriage	* 0.23	0.092	-	-	-	-
Top	* 0.22	0.13	-	-	-	-
Other	53	63	62	73	29	36

** Indicates significant over-representation.*

- Data not available.

Table 2-15 summarizes the severity of crashes for all three states. The majority of work zone crashes involve no injury or fatality, but injuries are significantly over-represented in work zone crashes in Michigan. In Alabama and Tennessee, there is no significant difference in the number of injury crashes between work zones and non-work zone locations. In Alabama, a work zone crash is significantly more likely to involve a fatality than a non-work zone crash. Fatal crashes are only slightly over-represented in work zones in Michigan and Tennessee. Though not shown in the table, it was also found that possible incapacitating injury is significantly over-represented in Michigan (O-R: MI-1.2*).

TABLE 2-15. Crash Severity

	Alabama 1994-1998		Michigan 1996-1998		Tennessee 1996-1997	
	Percentage of Crashes		Percentage of Crashes		Percentage of Crashes	
	WZ	NWZ	WZ	NWZ	WZ	NWZ
Property Damage	75	75	76	* 77	69	68
Injury	24	24	* 24	23	30	31
Fatality	* 1.0	0.73	0.29	0.31	0.82	0.66

** Indicates significant over-representation.*

Section 3

Analysis of Fatal Crashes in Alabama: Work Zone vs. Non-Work Zone

Because fatalities were significantly over-represented in work zones in Alabama, another IMPACT analysis was done focusing on fatal work zone crashes in Alabama. The same data set for Alabama (1994-1998) was used, and the set of 129 fatal crashes in work zones was compared to the set of approximately 4800 fatal crashes in non-work zone locations. The relatively small number of fatal crashes in work zones sometimes did not allow calculation of statistically significant over-representations. For example, categorizing the crashes by month split the sample into 12 smaller units, each unit too small to allow the over-representation calculations.

General Characteristics of Fatal Work Zone Crashes in Alabama

Fatal work zone crashes sometimes exhibited characteristics similar to "all" (fatal and non-fatal) work one crashes. Sometimes, they exhibited characteristics similar to fatal non-work zone crashes, and sometimes the results were unique. The following paragraphs will describe these features of fatal work zone crashes.

Where Fatal Crashes Occur

Table 3-1 shows the percentages of fatal crashes in rural and urban areas. Fatal crashes in both work zones and non-work zones occur twice as frequently in rural areas as in urban areas, almost certainly due to the higher travel speeds in rural areas. These numbers are in contrast to "all" Alabama work zone crashes, of which only 35% occur in rural areas (see Table 2-3.)

Table 3-1. Fatal Crashes in Rural and Urban Areas

	Percentage of Crashes	
	WZ	Non-WZ
Rural	67	66
Urban	33	34

The percentages of fatal crashes by highway classification are shown in Table 3-2. Fatal crashes in work zones occur most frequently on state roads, followed closely by Interstate and U.S. highways. Fatal crashes on Interstate roads are significantly over-represented in work zones (O-R: 2.60*). In non-work zone locations, fatal crashes occur most often on county roads.

Table 3-2. Fatal Crashes by Highway Classification

	Percentage of Crashes	
	WZ	Non-WZ
Interstate	* 27	10
U.S.	24.8	21
State	31	27
County	12	31.4
Municipal	5.4	11

** Indicates significant over-representation.*

TABLE 3-3. Speed Limits at Fatal Crash Sites

	Percentage of Crashes	
	WZ	Non-WZ
0 MPH	2.3	0.8
21-25 MPH	0.78	3.3
26-30 MPH	3.1	3.3
31-35 MPH	3.1	8.1
36-40 MPH	3.1	7.3
41-45 MPH	25	20
46-50 MPH	4.6	3.7
51-55 MPH	44.2	42
56-60 MPH	2.3	0.64
61-65 MPH	6.2	5.4
66-70 MPH	5.4	5.2

Table 3-3 shows speed limits at crash sites. Fatal crashes in and out of work zones occur most often in 51-55 mph speed zones.

Fatal crashes in work zones are significantly over-represented on four-lane roadways (O-R: 1.46*) and under-represented for two-lane roadways (O-R: 0.79*). This finding correlates with the large percentage of work zone fatal crashes occurring on Interstate highways.

Temporal Characteristics of Fatal Crashes

The percentages of fatal crashes by day of the week are shown in Table 3-4. Fatal crashes in work zones most frequently occur on Sunday, when the work zones are most likely inactive. In non-work zone locations, fatal crashes occur most often on Saturday.

Non-work zone fatalities are evenly distributed among all months, whereas work zone crashes are less prevalent during the winter months of November to February, when there are fewer work zones. This finding is similar to that for "all" work zone crashes.

Table 3-4. Fatal Crashes by Day of Week

	Percentage of Crashes	
	WZ	Non-WZ
Monday	10	12
Tuesday	12	11
Wednesday	15	11
Thursday	16	13
Friday	12	18
Saturday	14	19
Sunday	20	16

Tables displaying time-of-day and lighting characteristics are not included in this report. It was found, however, that most fatalities happen during the afternoon hours between noon and 6:00 p.m., with the peak hours being from 12:01 p.m. to 1:00 p.m. and 3:00 to 6:00 p.m. This finding of crashes peaking in the afternoon is the same as that for "all" work zone crashes (see Figure 2-1).

Driver Demographics In Fatal Crashes

Causal drivers who live more than 25 miles from the fatal crash site are significantly over-represented in work zones (O-R: 1.72*). Prime contributing circumstance data indicates that roughly 13% of causal drivers are DUI in both work zone fatalities and non-work zone fatalities.

Vehicle Characteristics Involved in Fatal Crashes

All crashes most frequently involve two vehicles, as shown in Table 3-5. Fatal crashes in work zones involving only one vehicle are significantly under-represented (O-R: 0.79*). This finding complements data from Section 2 indicating that "all" work zone accidents more frequently involve multiple vehicles than do non-work zone accidents.

Table 3-5. Number of Vehicles in Fatal Crashes

	Percentage of Crashes	
	WZ Fatalities	Non WZ Fatalities
1	* 42	22
2	44	40
3	12	6
4	2.3	0.91

** Indicates significant over-representation.*

Table 3-6 shows vehicle usage in fatal crashes. Both the causal and the second vehicle involved in fatal crashes both in and out of work zones were driven for personal use. Usage of the second vehicle to transport property is significantly over-represented in work zones (O-R: 2.27*). This value is similar to that given for "all" work zone crashes in Section 2.

Table 3-6. Vehicle Usage in Fatal Crashes

	Percentage of Crashes	
	WZ	Non-WZ
Causal Vehicle		
Null	0.78	0.58
Personal	84	* 92
Construction	3.9	0.64
Transport Property	7.8	3.7
Police	0.78	0.17
Other Business	3.1	2
Vehicle Number 2		
Personal	35	33.84
Construction	2.3	0.87
Transport Property	* 18	7.86
Wrecker, Tow	0.78	0.17
Other Business	2.3	2.3
No Second Vehicle	42	* 53

** Indicates significant over-representation.*

Causation Characteristics For Fatal Crashes

Table 3-7 shows primary contributing circumstance in fatal crashes. Driver not in control is most often the case in fatal crashes both in and out of work zones. 13% of fatal crashes in work zones and 14% of fatal crashes in non-work zones are due to DUI.

Table 3-7. Primary Contributing Circumstance in Fatal Crashes

	Percentage of Crashes	
	WZ	Non-WZ
Following Too Close	0.78	0.43
Misjudge Stop Dist	1.6	0.5
Over Speed Limit	7.8	11.6
Avoid Object/Person	1.6	2.1
Unseen Object/Person	3.1	3
Fail To Heed Sign/S	4.7	4.6
DUI	13	14
Fail To Yield Row	15	12
Driver Condition	7	5.3
Wrong Side Of Road	9.3	9.6
Driver Not In Control	16	14.3
Others	21	22

Section 4

Analysis of Work Zone Crashes in Alabama: Fatal vs. Non-Fatal

Another IMPACT analysis was done to compare 130 fatal work zone crashes to 12,375 non-fatal work zone crashes. It was found that fatal and non-fatal crashes in work zones differ significantly in relatively few of the characteristics studied.

Where Work Zone Crashes Occur

Table 4-1 shows that non-fatal work zone crashes occur more often in urban than in rural areas. Fatal crashes in work zones are twice as likely as non-fatal work zone crashes to have occurred in rural areas. This result makes sense due to higher speeds in rural areas.

Table 4-1. Work Zone Crashes in Rural and Urban Areas

	Percentage of Crashes	
	Fatal	Non-Fatal
Rural	* 67	34
Urban	33	* 66

** Indicates significant over-representation.*

Non-fatal work zone crashes occur most frequently in 45- and 55-mph speed zones. The 55-mph zones are significantly over-represented in fatal crashes. The percentages of work zone crashes in various speed zones are shown in Table 4-2.

Table 4-2. Speed Limits at Work Zone Crash Sites

	Percentage of Crashes	
	Fatal	Non-Fatal
0 MPH	2.3	1.3
21-25 MPH	0.77	5.4
26-30 MPH	3.1	6.5
31-35 MPH	3.1	11
36-40 MPH	3.1	11
41-45 MPH	25	27
46-50 MPH	4.6	6.2
51-55 MPH	* 45	24
56-60 MPH	2.3	1.5
61-65 MPH	6.2	3.5
66-70 MPH	5.4	2.6

** Indicates significant over-representation.*

Table 4-3 shows the percentages of work zone crashes by number of traffic lanes. Non-fatal work zone crashes, like fatal crashes, most often happen on two-lane roadways. Work zone crashes on two-lane roads are significantly over-represented in fatalities.

Table 4-3. Traffic Lanes

	Percentage of Crashes	
	Fatal	Non-Fatal
Null	1.5	1.0
One Lane	0.77	2.7
Two Lanes	* 58	45
Three Lanes	0.77	3.5
Four Lanes	33	36
Five Lanes	0.77	2.9
Six Lanes Or More	4.6	9.1

**** Indicates significant over-representation.***

Though not shown in tables here, there were no significant differences in fatal and non-fatal work zone crashes with respect to highway classification. Fatal crashes occur most frequently on state highways (32%); non-fatal crashes, however, occur most frequently on U.S. roadways (27%). Off-roadway crashes are significantly over-represented in fatal crashes (O-R: 2.23*). On-roadway crashes are significantly under-represented in fatal crashes (O-R: 0.73*).

Temporal Characteristics of Work Zone Crashes

Table 4-4 shows percentages of work zone crashes by day of the week. Non-fatal work zone crashes, like non-work zone fatal crashes, occur most often on Friday. Sundays are significantly over-represented in fatal crashes.

Table 4-4. Work Zone Crashes by Day of Week

	Percentage of Crashes	
	Fatal	Non-Fatal
Monday	10	15
Tuesday	12	15
Wednesday	15	15
Thursday	17	17
Friday	12	19*
Saturday	14	11
Sunday	* 20	7.2

** Indicates significant over-representation.*

While most work zone crashes occur in daylight, daylight crashes in work zones are significantly under-represented in fatal crashes. Crashes in darkness that is not lit are significantly over-represented in fatal crashes (O-R: 3.0*).

Driver Demographics in Work Zone Crashes

There are no significant differences in fatal and non-fatal work zone crashes with respect to driver age or driver gender. 7.7% of fatal work zone crashes involved pedestrians, which is much larger than the 0.74% of non-fatal work zone crashes. Drivers who live more than 25 miles from the crash site are over-represented in fatal crashes (O-R: 1.4*).

Table 4-5 shows driver usage of safety equipment in work zone crashes. Work zone crashes in which the driver did not use a lap or shoulder belt are significantly over-represented in fatal crashes (44%), but those in which the driver used both the lap and shoulder belts are significantly under-represented (25%).

Table 4-5. Restraint Use in Work Zone Crash sites

	Percentage of Crashes	
	Fatal	Non-Fatal
Unknown	10	6.4
Lap Belt Not Fasten	3.9	0.67
L+S, Lap Only Used	2.3	0.99
L+S, Neither Used	* 44	11
L+S, Shoulder Only	0.77	0.26
L+S, Both Used	25	* 67
Air Bag Deployed	9.2	2.8
Air Bag Not Deployed	5.4	9.1

** Indicates significant over-representation.*

As shown in Table 4-6, work zone crashes in which the driver is sober are significantly under-represented and those in which the driver is suspected of being under the influence of alcohol (26%) are significantly over-represented in fatal crashes.

Table 4-6. Officer Opinion of Sobriety in Work Zone Crashes

	Percentage of Crashes	
	Fatal	Non-Fatal
Sober	42	* 90
Alcohol Only	* 26	4.0
Unknown	* 32	5.9

** Indicates significant over-representation.*

Vehicle Characteristics Involved in Work Zone Crashes

Table 4-7 shows number of vehicles involved in work zone crashes. Both fatal and non-fatal crashes usually involve two vehicles, but one-vehicle crashes (42%) are significantly over-represented in fatal crashes, while two-vehicle crashes (45%) are significantly under-represented.

Table 4-7. Number of Vehicles in Work Zone Crashes

	Percentage of Crashes	
	Fatal	Non-Fatal
1	* 42	21
2	45	* 68
3	12	8.5
4	2.3	1.6

** Indicates significant over-representation.*

In Table 4-8, vehicle usage is shown. In both fatal and non-fatal work zone crashes, the causal vehicle is most often for personal use, as is the second vehicle, if one is involved. There are no significant differences in causal vehicle usage between fatal and non-fatal work zone crashes. Second vehicles used for transporting property, however, are significantly over-represented in fatal crashes (18%), while second vehicles for personal use are significantly under-represented.

Table 4-8. Vehicle Usage in Work Zone Crashes

	Percentage of Crashes	
	Fatal	Non-Fatal
Causal Vehicle		
Null	0.77	1.1
Personal	84	83
Construction	3.9	3.8
Transport Property	7.7	6.5
Police	0.77	0.35
Other Business	3.1	3.7
Vehicle number 2		
Personal	35	* 67
Construction	3.1	2.8
Transport Property	* 18	4.0
Wrecker, Tow	0.77	0.14
Other Business	2.3	3.3
No Second Vehicle	* 42	21

** Indicates significant over-representation.*

Causation Characteristics For Work Zone Crashes

Table 4-9 shows primary contributing circumstances for work zone crashes. Non-fatal crashes were most often due to the causal driver misjudging stopping distance. DUI and wrong side of road are over-represented in fatal crashes.

Table 4-9. Primary Contributing Circumstance in Work Zone Crashes

	Percentage of Crashes	
	Fatal	Non-Fatal
Following Too Close	0.77	12
Misjudge Stop Dist	1.5	15
Over Speed Limit	7.7	2.0
Avoid Object/Person	1.5	4.6
Unseen Object/Person	3.1	9.0
Fail To Heed Sign/S	4.6	3.4
DUI	18	2.6
Fail To Yield Row	15	11
Driver Condition	6.9	1.5
Wrong Side Of Road	9.2	0.99
Driver Not In Control	16	13
Others	22	21

Severity of Work Zone Crashes

Table 4-10 shows that while the initial impact on the causal vehicle is most often head on, the impact on the second vehicle is usually on the center of the rear end. Crashes in which the second vehicle is hit head on are significantly over-represented in fatal crashes. Work zone crashes in which the causal or second vehicle is disabled are significantly over-represented in fatal crashes.

Table 4-10. Initial Impact in Work Zone Crashes

	Percentage of Crashes	
	Fatal	Non-Fatal
Causal Vehicle		
Null	0.77	2.0
Head On Center	48	57
Right Front Angle	11	9.6
Broadside Right	10	3.8
Right Rear Angle	0.77	3.4
Rear End Center	2.3	4.5
Left Rear Angle	1.5	3.1
Broadside Left	12	3.5
Left Front Angle	8.5	9.3
Top of Vehicle	2.3	0.57
Undercarriage	3.1	2.0
Attachment	0.77	1.5
Vehicle Number 2		
Head On Center	* 35	14
Right Front Angle	1.5	5.3
Broadside Right	1.5	2.3
Rear End Center	9.2	40
Left Rear Angle	0.77	3.3
Broadside Left	2.3	3.2
Left Front Angle	1.5	5.7
Undercarriage	0.77	0.23
Attachment	6.2	1.6
No Second Vehicle	* 42	* 21

** Indicates significant over-representation*

Section 5

Additional Information On Work Zones in Alabama

While much can be learned from the information in CARE, this information is limited to that obtained from crash reports. The report form only allows for the indication of whether a construction zone was present or not. There is no way to determine if the work zone was active at the time of the crash, what type of project was underway, how long the work zone was in place, whether lanes were closed or not at the time of the crash, what particular traffic control techniques or devices were used, where in the work zone the crash occurred, whether the pedestrian involved or a person killed was a highway or construction worker, etc.

Using another module of CARE, 20 sections of roadway were identified as having large numbers of work zone crashes. The research team contacted Alabama Department of Transportation (ALDOT) district engineers at these locations by phone and sent questionnaires by fax in an attempt to gather additional information about particular work zones in which crashes occurred. A sample questionnaire is included in the appendix. In a few cases, the team was able to contact the project engineer directly.

It must be noted that the data in CARE only provided dates and locations of crashes, and whether or not those crashes occurred in a work zone. For the work zone in which one of these crashes occurred, it was not possible to discover through CARE the precise dates that the work zone was in place or the starting and ending points of the work zone. It was necessary, therefore, to estimate dates and locations by the clustering of crash data.

With little information to go on, it was difficult for the district engineers to determine the appropriate projects and to respond to the questionnaire. District engineers are busy and have little extra time to spend on such extraneous tasks. Also, ALDOT district offices are only required to keep traffic control plans for about five years. Since this study analyzed data from as far back as 1994, it is possible that the plans for some of the work zones of interest were no longer available. Several district engineers were understandably reluctant to disclose crash information because of legal restrictions.

Only six of 20 questionnaires were returned. Two people from the research team went to one ALDOT division office to try to locate specific work zone plans but were unsuccessful. From the few questionnaires that were returned and some fruitful phone conversations, however, some interesting things were learned.

These work zones were all long-term projects (one to more than three years). The high number of crashes was probably due to the long duration of the project and not necessarily due to any design flaw. All traffic control plans reportedly followed the Manual on Uniform Traffic

Control Devices (MUTCD) requirements for traffic control devices. In four of the six locations, a patrol car was also stationed at the beginning of the work zone.

Five of the six work zones were active only during the day on Monday through Friday or Saturday. The other work zone was active only on Sunday through Thursday nights. Comparing this information with times of crashes in CARE, it appears that about two-thirds of the 14 fatal crashes that occurred in these work zones happened during periods when the work zones were inactive.

Section 6

Current Procedures in Alabama

Project personnel traveled to Montgomery, Alabama, to interview ALDOT personnel concerning current procedures employed in Alabama. The meeting included personnel from ALDOT's Design, Construction, Maintenance, and Materials and Tests bureaus. The results of the interview are given below.

Traffic Control Plans

For ALDOT projects, traffic control plans (TCPs) usually originate from one of five places:

- If the project is a grade, drain, base, and pave project, the Design Bureau originates the TCP.
- For smaller "division" projects or for projects designed by consultants, the ALDOT division office or the contractor designs the TCP. Then, the Design Bureau has an opportunity to check the plan during the Plan-in-Hand and the Plans, Specifications, and Estimates reviews.
- If the project is a maintenance overlay, then the Maintenance Bureau designs it.
- If it is a routine maintenance project (mowing, crack filling, etc.), then the local maintenance group probably does not produce a written TCP. The crew usually just brings enough drums, cones, etc. to erect the work zone control devices on the fly.

During a construction project, Construction Bureau personnel can request changes to the TCP, but that does not usually happen.

Construction Zone Traffic Control Program

ALDOT has an agreement with the Alabama Department of Public Safety concerning the use of State Troopers on construction projects. The Project Engineer makes arrangements through the Division Construction Engineer's office if it is determined that Trooper assistance will be needed. This decision is usually made in the planning stage and the cost is incorporated into the plan cost.

Work Zone Traffic Control Inspections

A trained Project Traffic Control Inspector (PTCI) is assigned to each project, though traffic control is usually not his only duty. He inspects the TCP items after they are installed and after that makes at least one inspection per day, which is recorded on form C-25. He is also required to make a nighttime inspection at least once per month.

The Division Traffic Engineer is asked to make periodic inspections of traffic control setups on all Federal Aid projects. Additionally, once per year, a statewide review team headed by the

State Construction Engineer inspects one project in each of three Divisions. A report of the inspections is sent to the State Construction Engineer.

A Division Traffic Engineer currently might have five to six inspections to complete per week in addition to regular duties. The PTCI also has other responsibilities in addition to traffic control inspection. States with more resources than ALDOT are able to devote more personnel to TCP inspections. For example, the New York DOT currently inspects at least 25% of active construction work zones in addition to maintenance work zones in each of its 11 regions each year (Bryden, 2001).

Traffic Crashes

The method for crash reporting in work zones is specified in Part 1:2:P Contract Administration (Traffic Control Policy) of the ALDOT Construction Manual. When crashes take place (whether during construction or not) the PTCI attempts to obtain a copy of the Alabama Uniform Traffic Accident Report from police or troopers and uses it to help prepare a written report of the accident to be given to the Project Engineer. If the Project engineer decides that the crash was related to the work zone, he or she forwards the report to the District and Division offices, and it ends up in the Central Office. However, ALDOT Central Office personnel report that they get very few such reports. Reports for crashes that are not construction-related are not forwarded but are kept in the project records for five years after project completion.

Training

Work zone traffic control training is available to ALDOT and contractor personnel. Traffic Control Inspector training is required and training for other personnel (flagger, highway maintenance technician, engineering assistant), though not required, is encouraged. Many ALDOT personnel receive this training, because they may be asked to act in a variety of capacities on a construction site during any given day.

Lane Closure Policy

ALDOT desires to close lanes for as short a time as possible, particularly in high-volume traffic areas. Thus, personnel from the Design Bureau usually include lane closure policy statements on the Project Notes Sheet. Some of the statements are location-specific, such as "no lane closure allowed during an event at [a nearby sports arena]", or "no lane closures on Sundays" if there are many churches in the area, which would cause high traffic volumes then. Other statements are general and appear frequently on various project notes, such as "local traffic shall be maintained at all times", "road closure shall be limited to one lane", and "both lanes must be opened to through traffic at the end of each day's work."

ALDOT recently added a lane closure policy for Interstates during the summer construction season. It states that no Interstate lane can be closed from noon Friday until 6 a.m. Monday without special permission.

Traffic Control Devices

Before any traffic control device may be used in a work zone in Alabama, it must be tested and approved by the Alabama Department of Transportation, which adheres to the requirements of the National Transportation Product Evaluation Program (NTPEP), a division of the American

Association of State Highway and Transportation Officials (AASHTO). ALDOT published (2001) *Standards Specifications for Highway Construction*, which includes sections on pavement markers, barricades, signs, impact attenuators, traffic control officers, delineators, fencing, and portable arrow panels. ALDOT also publishes lists of approved devices and materials and provides a list of vendor names and addresses (Texas A&M University).

Section 7

Review of Work Zone Safety Across the U.S.

Work Zone Traffic Management

Proper management of work zone activities to ensure acceptable traffic flow and safety is one of the most challenging tasks facing transportation experts. Effective work zone traffic management has many benefits including reduced traffic crash costs, reduced traffic congestion and delay, lower tort liability risks, and payments associated with fewer accidents, among others (ITE). The Manual on Uniform Traffic Control Devices (MUTCD) is a federal standard for the design of work zone traffic control plans. The MUTCD explains, however, that variability in these plans is necessary. "*No one set of signs or other traffic control devices can typically satisfy all conditions for a given project. At the same time, defining detailed standards that would be adequate to cover all applications is simply not practical.*"

Training and Certification

Because flexibility in designs in certain instances may have an adverse impact on safety, inspection and evaluation of the traffic control plan must be performed frequently throughout the project. Many states have increased training or certification requirements for workers, designers, and inspectors of traffic control plans.

Reducing Exposure

There are continuing efforts across the country to enhance the safety of motorists and highway workers. Many techniques are being employed which focus on various aspects of the problem. By reducing exposure of motorists to work zones, the number of crashes, injuries, and fatalities in work zones are reduced. Innovative contracting techniques, such as 'cost plus time' (A+B) bidding, lane rentals, and flexible start times, encourage expeditious completion of the work. Contractors are offered a bonus for completing work early and/or are fined if work is not completed in the specified time (FHWA, 1998). Alabama currently uses incentive/disincentive clauses in its contracts to encourage timely completion of the work.

Lane and road closure policies have been developed in some states, which limit the times when lane closures are allowed or limit the length of a lane closure. These limitations are based on factors such as traffic volumes, percent grade, and directional travel demand and serve to reduce the probability of collisions and congestion. Weekend and nighttime closures are common. In some states, but not in Alabama, an analysis is performed to determine the impact of a lane closure. If the closure is predicted to produce a delay that exceeds a preset maximum, then other alternatives are explored (FHWA, 1998).

Another way of reducing motorist exposure to a work zone is to re-route the traffic altogether. Sometimes a specific detour path around the work zone is included in the traffic control plan. If motorists are informed about work zone activity, however, many will choose their own alternate route, thus reducing the volume of traffic through the work zone. Many states, including Alabama, use web sites and bulletin boards in rest areas to inform the public of active work zone locations. These web sites and bulletin boards also help to increase public awareness of the dangers of work zones.

Speed and Enforcement

Excessive speed and driver inattention have been shown in other studies to be leading causes of work zone crashes. The most effective method of controlling these factors is to have a staffed police car with flashing lights at the beginning of the work zone. Many states have formed partnerships with law enforcement agencies to provide off duty officers to be stationed at work zones (FHWA, 1998). As discussed in Section 5 of this report, Alabama uses State Troopers for speed enforcement on many of its high-speed roadway projects.

Section 8

Summary, Conclusions and Recommendations

Summary

The comparison of crash data from Alabama, Michigan, and Tennessee indicates that the problems occurring in work zones are similar in all three states. The following characteristics were found to be common:

- This study found the "typical" work zone crash includes the following factors: a male driver, age 25 to 34, while driving in clear weather during mid-afternoon on a U.S. highway or interstate roadway comes upon slow or stopped traffic due to construction and crashes into another vehicle; or else in the process of avoiding such, crashes into a barrier or construction equipment. The characteristics used to describe the "typical" crash do not necessarily happen in over 50% of work zone crashes. They represent "most frequently found" characteristics, not necessarily "majority" characteristics.
- In all three states, work zone crashes are more likely to involve speeding and large trucks.
- Work zone crashes are significantly over-represented on Interstates and U.S. highways in all three states.
- Work zone crashes most frequently occur in urban areas, but work zone crashes are over-represented in rural areas compared to non-work zone crashes.
- Drivers in work zone accidents are typically wearing seat belts.
- Less than 1% of work zone crashes involve pedestrians.
- Work zone crashes most often involve only two vehicles, but are more likely than non-work zone crashes to involve more than two vehicles.
- Misjudging stopping distance and following too closely are the most frequent contributing circumstances of work zone crashes.
- While the vehicles are usually not disabled, work zone crashes most often result in damage to the front of the causal vehicle and to the rear of the second vehicle.
- Fatalities are significantly over-represented in Alabama work zone crashes.
- The speed limit at a crash site is most frequently between 41 and 55 miles per hour (mph) as shown in Table 2-5.

Of the three states, only Alabama had significantly over-represented work zone fatalities, and, for that reason, Alabama's fatal crashes were studied in more detail. The comparison of fatal work zone crashes with fatal non-work zone crashes in Alabama uncovered the following facts:

- 67% of work zone fatalities take place in rural areas, 33% in urban areas.
- Causal drivers who live more than 25 miles from the crash site are significantly over-represented in work zone fatalities (O-R: 1.72*).

- State, U.S., and Interstate highways represent 83% of work zone fatalities in Alabama, and Interstates are significantly over-represented (OR: 2.6*). By contrast, those three road types represent only 58% of non-work zone fatalities.
- Pedestrian fatality rates were very similar for work zone crashes vs. non-work zone crashes, comprising 7.8% of work zone fatal crashes and 7.5% of non-work zone fatal crashes.
- DUI as the primary contributing circumstance represents 13% of work zone fatalities and 14% of non-work zone fatalities. This compares to a value of 2.7% for all work zone crashes and 3.6% for all non-work zone crashes.
- Driver not in control is most frequently the primary contributing circumstance in work zone fatalities (16%) and non-work zones (14%) fatalities.

The comparison of fatal work zone crashes with non-fatal work zone crashes in Alabama disclosed the following differences:

- In work zones, fatal crashes are more likely to have occurred off-roadway than are non-fatal crashes (O-R: 2.23*).
- Fatal crashes in work zones are less likely to occur in daylight. Work zone crashes that occur when it is dark in places where there are no streetlights are more likely to be fatal than non-fatal (O-R: 3.0*).
- In fatal work zone crashes, drivers were found not to be wearing seat belts more frequently than in non-fatal crashes (44% to 11%).
- Drivers were suspected of being under the influence of alcohol more often in fatal work zone crashes than in non-fatal crashes (26% to 4%). DUI is over-represented in fatal work zone crashes.
- Wrong side of the road is over-represented in fatal work zone crashes.
- Fatal work zone crashes take place more frequently in the higher speed zones found in rural areas.

Alabama crash data for day, month, highway type, number of vehicles involved, speed limits, primary contributing circumstance, and initial impact of causal vehicle are compared for all accident types. They are shown in Figures 8-1 through 8-7 and provide graphical representation for the information provided in the previous two sets of bulleted items. These figures appear at the end of this section.

From the additional information gathered about high-crash-frequency work zones in Alabama, the following observations were made:

- Most fatal crashes appear to have occurred when the work zone was inactive.
- Individual work zones exhibiting high numbers of crashes appear to have many crashes due to the long duration of the project rather than to design flaws.
- It is difficult to find any information beyond that available on the police report about a past work zone crash. Data would not be computerized and would have to be culled from ALDOT project diaries and project files stored in ALDOT division offices.

ALDOT is addressing safety in work zones in several ways:

- Forming partnerships with law enforcement agencies for assistance with speed control.
- Requiring frequent inspections of work zone traffic control by trained inspectors.
- Making traffic control training available to ALDOT and contractor personnel.
- Restricting lane closures to reduce exposure of motorists to work zones.
- Requiring testing and approval of all traffic control devices used in work zones.

Recommendations

Based on the results of this study and the literature review of safety enhancement efforts around the country, the following recommendations are presented:

- Work zone crashes occur disproportionately on Interstate and U.S. highways. Safety efforts focused on those highways will provide the greatest safety gains.
- Because misjudging stopping distance and following too closely are the most frequently cited causes of WZ crashes, emphasizing the following work zone safety practices will show the greatest safety improvements: limiting vehicle speeds, increasing time headway between vehicles, and warning vehicles of queues ahead.
- Further research can be performed to study characteristics of work zones that are not available in police crash reports. For example, in 2001, ALDOT will fund a research project to study vehicle speeds, time headways, and other parameters in active work zones. Other areas for further study might include identifying the locations inside work zones where crashes occur, the types of work zones where crashes most frequently occur, and the safety techniques that are most useful in decreasing work zone crashes, injuries, and deaths.

Other recommendations derived from the additional studies of work zone fatalities in Alabama follow:

- Additional emphasis can be placed on making work zones safer during inactive hours, as the majority of fatal crashes in Alabama appear to have taken place during inactive hours. Safety treatments aimed at reducing the number of fatalities in the following over-represented areas can be pursued: areas unlit at night, off-road crashes involving single vehicles, and drivers over 25 miles from home.
- ALDOT might consider increasing the number of independent inspections of work zones.

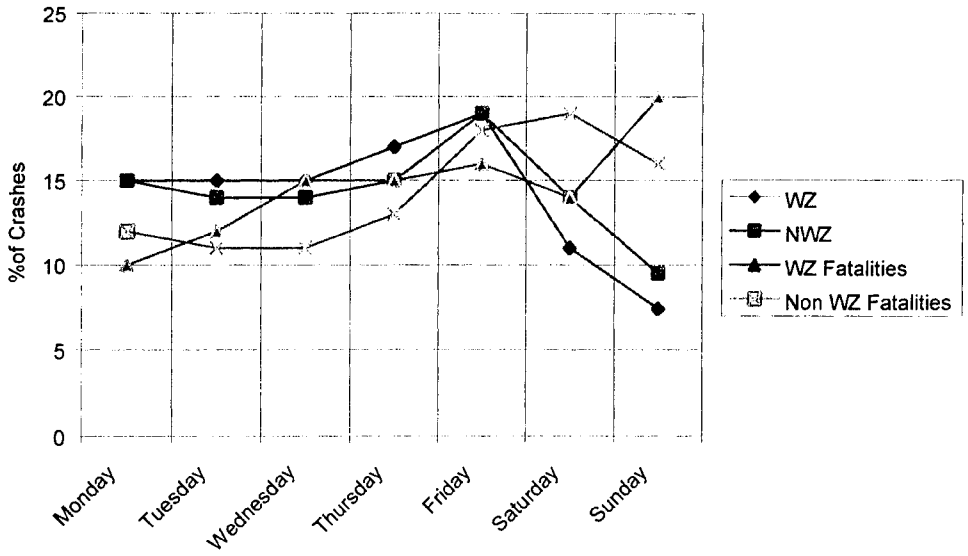


Figure 8-1. Alabama Crashes by Day of Week, 1994 - 1998

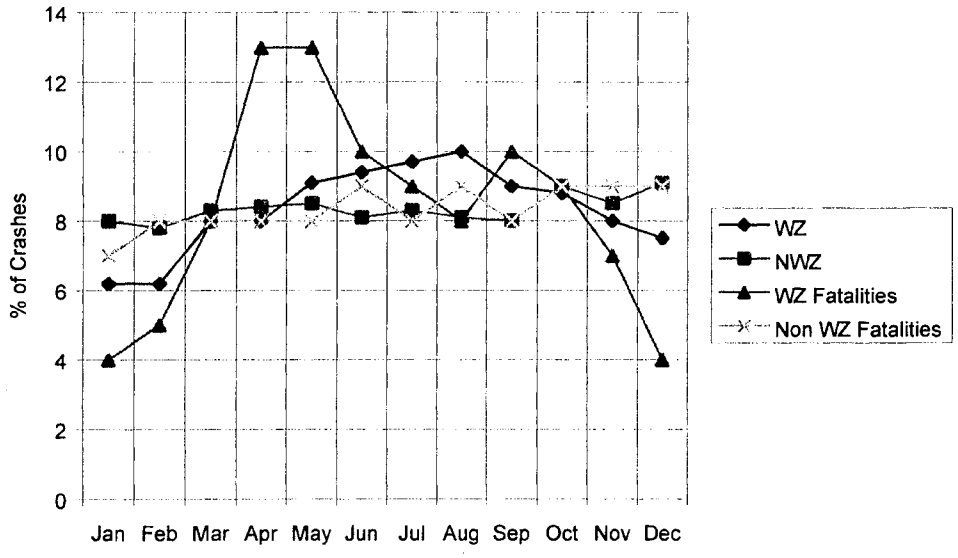


Figure 8-2. Alabama Crashes by Month, 1994 - 1998

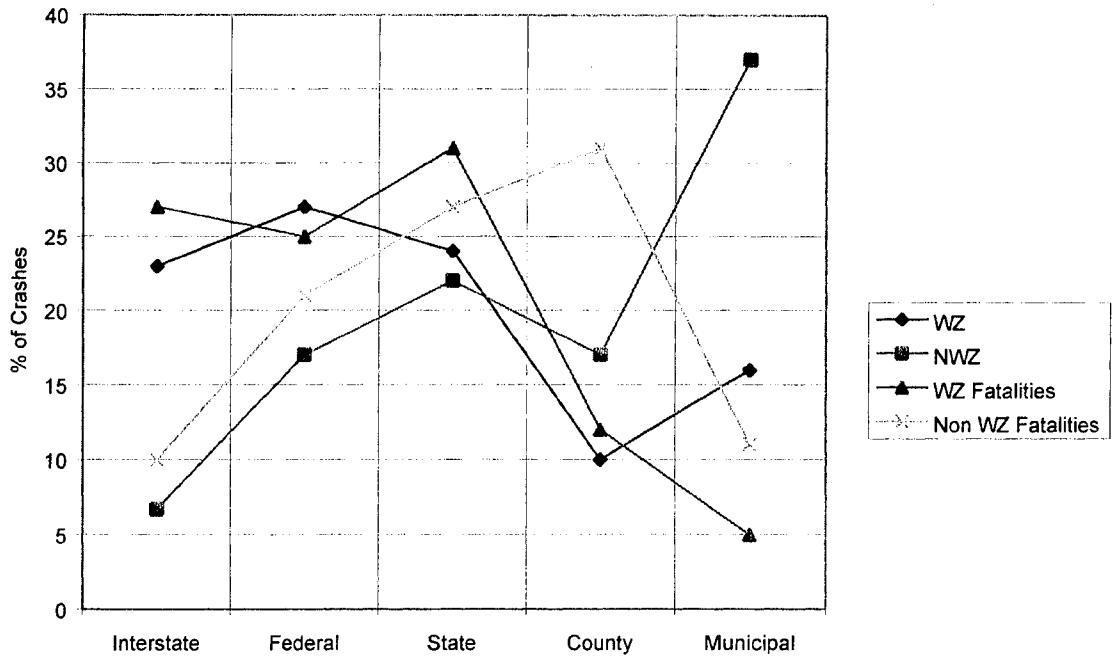


Figure 8-3. Highway Classification in Alabama Crashes, 1994-1998

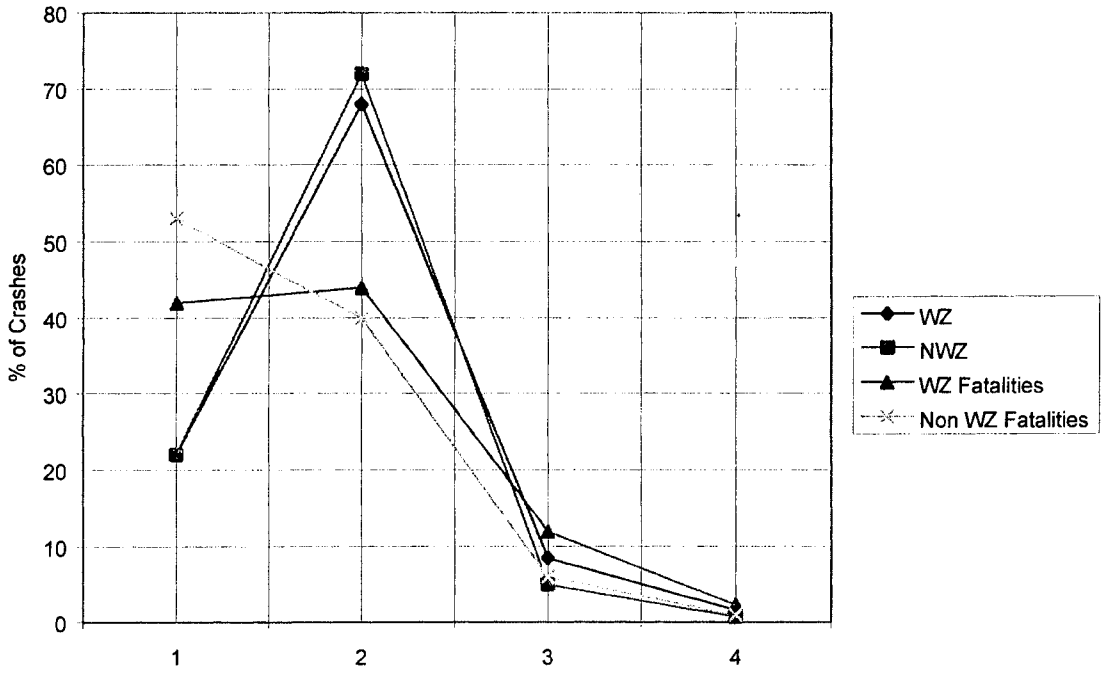


Figure 8-4. Number of Vehicles in Alabama Crashes, 1994 - 1998

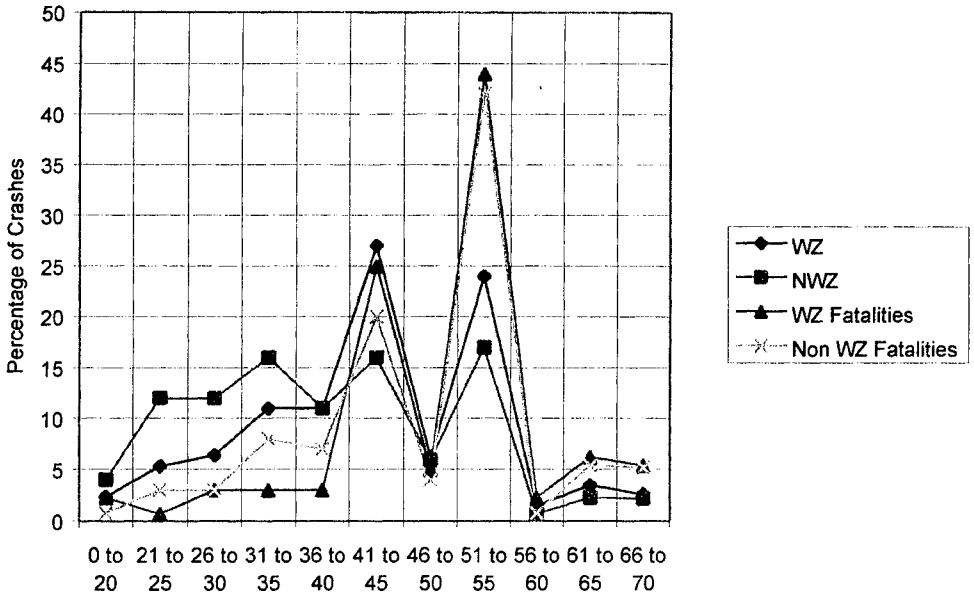


Figure 8-5. Speed Limits at Albama Crash Sites, 1994 - 1998

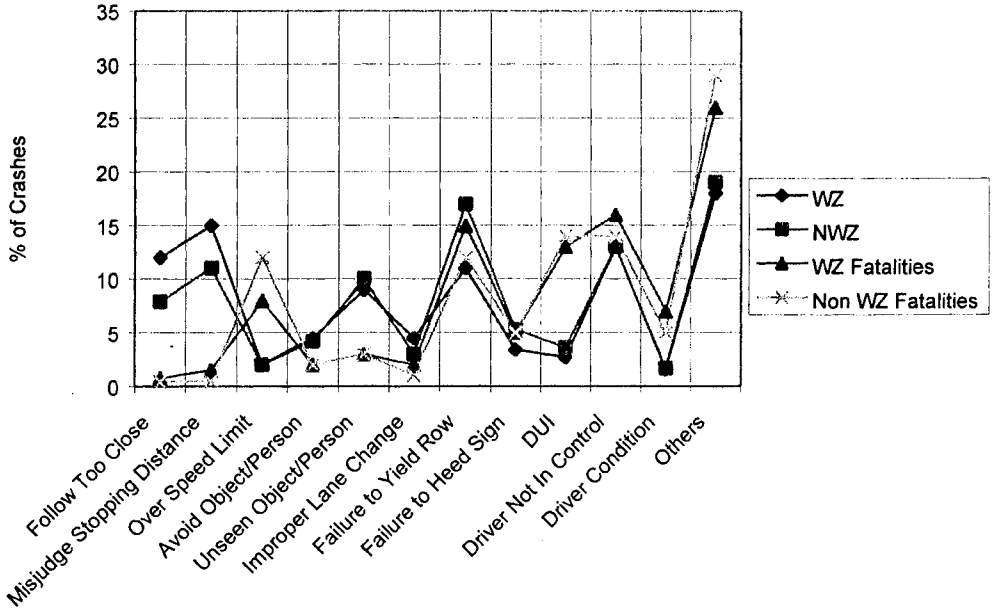


Figure 8-6. Primary Contributing Circumstances in Alabama Crashes, 1994-1998

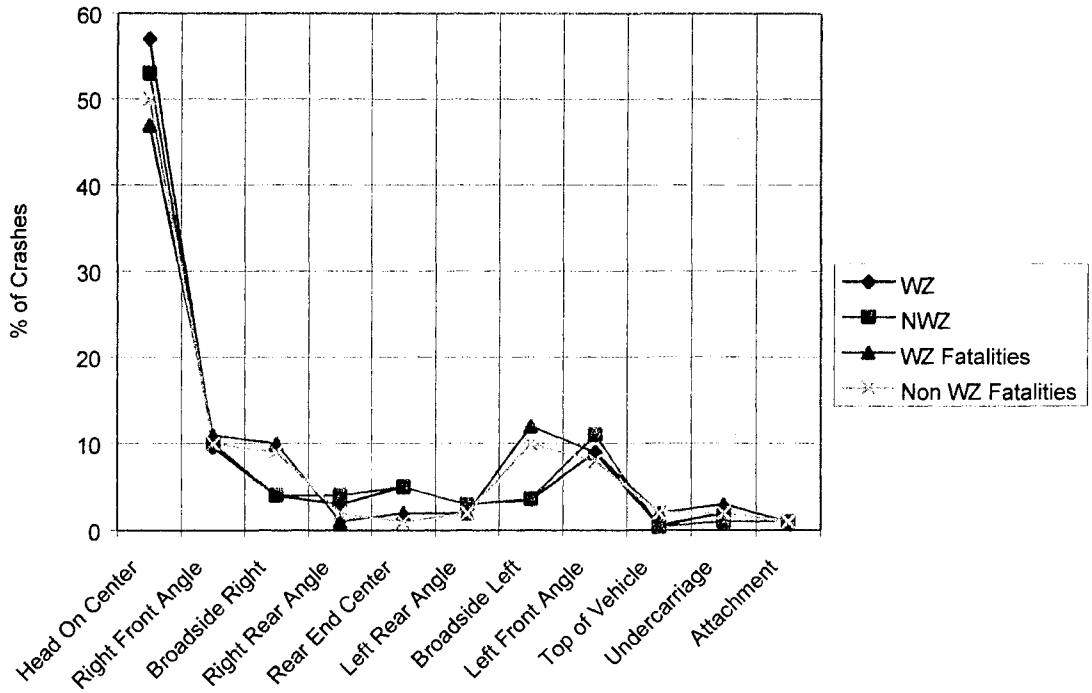


Figure 8-7. Initial Impact of Causal Vehicle in Alabama Crashes,1994-1998

Section 9

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Appendix

Sample Questionnaire

Division X District Y

Location: Given name (number) of roadway and either mileposts or node numbers.
Dates: Range given

Part I:
1. Project Number: _____
2. Project Engineer – Name: _____, Phone: _____
3. May we get a copy of the Traffic Control Plan for this work zone? _____

Part II:
4. What type of work was being done? (Ex: resurfacing, adding a lane, widening, etc.)
5. How long was the work zone in place? Approx. start date _____, End date _____
6. When was the work zone active? Please specify times.
   Days of week: _____
   Daily hours of activity: _____a.m./p.m. to _____a.m./p.m.
7. Was the work zone stationary; moving; stationary but moving during resurfacing; or other (please specify)?
8. What restrictions were placed on lane closures?
   No lane closure allowed during _____
   Lane closure allowed only during _____
   Other _____
9. Were special traffic control devices used (in addition to those required by the MUTCD)? Why?
   Variable Message Signs
   Flaggers
   Reflective clothing
   Active enforcement initiative (state trooper, VMS with radar, etc.)
   Other _____

Part III:
The following questions pertain to fatalities that occurred in crashes in this work zone.

Date of Crash: Given Time of Crash: Given
Number of fatalities: Given Pedestrian(s) involved: Yes/No given

10. Was the person who was killed
    - ❑ A driver of one of the vehicles?
      - o Causal vehicle
      - o Other vehicle
    - ❑ A passenger in one of the vehicles?
      - o Causal Vehicle
      - o Other Vehicle
    - ❑ A pedestrian?
    - ❑ A highway department worker?

- ❑ A construction company worker?
- ❑ Another worker in the work zone? _____

11. Where in the work zone did the crash occur?
    - ❑ Advance Warning Area
    - ❑ Transition Area
    - ❑ Activity Area
        - o Buffer Space
        - o Work Space
    - ❑ Termination Area
    - ❑ Other: _____
12. Was the work zone active at the time of the crash? _____

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