DISTRIBUTION AND CHARACTERISTICS OF CRASHES AT DIFFERENT LOCATIONS WITHIN WORK ZONES IN VIRGINIA

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ABSTRACT

Work zones tend to cause hazardous conditions for vehicle drivers and construction workers since these work zones generate conflicts between construction activities and the traffic, and therefore aggravate the existing traffic conditions. Every effort should therefore be made to minimize the negative impacts of work zones. A clear understanding of the characteristics of work zone crashes will enhance the selection of the appropriate measures that can minimize the negative impacts of work zones.

This study investigated the characteristics of work zone crashes in Virginia that occurred between 1996 and 1999. The information on each crash was obtained from the police crash records. Each crash was located in one of five areas of the work zone; (i) Advance Warning Area, (ii) Transition Area, (iii) Longitudinal buffer Area, (iv) Activity Area, and (v) Termination Area. An analysis of the percentage distributions was then carried out, with respect to the locations of the crashes, the severity, collision types and different types of highways. The proportionality test was used to determine significant differences at the 5% significance level. The results indicate that the Activity Area (Area 4) is the predominant location for work zone crashes regardless of the highway type, and that rear-end crashes are the predominant type of crashes. However, the results also indicated that the proportion of the sideswipe in same direction (SS) crashes in the Transition Area (area 2) is significantly higher than that in the Advance Warning Area (Area 1).

INTRODUCTION

With the completion of the interstate highway system in the United States, the roadwork has shifted from new construction to maintenance and rehabilitation. The transportation Equity Act for the 21st Century (TEA 21) provided a significant increase in the funding for highway construction and maintenance. Thus, it is expected that rehabilitation work will increase significantly during the next few years. In addition, it is expected that traffic volumes on the Nations' highways will continue to increase. Since it is not feasible to close long stretches of highways while rehabilitation work is being undertaken, it will be necessary to provide for the flow of the increased volumes of traffic while rehabilitation work is in progress. This in turn will result in a significant increase in the number of work zones, which will require an increased effort in improving safety at work zones. However, a clear understanding of the characteristics of work zone crashes will enhance the selection of effective counter measures that can be used to minimize the negative effects of work zones. This paper presents some of the results of a study to examine the characteristics of work zone crashes in Virginia. The specific objectives are:

1. to identify the predominant location within work zones where crashes occur
2. to determine the predominant types of crashes and the distribution of severity at each location
3. to study the collision type and severity distribution with respect to different road types

LITERATURE RIEW

Although several studies *(1,2,3,4,5,6,7,8,9,10,11.12,13)* have investigated the characteristics of work zone crashes, the results of these studies have not been wholly consistent.

A brief summary of the results of some of these studies is given under the following sub-headings:

- Crash Severity
- Crash Location
- Other Crash Characteristics

Crash Severity

Although the literature review does not indicate any studies that have compared the proportional distribution of crashes by severity level among the different work zone areas, a brief summary of the results of comparisons between work zones and non work zones is given.

Two studies *(9,11,12)* showed work zone crashes were more severe than other crashes, while two other studies *(2,6)* concluded the severity of work zone crashes was not significantly different from all crashes. Five studies *(5,7,8,10,13)* stated that work zone crashes were (slightly) less severe than all crashes.

Crash Location

Four studies *(3,7,8,13)* addressed the specific locations of crashes in work zones. Hargroves *(7)* found that most crashes occurred at the work area (combining the longitudinal buffer area and the activity area). Nemeth *(8)* concluded that 39.1% and 16.6% accidents occurred in longitudinal buffer area and activity area respectively. In another study *(13)*, Nemeth used another set of location categories and showed that most crashes occurred at single Lane zones, crossover or bi-directional zones (Two Lane Two Way Operation). Goddin *(3)* indicated that 69% of the crashes occurred in the activity area.

Other Crash Characteristics

The results of several studies *(2,3,5,6,7,8,9,11,13)* indicated that Rear-end crashes were the predominant collision type at work zones. Three studies *(2,6,12)* indicated that multi-vehicle crashes were over-represented at work zones while three studies *(6,7,11*) indicated that heavy vehicles were over-represented in work zone crashes.

Summary

The literature review revealed inconsistent results for many of the studies with respect to several characteristics. This discrepancy among the studies may be due to several factors, including the number of crashes considered, the time period during which the crashes occurred and the types of highways considered and whether the crashes considered were all work zone related. This study has therefore taken these factors into consideration in building up the data used for the analysis.

METHODOLOGY

Data Processing

Information on each work zone crash that occurred from 1996 through 1999 in Virginia was obtained from the police crash report. A review of each report was first undertaken to ascertain that each crash selected for the study was work zone related. A total of 1484 crashes out of the 1939 obtained from the database were then selected for the study. The location of each of the 1484 crashes was identified by a careful examination of the police accident report, which includes a diagram indicating the location of each crash within the work zone. This location was then noted as one of the five areas of a work zone. These areas are:

(1) Advance Warning Area

(2) Transition Area

(3) Longitudinal Buffer Area

(4) Activity Area

(5) Termination Area.

These locations are shown in figure 1. In addition, information was obtained on the severity (Fatal, Injury, or Property Damage Only), the collision type (rear end, angle, sideswipe, fixed object) and type of highway. Percentage distributions were then determined for the location of the crashes, the severity and the collision type. Each of these distributions was then determined for each road type. Proportionality tests[14] were then conducted to determine the significance of the distributions of these characteristics.

The proportionality test is a test of the quality of two independent means, namely p_1 and p_2, which are the probabilities of success resulting from two different processes. The test statistic is the Z value, which is given as:

$$Z = \frac{p_1 - p_2}{\sqrt{p(1-p)[(\frac{1}{n_1}) + (\frac{1}{n_2})]}}$$

where p_1 and p_2 are the two proportions to be compared, p is the pooled estimate, and n_1 and n_2 are the population sample sizes:

$$p_1 = \frac{Y_1}{n_1}$$

$$p_2 = \frac{Y_2}{n_2}$$

$$p = \frac{Y_1 + Y_2}{n_1 + n_2}$$

where Y_1 and Y_2 are the number of successes for populations 1 and 2. This test was used to test the null hypothesis $H_0 : p_1 = p_2$ against that of $H_1 : p_1 > p_2$. If the calculated Z-statistic is greater than Z_α, which is

the Z statistic corresponding to a significance level of α, then the null hypothesis is rejected and H_1 is accepted. A 5% significance level was used for all the hypotheses tested.

The following null hypotheses were tested:

(1) The proportion of crashes at each location is not significantly different from the proportion at the other locations

(2) The proportion of each severity level is not different from the others

(3) The proportion of crashes by severity is the same for all locations

(4) The proportion of each collision type is not different from the other collision types

The above null hypotheses were then repeated for each road type and by time of day.

RESULTS

Location Distribution

The location distribution for all the 1484 work zone accidents is shown in figure 2. This figure shows that the activity area (area 4) is the predominant crash location in a work zone, followed by the transition area (area 2), the advance warning area (area 1), the longitudinal buffer area (area 3) and the termination area (area 5) respectively. The results of the proportionality test show that the proportion of crashes occurring at the Activity Area (Area 4) is significantly higher than that at each of the other locations. The results also indicate that the proportions of crashes in the five areas are significantly different from each other

In order to study the effect of highway type on these distributions, the highways were first classified as Interstate, Primary and Secondary, and then each road was further classified as urban or rural. In classifying the urban and rural roads, the Northern Virginia urban

secondary roads were separated from the rest of the urban secondary roads as some urban secondary roads in Northern Virginia carry volumes that are as high as those on primary roads.

Table 1 shows the proportion of crashes by road type and location at the work zones. The results of the proportionality tests shown in table 2, indicate that the proportion of the crashes occurring in area 4 for interstate, primary or secondary roads is not significantly different from the proportion of the crashes in area 4 for all crashes combined. This indicates that area 4 is more susceptible to crashes regardless of the type of highways. It should be noted that only 24 crashes out of the 1484 occurred in the termination area (area 5). This indicates that the termination area is the safest area in a work zone.

Severity Distribution

Severity distributions were obtained for all crashes at different locations and for different road types. Table 3 shows the severity distribution by location and road type. Figure 3 shows the severity distribution for all crashes. The results of proportionality tests indicate that the most prevalent severity type is Property Damage Only (PDO) for all road types except for “rural primary” and “other secondary” roads, where the proportions for injury and PDO accidents are not significantly different from each other

The results of proportionality tests also indicate that the proportion of fatal crashes at any work zone area is not significantly different from the proportion of the fatal crashes in all crashes combined for the other work zone areas. Similarly the proportionality test results indicated that the proportion of fatal crashes on any road type (interstate, primary or secondary) is not significantly different from the proportion of fatal crashes in all crashes combined for the other road types. Also the proportion of PDO crashes at each work zone area is not significantly

different form that for all crashes at the other work zone areas combined. Note that the proportions given in Table 4 are with respect to all crashes on each highway and therefore the high proportions shown for area 4, reflect the high percentage of crashes occurring in this area.

Collision Type Distribution

Figure 4 shows the distribution of all crashes by collision type. Table 4 shows the distribution of crashes by collision type, location and highway type and. The collision types with percentages of 5% or less were combined together and categorized as “others”. The results of Proportionality tests indicated that RE (rear end) was the predominant collision type and FI (fixed object in road) was the least prevalent collision type among the five collision types examined. The results of the proportionality tests also indicated that the proportion of AN (angle) crashes is significantly higher than the proportion of SS (sideswipe in same direction) crashes. However, the proportion of FO (fixed object off road) crashes is not significantly different from the proportion of SS (sideswipe in same direction) and AN (angle) crashes.

Collision type distributions for areas 1 and 2 are shown in figures 5 and 6 respectively. RE (rear end) crash is the predominant crash type in area 1. The high percentage of RE (rear end) crashes in area 1 may be due to increased speed variance in this area, caused by some drivers observing the speed reduction signs and reducing their speeds, while others do not. Although RE (rear end) crash is the predominant crash type in area 2, the percentage (26%) of the SS (sideswipe in same direction) crashes has increased to a level much higher that that for area 1. This increase in SS (sideswipe in same direction) crashes may be due to the increase in merging maneuvers necessitated by the reduction of the number of through lanes.

Collision type distributions for areas 3 and 4 are shown in figures 7 and 8 respectively. The results of proportionality tests show that the percentage distribution of crashes by collision types is not significantly different for areas 3 and 4. It is therefore reasonable to combine these two locations in carrying out crash analysis at work zones. As one moves from the transition area (area 2) to work area (combing areas 3 and 4), the proportions of RE (rear end) and SS (sideswipe in same direction) crashes decrease and the proportion of FO (fixed object off road) and AN (angle) crashes increase. This may be due to the increase of conflicts between traffic and the construction activities

Collision type distributions for interstate and primary roads are shown in figures 9 and 10 respectively. The results of proportional tests indicated that RE (rear end) is the predominant collision type for interstate highways, followed by SS (sideswipe in same direction), FO (fixed object off road), AN (angle) and FI (fixed object in road). However, the proportion of SS (sideswipe in same direction) crashes is not significantly different from the proportion of FO (fixed object off road) crashes. Similarly the proportion of AN (angle) crashes is not significantly different from the proportion of FI (fixed object in road) crashes. For primary roads, RE (rear end) is also the predominant collision type, followed by AN (angle), FO (fixed object off road) and SS (sideswipe in same direction). However, the proportion of FO (fixed object off road) crashes is not significantly different from the proportion of SS (sideswipe in same direction) crashes. The results also indicate that for secondary roads, RE (rear end) is also the predominant collision type, followed by AN (angle), FO (fixed object off road) then SS (sideswipe in same direction), BI (backed into) and PE (collision with pedestrian). In this case the proportions of FO (fixed object off road), SS (sideswipe in same direction), BI (backed into), and PE (collision with pedestrian) crashes are not significantly different from each other. However, the proportion of

FO (fixed object off road) is significantly larger than the proportion of PE (collision with pedestrian). RE (rear end) crash is also the predominant type of crashes at theses areas.

In order to test whether the proportion of a collision type is influenced by the type of highway, the proportionality test was conducted on the distributions by collision type for the different types of highways. The following results were obtained:

(1) The proportions of RE (rear end) crashes on interstate and primary highways are significantly higher than the proportion of RE (rear end) crashes on secondary roads.

(2) The proportions of AN (angle) crashes on primary and secondary roads are significantly larger than the proportion of AN (angle) crashes on interstates.

(3) The proportion of SS (sideswipe in same direction) crashes for interstates is significantly higher than the proportions of SS (sideswipe in same direction) crashes on primary and secondary roads.

(4) The proportion of BI (backed into) crashes on secondary roads is significantly higher than the proportion of BI (backed into) crashes on interstates.

(5) The proportion of FO (fixed object off road) crashes on interstates is significantly higher than the proportion of FO (fixed object off road) crashes on primary roads.

(6)The proportions of FI (fixed object in road) crashes on primary and secondary roads are not significantly different from each other.

In comparing urban with rural roads, the results of the proportionality tests indicated the following:

(1) The proportion of each collision type for urban interstates is not significantly different from that for the rural interstates.

(2) The proportions of AN (Angle), FI (fixed object in road), PE (collision with pedestrian) and RE (rear end) crashes for urban primary roads are not significantly different from those for rural primary roads, while the proportions of BI (backed into), FO (fixed object off road) and SS (sideswipe in same direction) crashes for urban primary roads are significantly different from those for rural primary roads.

SUMMARY OF RESULTS

- Activity area (Area 4) is the most prevalent accident location in a work zone, and termination area (area 5) is the safest area in a work zone.
- For all the crashes studied, PDO is the predominant severity type, followed by injury and fatal. Fatal accidents comprise the smallest fraction of crashes.
- RE is the predominant collision type. The vast majority (83%) of the crashes occurring in the advance warning area (area 1) is RE (rear end). The proportion of SS crashes increase when the traffic moves from the advance warning area to the transition area (area 2) and SS (sideswipe in same direction) crashes become the second largest proportion of crashes in the transition area. As one moves from the transition area (area 2) to the work area (combing areas 3 and 4), the proportions of RE (rear end) and SS (sideswipe in same direction) crashes decrease and the proportion of FO (fixed object off road) and AN (angle) crashes increase.

CONCLUSIONS

The results of the study clearly show that the most dangerous area within a work zone is the Activity (Area 4). Therefore any countermeasure that will significantly reduce the crashes in area 4 will have a significant impact on safety in the work zone.

The predominance of rear end crashes in work zones, strongly indicate that a major causal factor for work zone crashes is speed related. Rear End crashes are mainly caused by vehicles driving at different speeds, resulting in high speed variance. The implementation of a countermeasure that reduces speed variance or that causes drivers to drive at approximately the same speeds throughout the work zones, will therefore increase safety at work zones significantly. It should be noted that this does not necessarily mean lowering speed limit at the work zone, as a lower speed limit does not necessarily result in a lower speed variance.

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TABLES

Road Type	Number of Crashes	Work Zone Location				
		Area 1	Area 2	Area 3	Area 4	Area 5
Urban Interstate	544	7%	17%	6%	69%	1%
Rural Interstate	159	14%	14%	7%	65%	0%
Urban Primary	339	7%	10%	4%	76%	3%
Rural Primary	206	18%	16%	5%	58%	3%
NOVA Urban Secondary	94	10%	5%	8%	72%	5%
NOVA Rural Secondary	2	0%	0%	50%	50%	0%
Other Secondary	140	14%	10%	1%	74%	1%

Area 1 (Advance Warning Area) Area 2 (Transition Area) Area 3 (Longitudinal Buffer Area)

Area 4 (Activity Area) Area 5 (Termination Area)

Table 1 Percentage Distribution of Crashes by Work Zone Location and Road Type

	Crashes in Area 4	Total Crashes	Percentage of Crashes in Area 4	Proportionality Test*
All Crashes	1030	1484	69%	
Interstate	480	703	68%	Accept Ho
Primary	377	545	69%	Accept Ho
secondary	173	236	73%	Accept Ho

H_o: There is no difference in the proportion of crashes in area 4 for each highway type and the proportion of crashes in area 4, for all crashes in the other work zone areas combined.

Table 2 Proportionality Test Results between Crashes in Area 4 for Each Road Type and Crashes in Area 4 for All Crashes Combined (Area 4: Activity Area)

Road Type	Number of Crashes	Work Zone Location														
		Area 1			Area 2			Area 3			Area 4			Area 5		
		Fatal	Injury	PDO	Fatal	Injury	PDO	Fatal	Injury	PDO	Fatal	Injury	PDO	Fatal	Injury	PDO
Urban Interstate	544	0%	3%	5%	0%	6%	11%	0%	2%	4%	1%	26%	42%	0%	0%	0%
Rural Interstate	159	0%	5%	9%	0%	4%	10%	1%	3%	4%	2%	22%	40%	0%	0%	0%
Urban Primary	339	0%	3%	3%	0%	2%	8%	0%	2%	3%	1%	26%	50%	0%	1%	1%
Rural Primary	206	0%	8%	9%	0%	9%	7%	0%	3%	3%	1%	27%	30%	0%	1%	2%
NOVA Urban Secondary	94	0%	2%	8%	0%	1%	4%	0%	3%	4%	1%	28%	44%	0%	0%	5%
NOVA Rural Secondary	2	0%	0%	0%	0%	0%	0%	0%	0%	50%	0%	0%	50%	0%	0%	0%
Other Secondary	140	0%	4%	9%	0%	5%	5%	0%	1%	0%	1%	38%	36%	0%	0%	1%

Area 1 (Advance Warning Area) Area 2 (Transition Area) Area 3 (Longitudinal Buffer Area)

Area 4 (Activity Area) Area 5 (Termination Area)

Table 3 Percentage Distribution of Crashes by Severity, Location and Road Type

Road Type	Number of Crashes	Work Zone Location											
		Area 1						Area 2					
		AN	FI	FO	RE	SS	Other	AN	FI	FO	RE	SS	Other
Urban Interstate	544	1%	0%	0%	6%	0%	0%	1%	1%	1%	8%	6%	0%
Rural Interstate	159	1%	0%	1%	12%	0%	0%	0%	2%	1%	7%	4%	0%
Urban Primary	339	1%	0%	0%	5%	1%	0%	0%	1%	0%	6%	3%	0%
Rural Primary	206	0%	0%	1%	16%	0%	1%	0%	0%	1%	12%	2%	1%
NOVA Urban Secondary	94	0%	0%	1%	9%	0%	0%	0%	1%	0%	3%	0%	1%
NOVA Rural Secondary	2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other Secondary	140	0%	0%	2%	10%	0%	1%	1%	0%	1%	5%	1%	2%
Road Type	Number of Crashes	Area 3						Area 4					
		AN	FI	FO	RE	SS	Other	AN	FI	FO	RE	SS	Other
Urban Interstate	544	0%	1%	1%	3%	1%	1%	3%	3%	12%	40%	8%	3%
Rural Interstate	159	0%	1%	2%	3%	1%	0%	6%	3%	12%	29%	6%	9%
Urban Primary	339	0%	0%	0%	3%	1%	0%	18%	2%	6%	40%	6%	6%
Rural Primary	206	1%	1%	1%	3%	0%	1%	18%	2%	10%	17%	1%	9%
NOVA Urban Secondary	94	1%	0%	0%	4%	1%	1%	19%	6%	8%	19%	9%	12%
NOVA Rural Secondary	2	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	50%
Other Secondary	140	1%	0%	0%	0%	0%	0%	18%	2%	9%	21%	4%	20%
Road Type	Number of Crashes	Area 5											
		AN	FI	FO	RE	SS	Other						
Urban Interstate	544	0%	0%	0%	0%	0%	0%						
Rural Interstate	159	0%	0%	0%	0%	0%	0%						
Urban Primary	339	1%	0%	0%	0%	0%	0%						
Rural Primary	206	2%	0%	0%	0%	0%	0%						
NOVA Urban Secondary	94	4%	0%	1%	0%	0%	0%						
NOVA Rural Secondary	2	0%	0%	0%	0%	0%	0%						
Other Secondary	140	2%	0%	0%	0%	0%	0%						

Area 1 (Advance Warning Area) Area 2 (Transition Area) Area 3 (Longitudinal Buffer Area)

Area 4 (Activity Area) Area 5 (Termination Area)

Table 4 Percentage Distribution of Crashes by Collision Type, Location and Road Type

FIGURES

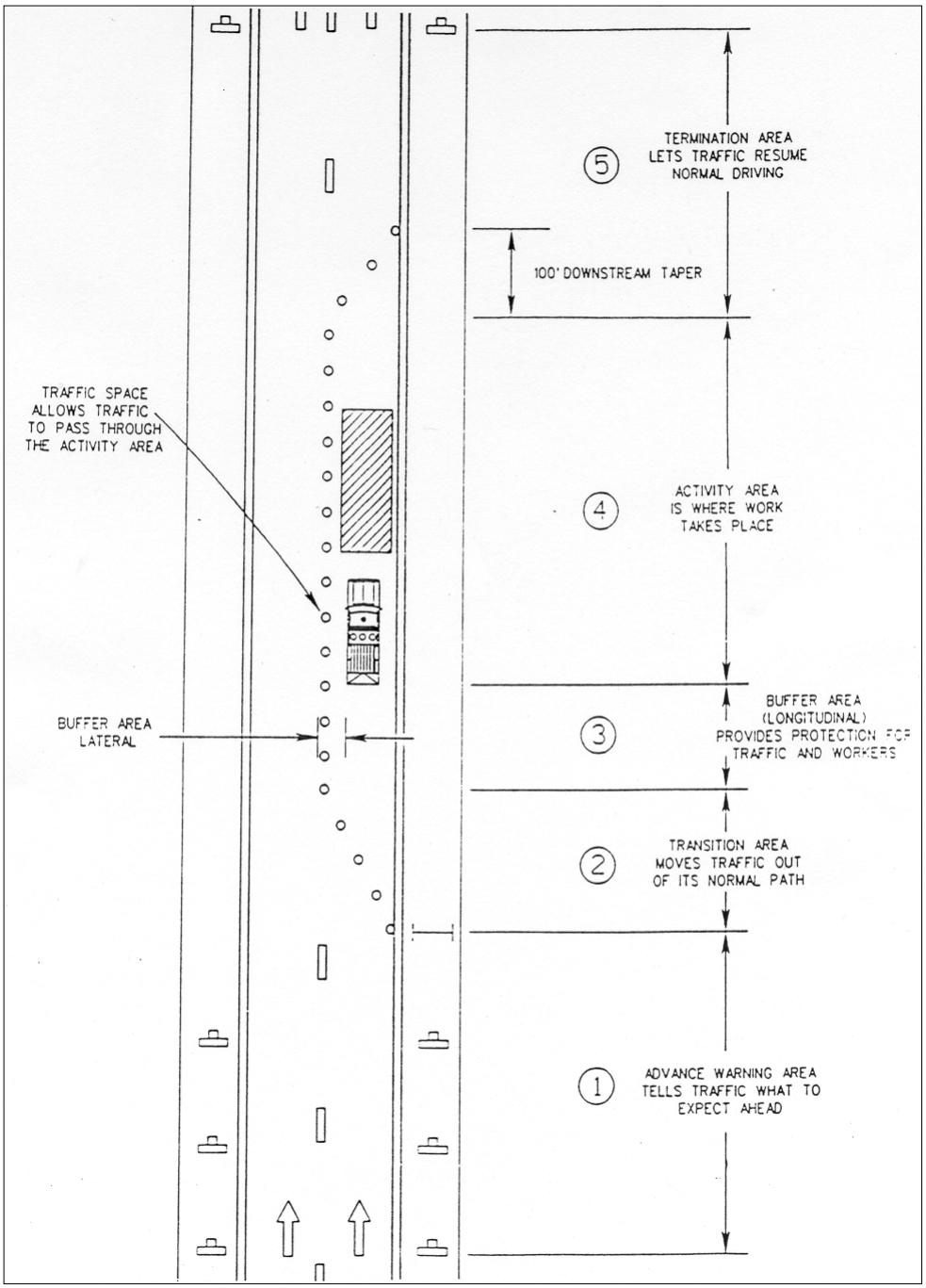
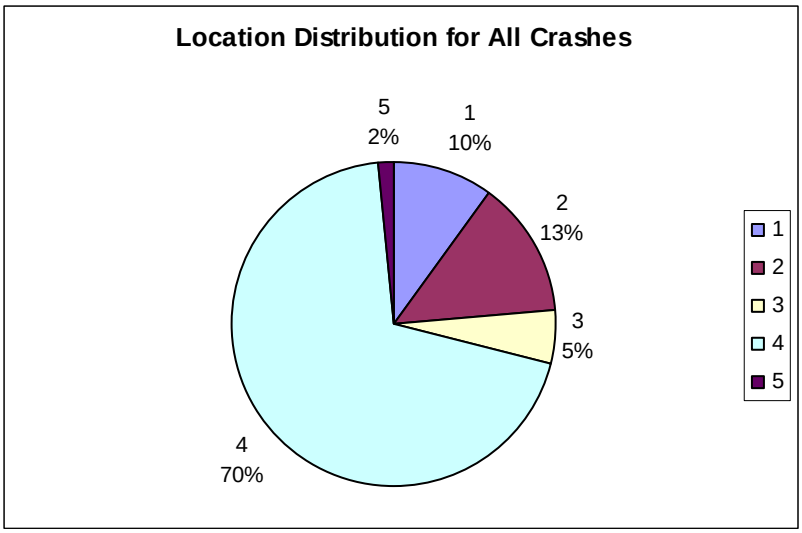


Figure 1 The Five Defined Areas of the Common Work Zone



Area 1 (Advance Warning Area) Area 2 (Transition Area) Area 3 (Longitudinal Buffer Area)

Area 4 (Activity Area) Area 5 (Termination Area)

Figure 2 Location Distribution for All Work Zone Crashes

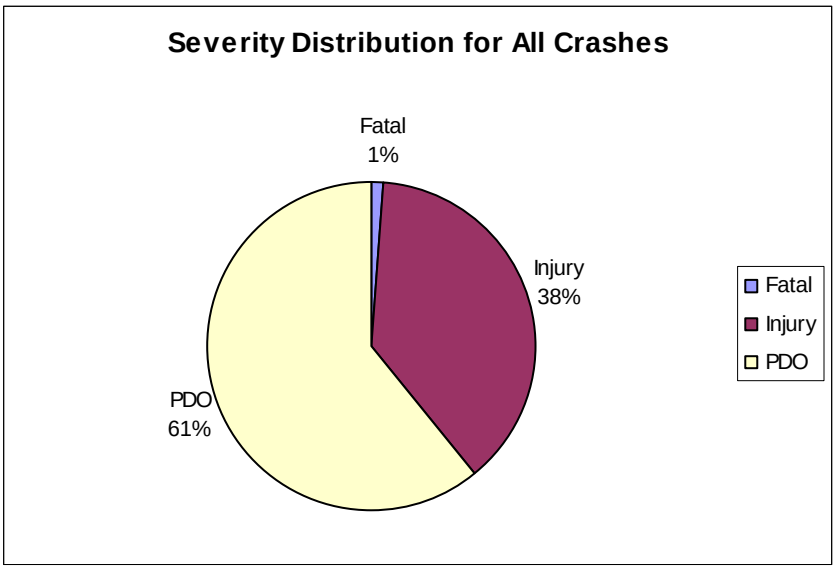
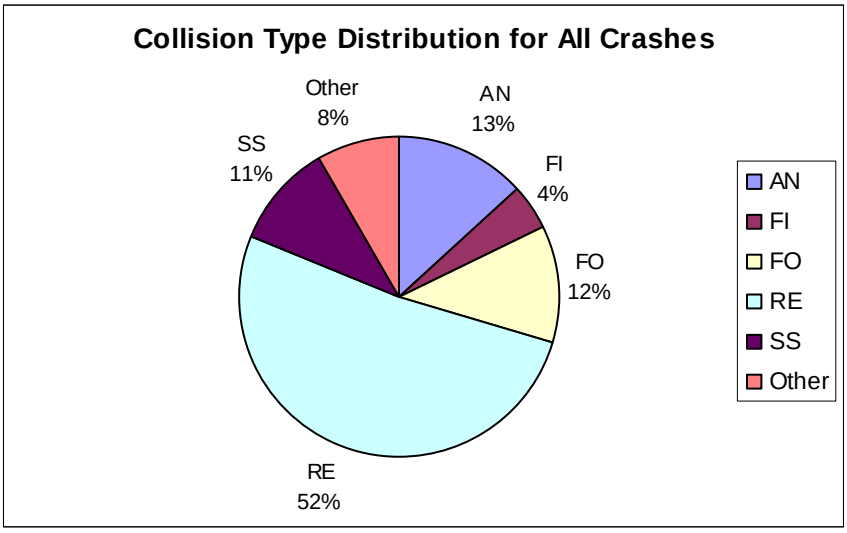


Figure 3 Severity Distribution for All Work Zone Crashes



AN (Angle) FI (Fixed object In road) FO (Fixed object Off road)

RE (Rear End) SS (Sideswipe in Same direction)

Figure 4 Collision Type Distribution for All Work Zone Crashes

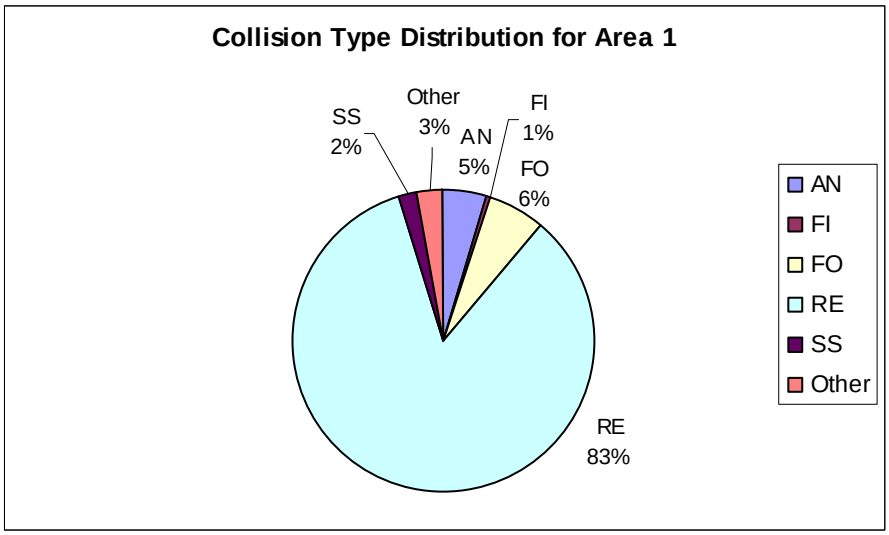
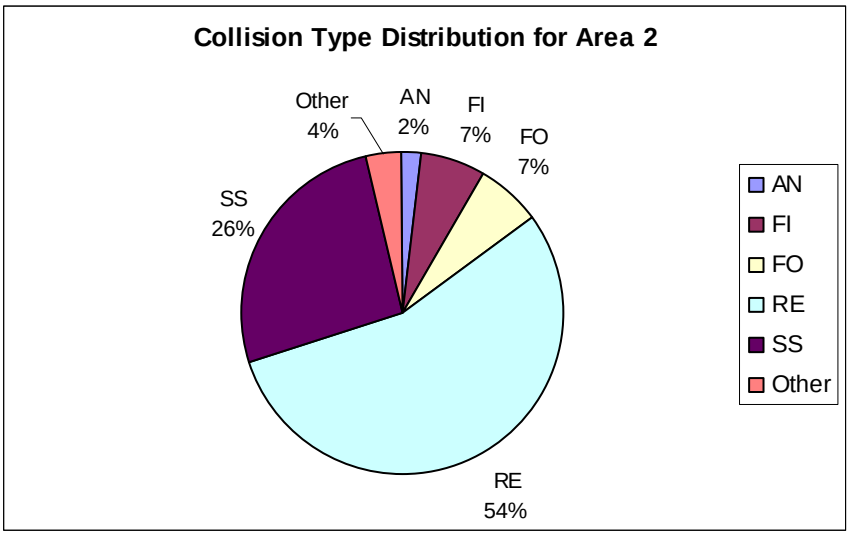


Figure 5 Collision Type Distribution for Work Zone Crashes Occurring in Area 1 (Advance Warning Area)



AN (Ange) FI (Fixed object In road) FO (Fixed object Off road)

RE (Rear End) SS (Sideswipe in Same direction)

Figure 6 Collision Type Distribution for Work Zone Crashes Occurring in Area 2 (Transition Area)

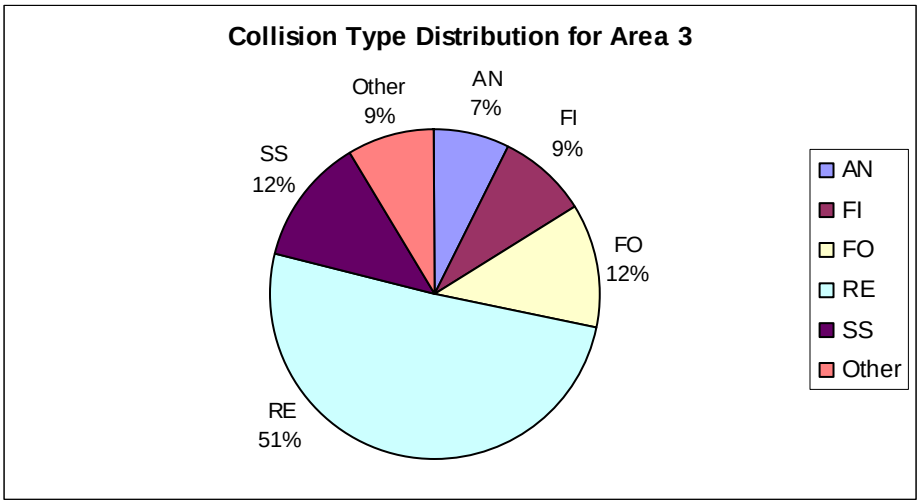
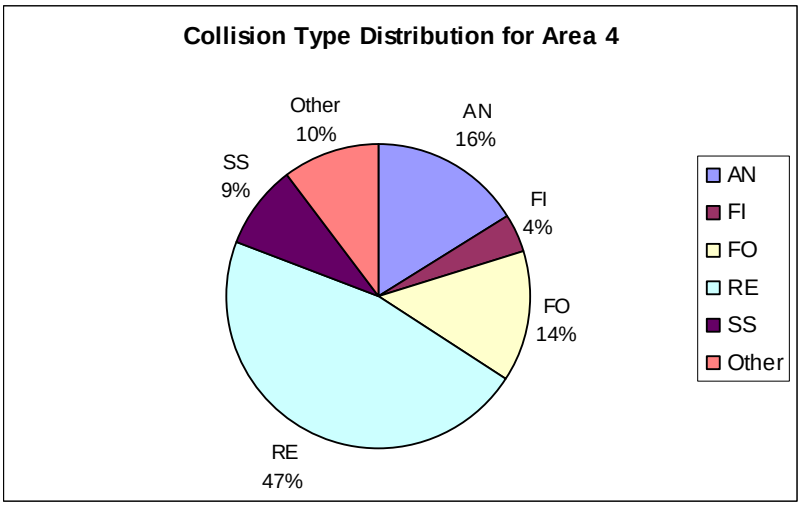


Figure 7 Collision Type Distribution for Work Zone Crashes Occurring in Area 3 (Longitudinal Buffer Area)



AN (Angle) FI (Fixed object In road) FO (Fixed object Off road)

RE (Rear End) SS (Sideswipe in Same direction)

Figure 8 Collision Type Distribution for Work Zone Crashes Occurring in Area 4 (Activity Area)

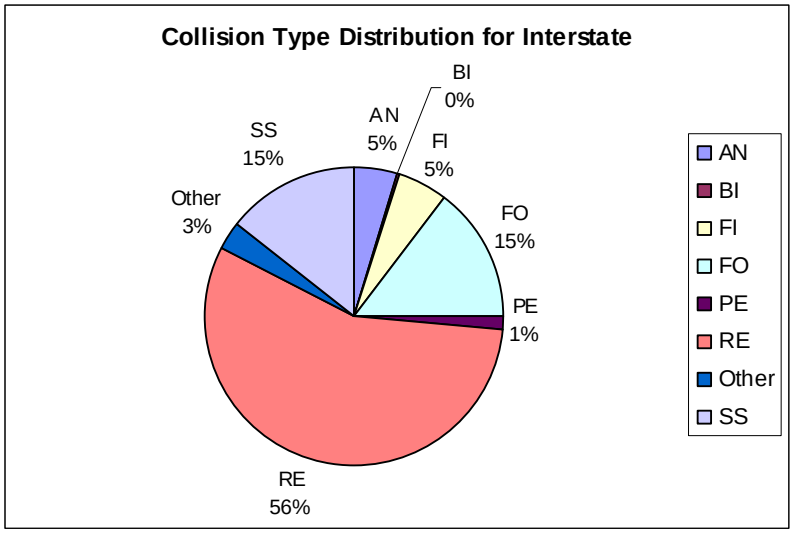
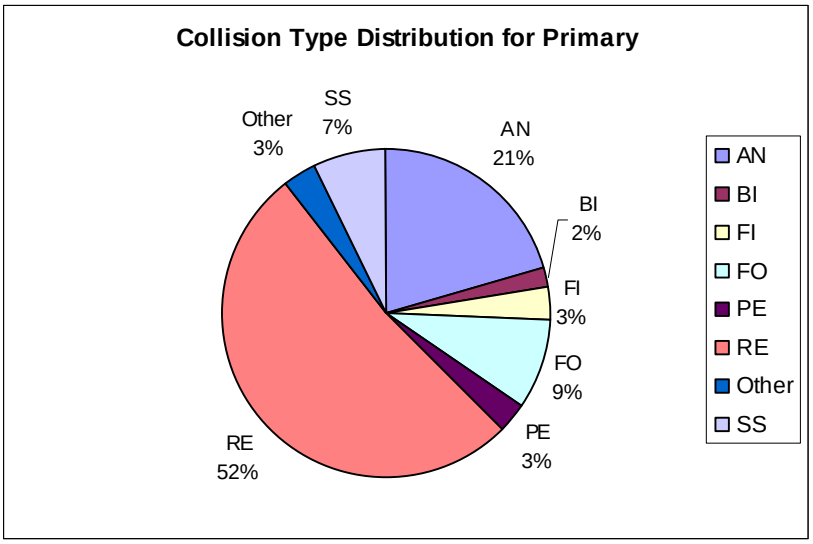


Figure 9 Collision Type Distribution for Work Zone Crashes Occurring on Interstate



AN (Angle) BI (Backed Into) FI (Fixed object In road) FO (Fixed object Off road)

PE (collision with PEdestrian) RE (Rear End) SS (Sideswipe in Same direction)

Figure 10 Collision Type Distribution for Work Zone Crashes Occurring on Primary Roads