ARIZONA DEPARTMENT OF TRANSPORTATION

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EFFECTIVE COUNTERMEASURES TO REDUCE ACCIDENTS IN WORK ZONES

Final Report

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16. Abstract

Nationally, work zone fatalities peaked at over 800 per year during the 1990's. Arizona tallied 82 fatal and 5,009 injury accidents in work zones during a five year period. In response to this problem, the objectives of this project included:

Characterizing the nature of work zone accidents in Arizona
Reviewing countermeasures used throughout the country, and the effectiveness of those countermeasures
Recommending countermeasures for use in Arizona to improve work zone safety and reduce accidents

Work zone accidents account for about 3 percent of all reported accidents in Arizona, or about 3,000 work zone accidents per year. These accidents produce about 18 fatalities and 1,600 injuries per year. Compared to all accidents statewide: work zone accidents tend to be less severe; larger vehicles tend to be over-represented in work zone accidents; a greater proportion of work zone accidents occur in rural areas; and work zone accidents are over-represented on the State Highway System.

A detailed analysis of fatal accident reports did not clearly identify any common or widespread factors that contribute to fatal accidents occurring in work zones.

A national review of work zone countermeasures was conducted, focussing on the documented effectiveness of various work zone countermeasures. To identify which countermeasures are most appropriate for use in Arizona, a panel of 21 experts was convened. The panel included representatives with a variety of perspectives on the work zone accident problem. ADOT personnel dealing with construction operations, maintenance, traffic operations, safety, and research were represented. Department of Public Safety officers, construction industry representatives, a traffic control contractor, an FHWA representative, and university researchers also attended.

The panel selected six principal countermeasures for implementation in Arizona: 1) Work Zone Speed Limits; 2) Police Presence; 3) Speed Limit Enforcement; 4) Public Education; 5) Sign Credibility; and 6) Temporary Pavement Markings in Work Zones

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	6.452	centimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3.

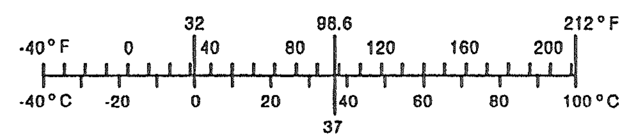
Symbol	When You Know	Multiply By	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
yd^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	millimeters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

PROBLEM STATEMENT

Work zone fatalities reached an all time high in 1994 nationwide when 833 people were killed in work zone related accidents. This represented a 29 percent increase over the 1992 level, which was the lowest recorded number of fatalities in ten years.

Work zones include sections of roadway where roadway construction, roadway maintenance, and utility work is taking place. It has been clearly demonstrated that work zones are more hazardous than the typical roadway environment. Considering exposure (such as vehicle-miles traveled), accidents are higher in work zones than on roadways in general. For that reason, work zone safety continues to be a high priority for traffic engineering professionals and highway agencies.

Work zone fatalities and injuries include not only the occupants of vehicles but also pedestrians. In many instances these "pedestrians" are workers in the work zone, either construction workers or public agency employees who are maintaining the roadway.

The following statistics summarize the extent of the problem in Arizona. This summary is for reported accidents in the 1995 calendar year.

TABLE 1: 1995 WORK ZONE ACCIDENTS IN ARIZONA

Type of Unusual Road Condition	Number of Crashes				No. of Victims	
	Total	Fatal	Injury	PDO*	Killed	Injured
Under Construction Thru Traffic Allowed	3,049	19	940	2,090	19	1,483
Under Construction Traffic Detoured	62	0	20	42	0	32
Under Repairs	129	0	51	78	0	66
Temporary Lane Closure	385	1	124	260	2	219

* PDO = Property Damage Only

It is estimated that the statewide economic loss due to the above accidents is $70 million.

Solving work zone problems and improving work zone safety have even been emphasized in recent legislation. The Intermodal Surface Transportation Efficiency Act (ISTEA) specifically required the Secretary of Transportation to develop and implement a work zone safety program to improve safety at construction zones and to develop a uniform accident reporting system.

Currently there is significant on-going research that is studying procedures for determining work zone speed limits, establishing their effectiveness and implementability and improving traffic control device design and placement. These studies will provide additional needed knowledge to procedures for ensuring safer and more convenient work zone experiences.

Due to its importance and the amount of previous and on-going research efforts, there is a need to prepare a state-of-the-practice report to synthesize current knowledge and to formulate recommendations for reducing accidents in work zones.

OBJECTIVES OF THE PROJECT

The objectives of this project are:

Characterize the nature of work zone accidents in Arizona.

Prepare a state-of-the-practice report on effective countermeasures to reduce accidents in work zones.

Recommend countermeasures which should be implemented in Arizona to improve work zone safety and to reduce accidents.

Prepare procedures and guidelines for implementing these countermeasures.

CHAPTER 2

ANALYSIS OF WORK ZONE ACCIDENTS

The first objective of this project is to characterize the nature of work zone accidents in Arizona. To accomplish this objective, Arizona work zone accidents for calendar years 1992 through 1996 were reviewed and analyzed. The ALISS accident records system served as the source of information for this study. Through ALISS, information on ***reported*** accidents occurring in all jurisdictions and on all roadway networks (state, county, city) were obtained and evaluated.

In this chapter, "work zone accidents" refers to those accidents occurring in a work zone. "Statewide accidents" refers to all reported accidents throughout the state of Arizona

Accidents occurring in work zones were identified by the "unusual condition" category in the accident records database. Accident records with the following coding comprised the set of accidents that were evaluated.

1 - Under construction - through traffic allowed
2 - Under construction - traffic detoured
3 - Under repairs
11 - Temporary lane closure

ALISS includes 521,345 reported accidents for calendar years 1992 through 1996. Of these, 14,905 accidents are coded as occurring in a work zone (codes 1, 2, 3 and 11 above).

This set of 14,905 work zone accidents was sorted and summarized in a variety of ways to identify trends, patterns, circumstances and other ways of characterizing the work zone accident problem. Sorts and summaries included the following.

By year
Number of accidents
By severity
Number of fatal accidents
Number of injury accidents
Number of property damage only accidents
Number of fatalities
Number of injuries
The type of unusual condition (1, 2, 3, 11, above)
Whether injured and fatal individuals were vehicle
occupants or pedestrians (possibly work zone
workers)
Light condition
Weather condition
Road surface condition
Driver physical condition
Vehicle type
Collision type
Urban vs. Rural location
Roadway System (Interstate, State Highway System)

The work zone accident data were also compared to statewide accident data.

COMPARISON OF ARIZONA'S 5-YEAR ACCIDENTS IN WORK ZONES Vs. TOTAL STATEWIDE ACCIDENTS

Table 2 summarizes work zone accidents and statewide accidents by year. Work zone accidents have accounted for 2.86 percent of statewide accidents during the five-year period. Work zone accidents had their highest percentage of the total statewide accidents in 1995 and the lowest percentage in 1996.

TABLE 2: WORK ZONE ACCIDENTS AND STATEWIDE ACCIDENTS: 1992-1996

	WORK ZONES	**STATE-WIDE**	Work Zone Accidents as a % of Statewide Accidents
1992	2595	89862	2.89
1993	2844	97903	2.90
1994	2954	106728	2.77
1995	3627	113888	3.18
1996	2885	112964	2.55
5-year TOTAL	14905	521345	2.86

Tables 3 and 4 show a comparison of the injury severity between work zone and statewide accidents. Property damage only (PDO) accidents include both those with only property damage and those with unknown injury conditions.

TABLE 3: INJURY SEVERITY COMPARISON: NUMBER OF ACCIDENTS

YEAR	WORK ZONE			STATEWIDE		
	PDO	INJURY	FATAL	PDO	INJURY	FATAL
1992	1691	894	10	53137	36024	701
1993	1833	995	16	58765	38434	704
1994	1931	1001	22	64123	41809	796
1995	2470	1137	20	69248	43721	919
1996	1889	982	14	68792	43314	858
5-year TOTAL	9814	5009	82	314065	203302	3978

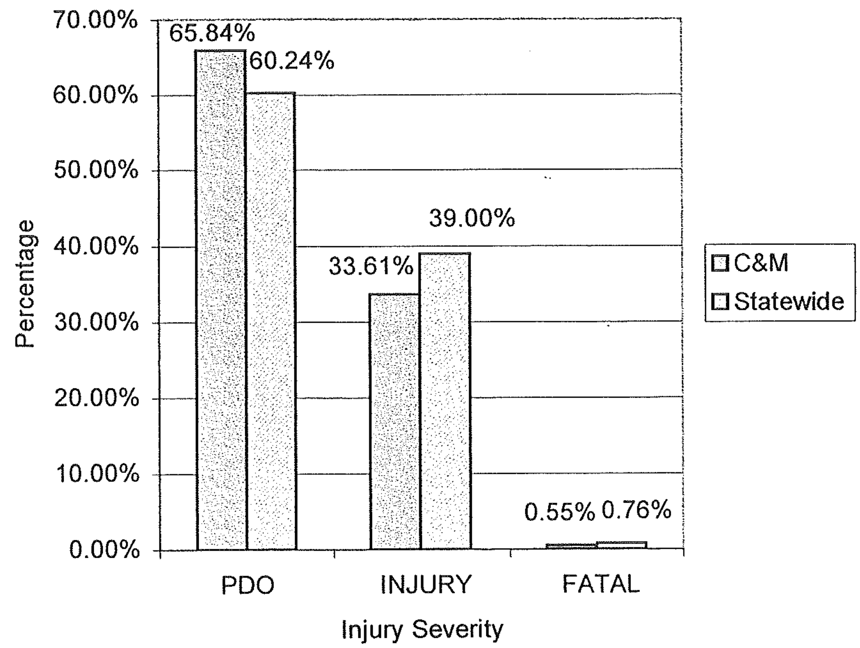
TABLE 4: INJURY SEVERITY COMPARISON: PERCENT OF ACCIDENTS

YEAR	WORK ZONE			STATEWIDE		
	PDO	INJURY	FATAL	PDO	INJURY	FATAL
1992	65.16%	34.45%	0.39%	59.13%	40.09%	0.78%
1993	64.45%	34.99%	0.56%	60.02%	39.26%	0.72%
1994	65.37%	33.89%	0.74%	60.08%	39.17%	0.75%
1995	68.10%	31.35%	0.55%	60.80%	38.39%	0.81%
1996	65.48%	34.04%	0.49%	60.90%	38.34%	0.76%
5-year TOTAL	65.84%	33.61%	0.55%	60.24%	39.00%	0.76%

As indicated by the lower portion of Table 4 and as highlighted in Figure 1, accidents in work zones tended to be less severe than statewide accidents. In each year, the proportion of statewide accidents that included a fatality was larger than the proportion of work zone accidents that included a fatality. For the 5-year period as a whole, 0.76 percent of the statewide accidents had a fatality while only 0.55 percent of the work zone accidents had a fatality. Similarly, in each year the proportion of statewide accidents that included an injury was larger than the proportion of work zone accidents that included an injury. This phenomenon could be the result of lower speeds in work zones.

FIGURE 1: INJURY SEVERITY COMPARISON

As highlighted by the chart to the right, total incidents in C&M zones tended to be less severe than those statewide (0.55% vs 0.76% fatalities and 65.84% vs 60.24% PDO).



The evidence that work zone accidents are less severe is further supported by Table 5 on the following page which breaks down each year by injury severity category. The key for Injury Severity Type is presented following the table. The table is also subdivided by Road Condition.

TABLE 5: NUMBER OF ACCIDENTS BY YEAR, ROAD CONDITION, AND INJURY SEVERITY TYPE

YEAR	ROAD CONDITION	INJURY SEVERITY TYPE						ROAD COND TOTAL
		1	6	2	3	4	5	
1992	1	1367	27	392	234	123	9	2152
	2	20	2	3	6	2	0	33
	3	67	2	15	11	4	1	100
	11	200	6	57	32	15	0	310
TOTAL 1992 WORK ZONE BY SEVERITY		1654	37	467	283	144	10	2595
% OF 1992 WORK ZONE ACCIDENTS		65.16%		34.45%			0.39%	100.00%
% OF 1992 TOTAL ACCIDENTS		59.13%		40.09%			0.78%	100.00%
1993	1	1434	29	440	217	154	12	2286
	2	36	5	10	1	0	2	54
	3	88	0	21	10	4	1	124
	11	236	5	76	50	12	1	380
TOTAL 1993 WORK ZONE BY SEVERITY		1794	39	547	278	170	16	2844
% OF 1993 WORK ZONE ACCIDENTS		64.45%		34.99%			0.56%	100.00%
% OF 1993 TOTAL ACCIDENTS		60.02%		39.26%			0.72%	100.00%
1994	1	1575	28	456	246	117	21	2443
	2	36	1	12	2	6	0	57
	3	75	2	20	12	3	1	113
	11	214	0	77	37	13	0	341
TOTAL 1994 WORK ZONE BY SEVERITY		1900	31	565	297	139	22	2954
% OF 1994 WORK ZONE ACCIDENTS		65.37%		33.89%			0.74%	100.00%
% OF 1994 TOTAL ACCIDENTS		60.08%		39.17%			0.75%	100.00%
1995	1	2052	38	550	293	97	19	3049
	2	38	4	6	11	3	0	62
	3	77	1	27	18	8	0	131
	11	258	2	63	45	16	1	385
TOTAL 1995 WORK ZONE BY SEVERITY		2425	45	646	367	124	20	3627
% OF 1995 WORK ZONE ACCIDENTS		68.10%		31.35%			0.55%	100.00%
% OF 1995 TOTAL ACCIDENTS		60.80%		38.39%			0.81%	100.00%

	ROAD	INJURY SEVERITY TYPE						ROAD COND
YEAR	CONDITION	1	6	2	3	4	5	TOTAL
1996	1	1534	33	445	240	104	9	2365
	2	25	2	8	6	4	1	46
	3	51	3	30	9	3	1	97
	11	237	4	79	44	10	3	377
TOTAL 1996 WORK ZONE BY SEVERITY		1847	42	562	299	121	14	2885
% OF 1996 WORK ZONE ACCIDENTS		65.48%		34.04%			0.49%	100.00%
% OF 1996 TOTAL ACCIDENTS		60.90%		38.34%			0.76%	100.00%

ROAD CONDITION CODES:

1 = Under Construction, Traffic Allowed
2 = Under Construction, Traffic Not Allowed
3 = Under Repairs
11 = Temporary Lane Closure

SEVERITY TYPE CODES:

1 = No Injury
2 = Possible Injury
3 = Non-Incapacitating Injury
4 = Incapacitating Injury
5 = Fatal
6 = Unknown

Note:

- Type 1 plus Type 6 corresponds to the PDO category in Tables 3 and 4.
- Type 2 plus Type 3 plus Type 4 corresponds to the injury category in Tables 3 and 4
- Type 5 corresponds to the fatal category in Tables 3 and 4.
- Additional information on the number of persons injured or killed is presented in Table 6.

Additional information on the number of persons injured or killed is presented in Table 6. (All preceding tables have been comparisons of number of accidents.)

TABLE 6: NUMBER OF PERSONS INJURED OR KILLED

	WORK ZONES		STATEWIDE	
YEAR	INJURED	KILLED	INJURED	KILLED
1992	1387	10	58496	809
1993	1580	18	63037	801
1994	1590	26	68872	906
1995	1802	21	71994	1037
1996	1629	14	71807	995
Five Year TOTAL	7988	89	334206	4548

Table 7 presents an injury severity comparison of the total number of people injured and killed, the percent who were injured, and the percent who were killed.

TABLE 7: INJURY SEVERITY COMPARISON

	WORK ZONES		STATEWIDE	
YEAR	INJURED	KILLED	INJURED	FATAL
1992	99.28%	0.72%	98.64%	1.36%
1993	98.87%	1.13%	98.75%	1.25%
1994	98.39%	1.61%	98.70%	1.30%
1995	98.85%	1.15%	98.58%	1.42%
1996	99.15%	0.85%	98.63%	1.37%
Five Year TOTAL	98.90%	1.10%	98.66%	1.34%

Overall, if involved in an accident producing injuries or fatalities, the chances of being a fatality are slightly smaller if the accident occurred in a work zone. For example, 1.34 percent of the victims in statewide accidents (1992 through 1996) were killed while 1.10 percent of the victims in work zone accidents were killed. This phenomenon occurred in each year except 1994. The phenomenon could be the result of lower speeds in work zones.

The numbers of injuries and fatalities were further compared by road condition. Work zone accidents were identified from the accident data provided by four road condition codes: (1) under construction, traffic allowed; (2) under construction, traffic not allowed; (3) under repairs; and (11) temporary lane closure. As shown in Tables 8 and 9, the proportion between number of persons injured and number of fatalities is nearly identical for accidents occurring in work zones and those occurring statewide.

TABLE 8: NUMBER OF INJURIES/FATALITIES BY ROAD CONDITION

ROAD CONDITION	INJURY	FATAL	TOTAL
1	6526	75	6601
2	114	4	118
3	293	4	297
11	1055	6	1061
5-YR WORK ZONE TOTAL	7988	89	8077
5-YR STATEWIDE TOTAL	334206	4548	338754

TABLE 9: PERCENT OF INJURIES/FATALITIES BY ROAD CONDITION

ROAD CONDITION	INJURY	FATAL	TOTAL
1	98.86%	1.14%	100.00%
2	96.61%	3.39%	100.00%
3	98.65%	1.35%	100.00%
11	99.43%	0.57%	100.00%
5-YR WORK ZONE TOTAL	98.90%	1.10%	100.00%
5-YR STATEWIDE TOTAL	98.66%	1.34%	100.00%

ROAD CONDITION CODES:
1 = Under Construction, Traffic Allowed
2 = Under Construction, Traffic Not Allowed
3 = Under Repairs
11 = Temporary Lane Closure

There were 14,905 accidents that occurred in work zones in 1992 – 1996. A total of 44,224 individuals were involved in these accidents. The 14,905 accidents had a total of 89 fatalities and 7988 injuries. Others who were involved in these accidents were not injured. These included 22,666 drivers, 12,190 passengers, 6 pedestrians, and 12 pedalcyclists. In addition, 1,273 individuals were involved but their injury severity is unknown. Data on injury severity by person type for work zone accidents is presented in Tables 10-12. Comparable data for statewide accidents during the five year period is not available. However, the data for the work zones is presented for consideration.

TABLE 10: NUMBER OF INJURIES BY PERSON TYPE AND INJURY SEVERITY TYPE

PERSON TYPE	INJURY SEVERITY TYPE						PERS TYPE TOTAL
	1	2	3	4	5	6	
1 - Driver	22666	3018	1408	606	57	1112	28867
2 - Pedestrian	6	35	50	34	13	0	138
3 - Pedalcyclist	12	25	36	18	1	0	92
4 - Passenger	12190	1655	806	297	18	161	15127
5-YR TOTAL BY SEVERITY TYPE	34874	4733	2300	955	89	1273	44224
	34874	7988			89	1273	

TABLE 11: PERCENT OF INJURIES BY INJURY SEVERITY TYPE

PERSON TYPE	INJURY SEVERITY TYPE						SEVERITY TYPE TOTAL
	1	2	3	4	5	6	
1 - Driver	78.52%	10.45%	4.88%	2.10%	0.20%	3.85%	100.00%
2 - Pedestrian	4.35%	25.36%	36.23%	24.64%	9.42%	0.00%	100.00%
3 - Pedalcyclist	13.04%	27.17%	39.13%	19.57%	1.09%	0.00%	100.00%
4 - Passenger	80.58%	10.94%	5.33%	1.96%	0.12%	1.06%	100.00%
% BY SEVERITY TYPE	78.86%	10.70%	5.20%	2.16%	0.20%	2.88%	100.00%

TABLE 12: PERCENT OF INJURIES BY PERSON TYPE

PERSON TYPE	INJURY SEVERITY TYPE						% BY PERS TYPE
	1	2	3	4	5	6	
1 - Driver	64.99%	63.77%	61.22%	63.46%	64.04%	87.35%	65.27%
2 - Pedestrian	0.02%	0.74%	2.17%	3.56%	14.61%	0.00%	0.31%
3 - Pedalcyclist	0.03%	0.53%	1.57%	1.88%	1.12%	0.00%	0.21%
4 - Passenger	34.95%	34.97%	35.04%	31.10%	20.22%	12.65%	34.21%
SEVERITY TYPE TOTAL	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

INJURY SEVERITY TYPE CODES:
1 = No Injury
2 = Possible Injury
3 = Non-Incapacitating Injury
4 = Incapacitating Injury
5 = Fatal
6 = Unknown

Data was available to allow comparison between pedestrians injured or killed in work zone accidents and accidents statewide. Of all people killed in work zone accidents, 14.61 percent were pedestrians. In comparison, of all people killed in statewide accidents, 15.96 percent were pedestrians. Similar information is presented for injuries. This data is shown in Table 13.

TABLE 13: PERCENT OF INJURIES AND FATALITIES INVOLVING PEDESTRIANS

	INJURED	KILLED
5-YR WORK ZONE ACCIDENTS	1.49%	14.61%
5-YR TOTAL ACCIDENTS	2.31%	15.96%

The Table 13 data shows that the proportion of injuries and fatalities in work zones involving pedestrians is slightly lower than the proportion of injuries and fatalities involving pedestrians in accidents statewide. The data indicate that work zones are not more hazardous to pedestrians than other roadways. The available data did not indicate how many of the pedestrians injured were workers in the work zone. Review of fatal accident reports (described later) identified two workers who were killed in accidents. Both of these fatalities involved construction vehicles.

Further comparisons were done between various conditions in work zone accidents and accidents statewide. The results are shown in Tables 14 and 15.

TABLE 14: NUMBER OF ACCIDENTS BY ROAD CONDITION AND LIGHT

ROAD CONDITION	LIGHT TYPE				ROAD COND TOTAL
	0	1	2	3	
1	0	9055	443	2797	12295
2	0	135	14	103	252
3	0	450	10	105	565
11	0	1379	42	372	1793
5-YR WORK ZONE LIGHT TOTAL	0	11019	509	3377	14905
5-YR STATE-WIDE TOTAL	1017	373222	23076	124030	521345

TABLE 15: PERCENT OF ACCIDENTS BY ROAD CONDITION AND LIGHT

ROAD CONDITION	LIGHT TYPE				ROAD COND TOTAL
	0	1	2	3	
1	0.00 %	73.65%	3.60%	22.75%	100.00%
2	0.00 %	53.57%	5.56%	40.87%	100.00%
3	0.00 %	79.65%	1.77%	18.58%	100.00%
11	0.00	76.91%	2.34%	20.75%	100.00%
5-YR WORK ZONE LIGHT TOTAL	0.00 %	73.93%	3.41%	22.66%	100.00%
5-YR STATEWIDE TOTAL	0.20 %	71.59%	4.43%	23.79%	100.00%

ROAD CONDITION CODES:
1 = Under Construction, Traffic Allowed
2 = Under Construction, Traffic Not Allowed
3 = Under Repairs
11 = Temporary Lane Closure

LIGHT TYPE CODES:
0 = Not Reported
1 = Daylight
2 = Dawn or Dusk
3 = Darkness

It could be hypothesized that nighttime accidents in work zones would occur more frequently than on normal roadways. This could occur if signing, marking and delineation treatments for the temporary conditions did not adequately guide the motorist in darkness. The accident data do not support this hypothesis. The comparison of lighting conditions shows that the proportion of work zone accidents occurring during darkness is slightly lower than for statewide accidents.

The proportion of work zone accidents occurring during daylight is slightly higher than for statewide accidents. These results could be due to the majority of work zone activities occurring during daylight conditions. However, it could also be an indication that work zones are adequately marked and lighted for non-daylight conditions.

It could be hypothesized that accidents during inclement weather in work zones would occur more frequently than on normal roadways. Comparison of weather conditions shows that the proportion of work zone accidents occurring during raining and snowing conditions is much smaller than that occurring statewide (see Tables 16 and 17). This effect could be due to less work zone activities occurring during these weather conditions. Also, a slightly higher proportion of work zone accidents occurs during strong wind as compared to statewide accidents. This could be the result of traffic control devices having been blown down or motorists distracted by the windy conditions and not being fully aware of the conditions in the work zone.

TABLE 16: NUMBER OF ACCIDENTS BY ROAD CONDITION AND WEATHER CONDITION

ROAD CONDITION	WEATHER CONDITION								ROAD COND TOTAL
	0	1	2	3	4	5	6	7	
1	31	10530	404	1255	6	58	6	5	12295
2	1	212	9	29	0	1	0	0	252
3	1	471	14	73	0	4	2	0	565
11	2	1488	82	205	6	9	0	1	1793
5-YR WORK ZONE WEATHER TOTAL	35	12701	509	1562	12	72	8	6	14905
5-YR STATE-WIDE WEATHER TOTAL	2286	432153	27169	53375	3819	2030	193	320	521345

TABLE 17: PERCENT OF ACCIDENTS BY ROAD CONDITION AND WEATHER CONDITION

ROAD CONDITION	WEATHER CONDITION								ROAD COND TOTAL
	0	1	2	3	4	5	6	7	
1	0.25%	85.64%	3.29%	10.21%	0.05%	0.47%	0.05%	0.04%	100.00%
2	0.40%	84.13%	3.57%	11.51%	0.00%	0.40%	0.00%	0.00%	100.00%
3	0.18%	83.36%	2.48%	12.92%	0.00%	0.71%	0.35%	0.00%	100.00%
11	0.11%	82.99%	4.57%	11.43%	0.33%	0.50%	0.00%	0.06%	100.00%
5-YR WORK ZONE WEATHER TOTAL	0.23%	85.21%	3.41%	10.48%	0.08%	0.48%	0.05%	0.04%	100.00%
5-YR STATEWIDE WEATHER TOTAL	0.44%	82.89%	5.21%	10.24%	0.73%	0.39%	0.04%	0.06%	100.00%

ROAD CONDITION CODES:
1 = Under Construction, Traffic Allowed
2 = Under Construction, Traffic Not Allowed
3 = Under Repairs
11 = Temporary Lane Closure

WEATHER CONDITION CODES:
0 = Not Reported
1 = Clear
2 = Raining
3 =Cloudy
4 = Snowing
5=Strong Wind
6=Dust
7=Fog

Table 18 compares road surface conditions and breaks down the data by accident severity. The accidents in work zones tend to be less severe than accidents statewide as previously shown. The last column in the table reveals that the "other" surface condition is much more common in work zone accidents. The "other" surface condition includes loose sand, dirt, or gravel surfaces such as are commonly found in work-zones, so it is not surprising that this surface condition is reported more commonly for work-zone accidents. Even when the "other" surface condition is ignored, it is still less likely that work zone accidents would occur during "wet" or "snowy/icy" conditions. This effect is probably because construction and maintenance activities are less likely during wet, snowy, and icy weather.

TABLE 18: COMPARISON OF ROAD SURFACE CONDITIONS FOR WORK ZONE ACCIDENTS vs. TOTAL STATEWIDE ACCIDENTS

	SURFACE	PDO		INJURY		FATAL		TOTAL	
		#	%	#	%	#	%	#	%
5-YR WORK ZONE	Dry	8119	54.47%	4214	28.27%	74	0.50%	12407	83.24%
	Wet	503	3.37%	251	1.68%	2	0.01%	756	5.07%
	Snowy/Icy	35	0.23%	7	0.05%	0	0.00%	42	0.28%
	Other	1157	7.76%	537	3.60%	6	0.04%	1700	11.41%
	TOTAL	9814	65.84%	5009	33.61%	82	0.55%	14905	100.00%
5-YR STATE-WIDE	Dry	280522	53.80%	184698	35.42%	3638	0.70%	468858	89.92%
	Wet	22321	4.28%	13598	2.61%	182	0.03%	36101	6.92%
	Snowy/Icy	4827	0.93%	1541	0.30%	39	0.01%	6407	1.23%
	Other	6485	1.24%	3465	0.66%	118	0.02%	10068	1.93%
	TOTAL	314155	60.25%	203302	38.99%	3977	0.76%	521434	100.00%

As shown in Table 19, drivers involved in work zone accidents generally have fewer detrimental physical conditions than accidents statewide with the exception of categories #4-ill-ability influenced and category #6 - other bodily defects/infirmities. The category of DUI is not more prevalent in work zone accidents than total statewide accidents.

TABLE 19: COMPARISON OF DRIVER PHYSICAL CONDITION: WORK ZONE ACCIDENTS vs STATEWIDE ACCIDENTS

PHYSICAL CONDITION	5-YR WORK ZONE		5-YR STATEWIDE	
	# DRIVERS	%	# DRIVERS	%
0-not reported	2017	6.93%	74067	7.59%
1-no apparent defects	25722	88.40%	848360	86.97%
2-had been drinking	1036	3.56%	39277	4.03%
3-appeared under influence of drugs	0	0.00%	1416	0.15%
4-ill-ability influenced	59	0.20%	1461	0.15%
5-sleepy/fatigued	31	0.11%	8339	0.85%
6-other bodily defects/infirmities	206	0.71%	2580	0.26%
7-unknown	27	0.09%		0.00%
TOTAL	29098	100.00%	975500	100.00%

The vehicle-type proportions between accidents occurring in work zones and those occurring statewide are similar for most vehicle types. Generally, larger vehicles tend to be over-represented in work zone accidents (see Table 20). For some vehicle categories the number of vehicles is small or the difference is not statistically significant. The vehicle types that are most obviously over-represented are: "truck tractor and semi-trailer" and "other truck combination." Other over-represented vehicle types are: "pickup truck," "pickup truck with camper," "motor home," and "emergency vehicle."

It is possible that some of the trucks involved in accidents are construction vehicles. However, this could be determined only by reviewing individual accident report forms. The over-representation of larger vehicles suggests that these vehicles may have more difficulty coping with the unusual conditions existing in work zones. It may also suggest that targeting enforcement of these vehicles would be effective.

TABLE 20: MOTOR VEHICLE ACCIDENT INVOLVEMENT BY VEHICLE TYPE

MOTOR VEHICLE TYPE	5-YR WORK ZONE		5-YR STATEWIDE	
	#	%	#	%
0-not reported	327	1.13%	14178	1.45%
1/2/3-passenger car	17849	61.83%	640537	65.69%
passenger car & trailer	0	0.00%	1270	0.13%
4-pickup truck (inc. panel & mini bus)	7772	26.92%	252706	25.92%
5-pickup with camper	176	0.61%	4561	0.47%
6-other vehicle with camper	2	0.01%	53	0.01%
7-truck tractor & semi-trailer	866	3.00%	13436	1.38%
8-truck tractor only	22	0.08%	541	0.06%
9-farm tractor or other farm vehicle	16	0.06%	178	0.02%
10-taxicab	18	0.06%	658	0.07%
11/12-bus	81	0.28%	2643	0.27%
13/14-school bus	39	0.14%	1271	0.13%
15-motorcycle (2 or 3-wheel)	339	1.17%	10826	1.11%
16-motorscooter or motor bicycle	0	0.00%	49	0.01%
17-RV (all-wheel drive, dune buggy, jalopy, custom)	440	1.52%	15356	1.57%
18-motor home or house car	108	0.37%	1838	0.19%
19-military	0	0.00%	13	0.00%
20-special controls	8	0.03%	93	0.01%
21-emergency vehicle	43	0.15%	649	0.07%
22-other truck combination	708	2.45%	13239	1.36%
23-other vehicle	53	0.18%	957	0.10%
24-moped	1	0.00%	39	0.00%
TOTAL	28868	100.00%	975091	100.00%

Tables 21 and 22 compare accidents by road condition and collision type. A higher proportion of accidents in work zones involve sideswipe (same direction) and rear-end collisions than accidents statewide. Work zones often route traffic on temporary alignments involving more severe curvature and less delineation. These factors may account for more sideswipe accidents. Rear-end collisions are often the result of congested or stop-and-go traffic. These conditions often occur in work zones due to reduction in capacity. A lower proportion of angle and left turn collisions occur in work zones than accidents statewide. Single-vehicle accidents are slightly lower in work zones than accidents statewide.

Collision Type 7 – Backing – occurred in 245 accidents. It would be interesting to know how many of these collisions involved public vehicles and how many involved construction vehicles. This information could be obtained only by reviewing individual accident report forms.

TABLE 21: NUMBER OF ACCIDENTS BY ROAD CONDITION AND COLLISION TYPE

	COLLISION TYPE													ROAD COND TOTAL
ROAD CONDITION	0	1	2	3	4	5	6	7	8	A	B	C	D	
1	2489	1646	119	1350	850	5036	71	176	404	0	1	16	137	12295
2	147	16	2	16	8	33	1	17	7	0	0	1	4	252
3	167	64	3	69	34	178	4	17	18	0	0	1	10	565
11	219	323	10	129	98	910	6	35	35	0	0	2	26	1793
5-YR WORK ZONE COLLISIONS	3022	2049	134	1564	990	6157	82	245	464	0	1	20	177	14905

TABLE 22: PERCENT OF ACCIDENTS BY ROAD CONDITION AND COLLISION TYPE

ROAD CONDITION	COLLISION TYPE													ROAD COND TOTAL
	0	1	2	3	4	5	6	7	8	A	B	C	D	
1	20.24%	13.39%	0.97%	10.98%	6.91%	40.96%	0.58%	1.43%	3.29%	0.00%	0.01%	0.13%	1.11%	100.00%
2	58.33%	6.35%	0.79%	6.35%	3.17%	13.10%	0.40%	6.75%	2.78%	0.00%	0.00%	0.40%	1.59%	100.00%
3	29.56%	11.33%	0.53%	12.21%	6.02%	31.50%	0.71%	3.01%	3.19%	0.00%	0.00%	0.18%	1.77%	100.00%
11	12.21%	18.01%	0.56%	7.19%	5.47%	50.75%	0.33%	1.95%	1.95%	0.00%	0.00%	0.11%	1.45%	100.00%
5-YR WORK ZONE COLLISIONS	20.28%	13.75%	0.90%	10.49%	6.64%	41.31%	0.55%	1.64%	3.11%	0.00%	0.01%	0.13%	1.19%	100.00%
3-YR STATEWIDE COLLISIONS*	23.22%	9.03%	0.92%	18.40%	10.15%	32.11%	0.59%	1.56%	4.00%	N/A	N/A	N/A	N/A	99.98%

*data not available for 1993 & 1994

ROAD CONDITION CODES :

1 = Under Construction, Traffic Allowed
2 = Under Construction, Traffic Not Allowed
3 = Under Repairs
11 = Temporary Lane Closure

COLLISION TYPE:

0 = Single Vehicle
1 = Sideswipe (Same Direction)
2 = Sideswipe (Opposite Direction)
3= Angle
4 = Left Turn
5 = Rear End
7 = Backing
8= Other
A = Driveway/Alley Related
B = Non-Contact (Motorcycle)
C = Non-Contact (Non-Motorcycle)
D = U-turn

TABLE 23: COMPARISON OF WORK ZONE ACCIDENTS VS. STATEWIDE ACCIDENTS

YEAR	SURFACE	PDO		INJURY		FATAL		TOTAL	
		#	%	#	%	#	%	#	%
5-YR WORK ZONE	Urban	7297	48.96%	3793	25.45%	40	0.27%	11130	74.67%
	Rural	2517	16.89%	1216	8.16%	42	0.28%	3775	25.33%
	TOTAL	9814	65.84%	5009	33.61%	82	0.55%	14905	100.00%
5-YR STATE WIDE TOTAL	Urban	249351	47.83%	166252	31.89%	1776	0.34%	417379	80.06%
	Rural	64714	12.41%	37050	7.11%	2202	0.42%	103966	19.94%
	TOTAL	314065	60.24%	203302	39.00%	3978	0.76%	521345	100.00%

The Table 23 comparison shows once again that work zone accidents tend to be less severe than those statewide; however, there is a difference between urban and rural accidents. Of total accidents statewide, 19.94% occur in rural areas; whereas, 25.33% of all work zone accidents occur in rural areas. This is graphically shown in Figure 2.

FIGURE 2: COMPARISON OF C&M Vs STATEWIDE URBAN AND RURAL ACCIDENTS

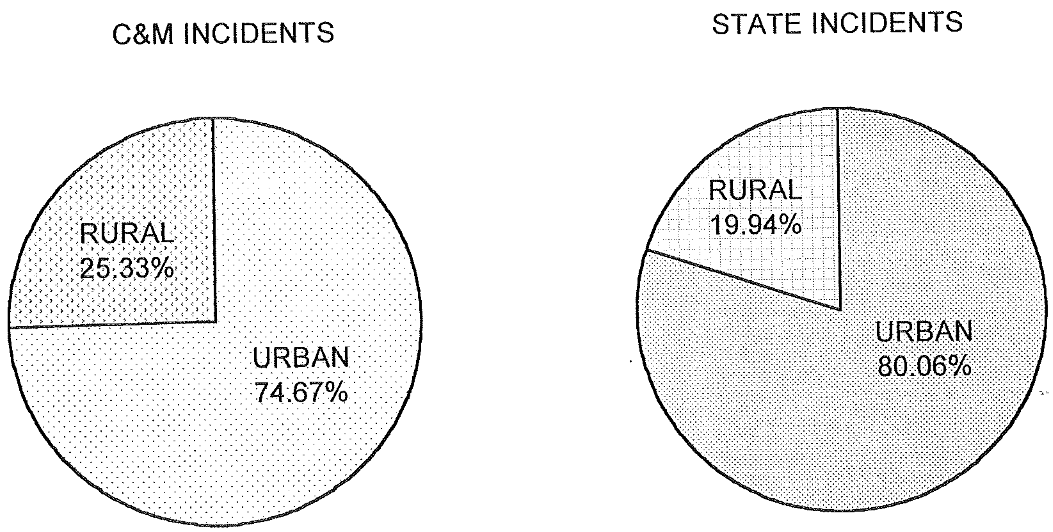


Table 24 is a comparison of work zone accidents on the State Highway System. The State Highway System is comprised of (1) Interstate Highways; and 2) other roadways on the State Highway System. Of the 14,905 work zone accidents occurring in 1992-1996, 5,320 occurred on the State Highway System. Of the 5,320 accidents, 3,095 occurred on the Interstate and 2,225 occurred on other roadways on the State Highway System.

TABLE 24: COMPARISON OF INTERSTATE vs. OTHER STATE HIGHWAY URBAN AND RURAL ACCIDENTS

YEAR	SURFACE	PDO		INJURY		FATAL		TOTAL	
		#	%	#	%	#	%	#	%
5-YR INTER-STATE	Urban	1331	43.00	537	17.35	9	0.29	1877	60.65
	Rural	864	27.92	343	11.08	11	0.36	1218	39.35
	TOTAL	2195	70.92	880	28.43	20	0.65	3095	100.00
5-YR OTHER STATE HWY	Urban	575	25.84	316	14.20	3	0.13	894	40.18
	Rural	851	38.25	464	20.85	16	0.72	1331	59.82
	TOTAL	1426	64.09	780	35.06	19	0.85	2225	100.00

This comparison shows that there is a difference in severity between the Interstate system and other state highways. Interstate accidents tend to be less severe; a smaller portion of Interstate accidents involve injuries or fatalities. This finding is consistent with past experience showing that the roadway design of Interstate facilities results in a lower fatality rate. A majority of Interstate accidents occur within the urban environment. In contrast, accidents on other state highways were more severe and occurred more often in the rural environment.

Table 25 compares work zone accidents on the State Highway System and total statewide accidents. Analysis showed that approximately 19.27% of all accidents statewide occur on the State Highway System. In contrast, 35.7% of all work zone accidents occur on the State Highway System. Overall, the proportion of work zone accidents occurring on the State Highway System divided by the proportion of all accidents occurring on the State Highway System is 1.85. This is very strong evidence that work zone accidents are over-represented on the State Highway System.

One possible reason for this over-representation could be due to more work zone activities occurring on the State Highway System than on other roadways since heavier pavement loadings on state roadways require more frequent construction and/or maintenance. Unfortunately, information on the relative amount of work zone activity on the State Highway System is not readily available. Another reason could be that cities and counties are doing a better job of traffic control. The apparent disproportion of work zone accidents on the State Highway System could be a phenomenon of accident reporting. The Department of Public Safety (which patrols the State Highway System) may do a better job of reporting than do local police agencies (which patrol other roadways). In addition, ADOT's work zones may be more "visible" or more likely to be noted as an "unusual condition." It was noted earlier in this report that larger vehicles are over-represented in work zone accidents. Large trucks travel much more on the State Highway System than on other roadways and may therefore contribute to the disproportion of work zone accidents on the State Highway System.

TABLE 25: COMPARISON OF WORK ZONE ACCIDENTS ON STATE HIGHWAY SYSTEM Vs. STATEWIDE ACCIDENTS ON STATE HIGHWAY SYSTEM

YEAR	PDO			INJURY			FATAL			TOTAL		
	# STATE	# TOTAL	%	# STATE	# TOTAL	%	# STATE	# TOTAL	%	# STATE	# TOTAL	%
1992 WORK ZONE	613	1691	36.25%	292	894	32.66%	8	10	80.00%	913	2595	35.18%
1992 TOTAL	11687	53137	21.99%	6065	36024	16.84%	280	701	39.94%	18032	89862	20.07%
1993 WORK ZONE	653	1833	35.62%	336	995	33.77%	5	16	31.25%	994	2844	34.95%
1993 TOTAL	12453	58765	21.19%	6450	38434	16.78%	271	704	38.49%	19174	97903	19.58%
1994 WORK ZONE	648	1931	33.56%	314	1001	31.37%	9	22	40.91%	971	2954	32.87%
1994 TOTAL	13160	64123	20.52%	6562	41809	15.70%	320	796	40.20%	20042	106728	18.78%
1995 WORK ZONE	1063	2470	43.04%	436	1137	38.35%	10	20	50.00%	1509	3627	41.60%
1995 TOTAL	14380	69248	20.77%	6957	43721	15.91%	323	919	35.15%	21660	113888	19.02%
1996 WORK ZONE	644	1889	34.09%	282	982	28.72%	7	14	50.00%	933	2885	32.34%
1996 TOTAL	14216	68792	20.67%	6981	43314	16.12%	346	858	40.33%	21543	112964	19.07%
5-YR WORK ZONE	3621	9814	36.90%	1660	5009	33.14%	39	82	47.56%	5320	14905	35.69%
5-YR TOTAL	65896	314065	20.98%	33015	203302	16.24%	1540	3978	38.71%	100451	521345	19.27%
RATIO*			1.76			2.04			1.23			1.85

**Ratio: Proportion of work zone accidents occurring on State Highway System divided by proportion of all accidents occurring on the State Highway System.*
Columns labeled "# STATE" refer to numbers of accidents on the State Highway System
Columns labeled "# TOTAL" refer to numbers of accidents statewide.
Rows labeled "WORK ZONE" refer to accidents in work zones.
Rows labeled "TOTAL" refer to all reported accidents statewide.

SUMMARY OF FINDINGS – WORK ZONE ACCIDENT ANALYSIS

Work zone accidents account for about 3 percent of all reported accidents in Arizona. About 3,000 work zone accidents per year occur in Arizona. These accidents produce about 18 fatalities and 1,600 injuries each year.

In general, the characteristics of work zone accidents are very similar to statewide accidents. The proportion of injuries and fatalities in work zones that involve pedestrians is no higher than the proportion of injuries and fatalities involving pedestrians statewide. Driving under the influence of alcohol is not more prevalent in work zone accidents than in statewide accidents. Areas in which work zone accidents are different include the following:

- Work zone accidents tend to be less severe than statewide accidents.
- Comparing work zone accidents with statewide accidents, a slightly smaller proportion of work zone accidents occur at night.
- Comparing work zone accidents with statewide accidents, a much smaller proportion of work zone accidents occur during inclement weather conditions, or when the pavement is wet, snowy, or icy.
- Work zone accidents are much more likely (than statewide accidents) to have unusual road surface conditions such as loose sand, dirt, or gravel surfaces.
- Generally, larger vehicles tend to be over-represented in work zone accidents compared to statewide accidents.
- Sideswipe (same direction) and rear-end collisions occur more commonly in work zone accidents than in statewide accidents.
- Angle and left turn collisions occur less commonly in work zone accidents than in statewide accidents.
- Compared to statewide accidents, a greater proportion of work zone accidents occur in rural areas.
- Work zone accidents on the Interstate System tend to be less severe than work zone accidents on the remainder of the State Highway System.
- Work zone accidents are over-represented on the State Highway System.

The available data indicated that two work zone workers were killed in accidents. The number of workers injured was not available in the data which was reviewed.

FATAL ACCIDENT ANALYSIS

To further characterize the nature of work zone accidents, this research project included a more detailed analysis of fatal accidents. Although most of the information appearing on an accident report form is coded into ALISS, other portions of the accident report do not lend themselves to digital coding. These portions include the narrative reports of all presiding officers, their description of the scene, and their diagrams of the accident, as well as the reports of all witnesses. Microfiche copies of the accident report forms for the 82 fatal work zone accidents occurring in 1992 through 1996 were reviewed to determine what additional information could be found which was not apparent by the coding required for entry into the accident data base. This review sought any qualitative information which could be pertinent to the accident occurring in the work zone. The information obtained by this review is shown in Table 26.

TABLE 26: TABULATION OF FATAL ACCIDENTS

year	accident time	1st harmful	officer opinion	other notation	# units	# injurd	# fatal
1992	15:45	16	driver inexperience	no shoulder striping	2	2	1
1992	11:30	16	excessive speed	obstruction by flashing device	2	1	1
1992	16:45	16	medical incapacity		2	1	1
1992	19:45	14	pedestrian crossing road	low illumination	2	0	1
1992	1:09	1	DUI		1	0	1
1992	23:40	16	speed, inattention		2	1	1
1992	21:15	1	speed, DUI	no shoulder striping	1	0	1
1992	6:00	41	faulty brakes (semi)		1	0	1
1992	16:00	1	speed		1	0	1
1992	11:15	16	speed, driver error		2	0	1
1993	11:10	14	pedestrian crossing road		2	0	1
1993	17:00	14	unknown		3	1	1
1993	5:45	41	ran off road		1	0	1
1993	0:13	37	passed road closed signs		1	2	1
1993	22:40	16	speed, DUI	no striping	2	2	2
1993	19:45	37	medical incapacity/DUI		1	0	1
1993	8:14	14		flagman run over by dump truck	2	0	1
1993	11:56	16	speed		3	2	1
1993	15:01	14	pedestrian crossing road		2	0	1
1993	2:37	37	speed, fleeing prior accident		1	0	2
1993	10:00	1	ran off road	no striping	1	0	1
1993	10:22	16	ignored no left turn signs		2	0	1
1993	12:15	1	speed, improper towing		2	1	1
1993	19:20	14	pedestrian crossing road		2	0	1
1993	18:45	14	pedestrian crossing road	no crosswalk striping	2	0	1
1993	13:55	1	speed, DUI	no shoulder striping	1	0	1
1994	15:08	13	motorcycle; evasive action		1	0	1

year	accident time	1st harmful	officer opinion	other notation	# units	# injurd	# fatal
1994	22:49	14	unknown, hit & run		2	0	1
1994	5:15	13	ran off road		1	0	1
1994	21:46	16	speed, DUI		2	1	1
1994	8:55	14		officer run over by construction semi	2	0	1
1994	20:19	14	pedestrian crossing road		2	0	1
1994	11:55	16	motorcycle; evasive action		2	0	1
1994	6:30	1	ran off road	no striping; uneven pavement	1	0	1
1994	19:40	14	DUI, pedestrian, hit & run	no striping (temporary tabs)	2	0	1
1994	16:57	16	DUI		2	2	1
1994	2:35	20	DUI, train/car		1	0	1
1994	10:29	16	faulty brakes		8	8	1
1994	15:00	41	unknown		1	3	1
1994	6:09	16	speed	no striping	2	1	2
1994	16:45	16	left turn on red		2	2	1
1994	23:15	27	speed, DUI	no striping	1	1	1
1994	15:00	16	DUI		2	2	3
1994	10:02	1	speed	no striping (temporary tabs)	1	2	1
1994	7:17	16	sleep		2	2	1
1994	20:30	16	unknown		2	1	2
1994	2:05	34	speed, DUI		1	1	1
1994	7:48	17	loss of control		2	2	1
1995	8:41	18	sleep		1	1	1
1995	2:30	1	DUI		1	2	1
1995	4:39	16	DUI		2	0	2
1995	6:00	16	speed, illegal passing		2	1	1
1995	17:10	50	faulty equipment		2	0	1
1995	22:38	16	medical incapacity		4	3	1
1995	2:53	26	speed, collision with animal	no striping	1	0	1
1995	7:05	16	speed, DUI	no striping (temporary tabs)	2	1	1
1995	8:30	16	ran red light, medical incapacity		3	2	1
1995	0:10	16	speed, DUI		3	0	1
1995	3:14	41	speed, DUI		1	2	1
1995	5:11	16	loss of control		2	0	1
1995	13:40	16	ran stop sign		2	5	1
1995	9:40	16	left turn		2	1	1
1995	19:10	13	speed	no striping (temporary tabs)	1	0	1
1995	10:35	16	failure to yield		2	1	1
1995	3:12	16	unsafe lane change		4	5	1
1995	18:22	16	ignored traffic signal		2	1	1
1995	23:34	16	DUI		2	2	1
1995	2:03	16	DUI		3	0	1

year	accident time	1st harmful	officer opinion	other notation	# units	# injurd	# fatal
1996	20:50	16	speed, DUI		3	2	1
1996	23:15	16	speed, inattention		2	1	1
1996	15:13	16	medical incapacity		3	5	1
1996	5:30	32	speed		2	0	1
1996	13:35	16	speed, inattention, ran into stopped traffic		2	2	1
1996	5:53	41	ran stop sign, DUI	no striping	1	0	1
1996	23:00	14	DUI		2	2	1
1996	15:58	37	speed		1	0	1
1996	17:15	16	ignored traffic signal		2	3	1
1996	8:15	40	ran stop sign, DUI	no striping	1	0	1
1996	18:09	37	speed, DUI		1	1	1
1996	11:23	49	cherry picker hit underneath by passing semi		2	0	1
1996	9:15	16	ran red light		2	0	1
1996	17:58	37	speed, DUI		1	0	1

There were 82 fatal accidents with 89 fatalities during the period of 1992-1996. Of those accidents, 24 (29.3%) involved a DUI, and 28 (34.1%) were speed related. The location of the accidents was evenly split with 39 (47.6%) occurring on the Interstate and elsewhere on the State Highway System and 43 (52.4%) occurring on other roadways. Forty-two (51.22%) of the accidents happened during daylight and 40 (48.78%) happened during dusk or darkness.

Many of the accident reports included some comments noting that the accident occurred in a work zone. Most reports stated that the construction or maintenance being conducted was not a factor in the accident. However, as shown in the above table under the "other" column heading, there were 20 accident reports that included comments suggesting that a feature of the work zone itself could have been a contributory factor.

- Two accidents involved work zone personnel - one in which a flagman was backed over by a dump truck, and one in which the officer directing traffic through the work zone was run over by the back end of a turning construction semi. In both accidents, the vehicles and the victims were directly involved with work zone operations. These accidents most likely would not have been prevented by any of the countermeasures mentioned in this report.

- One accident noted that there was possible visual obstruction by a flashing device so that one vehicle traveling on the roadway may not have seen the other vehicle pulling onto the roadway until it was too late to stop.

- One accident noted a low level of illumination, which may have been a temporary condition related to construction activity.

- The remaining 16 (19.5%) accidents noted that there was no striping in the location of the accident. Although these accidents were also noted as being caused by speed and/or DUI, or driver inexperience, the lack of roadway striping combined with those factors could have contributed to the occurrence of the accident

The review and analysis of the fatal accident reports did not clearly identify any common or widespread factors that contribute to incidents occurring in work zones. Rather, it appears that many of these accidents could have occurred anywhere and randomly occurred in the work zone.

CHAPTER 3

EFFECTIVE COUNTERMEASURES TO REDUCE ACCIDENTS IN WORK ZONES

STATE-OF-THE-PRACTICE REPORT

The second objective of this project is to prepare a state-of-the-practice report on effective countermeasures to reduce accidents in work zones. This chapter presents the state-of-the-practice report.

Work zone incidents in recent years have averaged approximately 700-800 deaths and 5000 injuries per year nationally and have imposed an economic cost exceeding $3 billion annually. The National Highway Traffic Safety Administration (NHTSA) estimates that 14 percent of work zone fatalities involve construction workers and pedestrians and 86 percent involve motorists.

The Federal Highway Administration (FHWA) has emphasized the importance of work zone safety since the mid 1970s; however, since the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) was enacted, there has been increased interest from national associations, organizations, government agencies, and industry for improving work zone safety. There is currently significant ongoing research studying procedures for determining work zone speed limits, establishing their effectiveness and implementability, and improving traffic control device design and placement in order to reduce the number of traffic accidents in work zones.

On February 17, 1998, the FHWA and the American Road & Transportation Builders Association (ARTBA) opened the National Work Zone Safety Information Clearinghouse as a central repository and resource for these study results. Information provided by the Clearinghouse will be "best practice" information on the research topics listed above, as well as information on public awareness and law enforcement campaigns, and data on safety consultants, products, and training courses. These studies will provide additional needed knowledge as to procedures for ensuring safer and more convenient work zone environments. The following report summarizes the countermeasures from the literature review which are currently being considered in the ongoing effort to reduce accidents in work zones. Although all methods are being investigated, some have received minimal evaluation and quantitative data as to their effectiveness is limited at this time.

Countermeasure	**Study Type**
Work Zone Speed Limits	Effectiveness Study
Police Presence	Effectiveness Study
Enhanced Fines	Effectiveness Study
Additional Legislation	No Study to Date
Speed Limit Enforcement	No Study to Date

Countermeasure	Study Type
Smart Work Zones (ITS)	Demonstration Study Only
SHRP Safety Devices	Product Testing Only
Photo-radar	Demonstration Study Only
Changeable Message Signs	Effectiveness Study
Radar-Activated Horn System	Effectiveness Study
Drone Radar	Effectiveness Study
Display License Plate Number and Speed of Speeding Vehicle	Effectiveness Study

WORK ZONE SPEED LIMITS

It has been widely accepted that the primary cause for increased accidents in construction work zones is the result of vehicles traveling at excessive speeds for the roadway conditions. As a result, many accident countermeasures are aimed at reducing or controlling the speed limits within the work zone. However, a survey of members of the American Association of State Highway and Transportation Officials (AASHTO) Highway Subcommittee on Traffic Engineering found that the safety problem in work zones is exacerbated by the lack of uniform guidelines for determining what those speed limits should be. There are inconsistencies in the methods used to determine work zone speed limits, noncompliance with the posted speed limit by motorists, and a growing practice of establishing work zone speed limits through administrative decision without the benefit of an engineering study. [8]

In the past, most speed limits in work zones were advisory speed limits. Recently, however, many highway agencies have begun using regulatory speed limits with the belief that a regulatory speed limit would reduce vehicle speeds and prevent accidents. Numerous reports have found that this is not necessarily the case. An Illinois study by Benekohal, found that both advisory and regulatory signs caused drivers to reduce speeds in work zones, although the 85^{th} percentile speed (49.3 mph for cars and 45.5 mph for trucks) was still higher than the posted speed limit. Most other studies, however, have shown either only small effects or no effect of work zone speed limits on vehicle speeds. [8]

In the early 1990s, Migletz, et al [8] conducted a survey of all 50 state highway agencies, as well as the District of Columbia and Puerto Rico, asking them to confirm their work zone speed limit policies. A summary of the responses is shown in Table 27 below (45/52).

TABLE 27: WORK ZONE SPEED LIMIT POLICIES BY STATE

States that avoid reducing work zone speed limits whenever possible	States with "blanket" reduced work zone speed limits	States that reduce work zone speed limits based on an identified procedure or set of factors
Alabama Alaska Arkansas California Connecticut District of Columbia Florida Iowa Main Maryland Massachusetts Mississippi Nevada North Carolina Oregon Puerto Rico South Dakota Virginia	Georgia Louisiana Michigan Montana Vermont	Arizona Colorado Delaware Hawaii Idaho Illinois Indiana Kansas Kentucky Minnesota Missouri Nebraska New Hampshire New Jersey New Mexico New York North Dakota Ohio Oklahoma Pennsylvania Rhode Island South Carolina Tennessee Utah Texas Washington West Virginia Wisconsin Wyoming

Source: Procedure for Determining Work Zone Speed Limits [8]

The 18 states which attempt to avoid reducing work zone speed limits whenever possible generally plan the work zone traffic control strategy and geometric design of the work zone to operate safely at the existing posted speed limit. In those situations where this is not possible, many states have specific factors they consider in assessing the need for a speed limit reduction. The five states with blanket work zone speed reduction policies use regulatory speed limits of 35-45 mph in work zones with limited exceptions. The 29 states with speed limit reductions based on specific factors generally use regulatory speed limits when the speed limit is reduced.

An analysis was conducted by Migletz, et al [8] to determine the effect of work zones and work zone speed limits on mean speeds, speed limit compliance, 85th percentile speeds, and speed variance. It was found that motorists do slow down in work zones even when there is no posted speed limit reduction. The mean speed in work zones where the speed limit was not reduced was 5.1 mph less than the mean speed upstream of the work zone. When the work zone speed limit was reduced, the reduction in mean speed was 7.2 mph for a 10-mph speed limit reduction and 20.7 mph for a 30-mph speed limit reduction. It was further found that while speed limit compliance increased in work zones with a 10-mph reduction in speed limit as compared to the upstream compliance, compliance actually decreased in work zones with a speed limit reduction of 15 mph or more. The analysis of the 85th percentile speed of traffic in work zones found patterns very similar to the mean speed data.

Analysis of speed variance found the variance in work zones to be significantly higher than upstream speed variances. For work zones with a 10-mph speed limit reduction, the increase in speed variance within the work zone was 34 percent. Work zones with no reduction in the speed limit had an increase in speed variance of 61 percent. Work zones with speed limit reductions of 15 mph or more experienced increases in speed variance of from 81 to 93 percent. See Figure 3. The same study also evaluated changes in accident rate as a function of the reduction in the speed limit. The data showed that the smallest increase in fatal plus injury accident rate occurred when the speed limit was reduced by 10 mph. Larger reductions in the speed limit resulted in larger increases in accident rate (see Figure 4). The study findings resulted in the following recommendations for establishing work zone speed limits.

- Work zone speed limit reductions should be avoided whenever possible, especially in work zones where all work activities are located in shoulder roadside areas and where no work activities are underway.

- A 10-mph reduction in work zone speed limit is desirable for work zones that involve work on or near the traveled way (especially on rural freeways) and when personnel are required to work for extended periods in an unprotected position within 10 ft of the edge of the traveled way.

- Work zone speed limit reductions larger than 10 mph are undesirable and should be avoided, except where required by restricted geometrics or other work zone features that cannot be modified.

Based upon the study findings, the National Committee on Uniform Traffic Control Devices recently (January 1999) recommended a new standard for Part 6 of the Manual on Uniform Traffic Control Devices. The recommended text is shown in Figure 5.

Since it has been found that work zone speed limits by themselves are relatively ineffective in influencing traffic speeds, the effectiveness of other methods of controlling speeds in work zones has been researched.

FIGURE 3: PERCENTAGE INCREASES IN SPEED VARIANCE FROM UPSTREAM TO WORK ZONE LOCATIONS

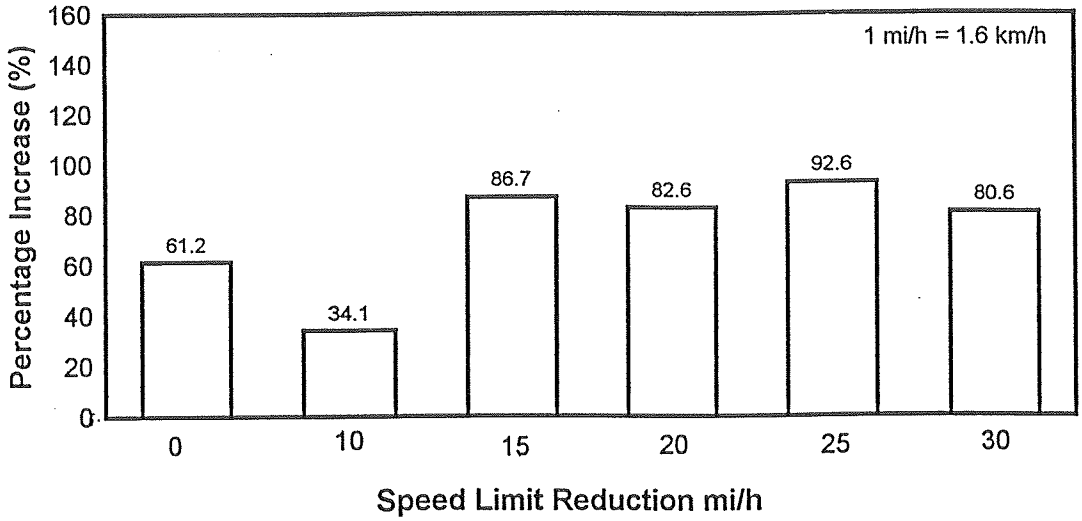
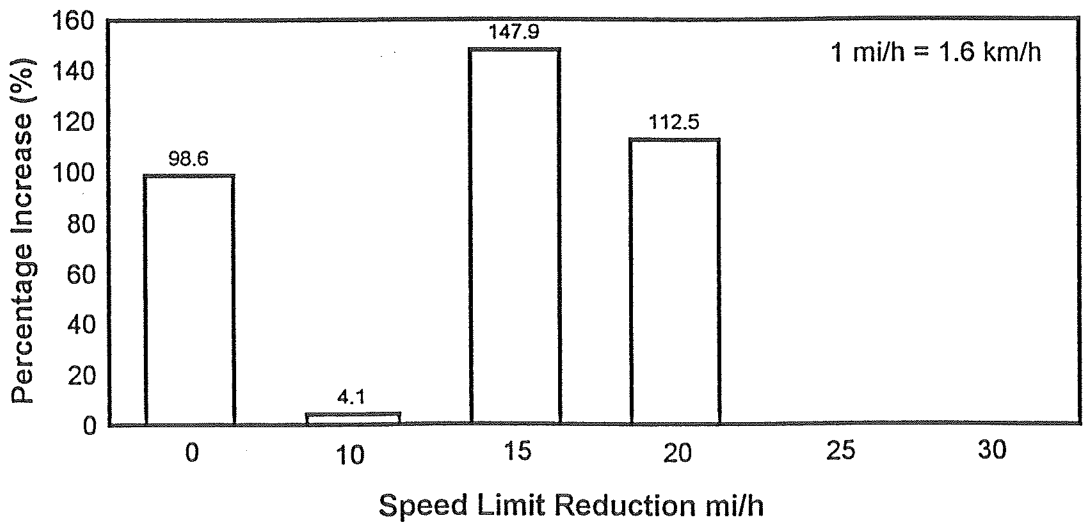


FIGURE 4: PERCENTAGE INCREASES IN FATAL PLUS INJURY ACCIDENT RATES FORM THE BEFORE TO DURING CONSTRUCTION PERIODS



Traveled way and detour sites on rural freeways.

The following text was recommended by the National Committee on Uniform Traffic Control Devices on January 8, 1999.

FIGURE 5. RECOMMENDED TEXT REGARDING WORK ZONE SPEED LIMITS

Changes to Section 6.8.2.a.
The words (regulatory speed limit) are added to the last sentence of 6.B.2.a. and a cross reference to Section 6C. 1 is added. The revised text would read as follows:

GUIDANCE

2. Traffic movement should be inhibited as little as practical.
    a. Traffic control in work and incident sites should be designed on the assumption that drivers will reduce their speeds only if they clearly perceive a need to do so. Reduced speed zoning (regulatory speed limit) should be avoided as much as practical. (See Section 6C.1)

Changes to Section 6C.1
The following is added to the end of Section 6C.1 - Traffic Control Plans

SUPPORT
It is a fundamental principle (Section 6B.2.a.) that reduced speed zoning (regulatory speed limit) should be avoided as much as practical because drivers will reduce only if they clearly perceive a need to do so.

Research has demonstrated that large reductions in speed limit (such as a 30 mph reduction) increase speed variance and accidents. Research has also demonstrated that smaller reductions in speed limit (up to 10 mph reduction) cause small changes in speed variance and accidents.

A reduction in the regulatory speed limit of up to 10 mph from the preconstruction speed limit has been shown to be effective under the following conditions:

a. The nature or location of the work is likely to affect normal traffic flow.
B. Workers are present near the traveled way without the protection of a positive barrier.

GUIDANCE
Reduced speed limits should be used only in the specific portion of the work zone where the above conditions or restrictive features are present; however, frequent changes in speed limit should be avoided.

A traffic control plan should be designed so that vehicles can safely travel through the work zone with a speed limit reduction of no more than 10 mph.

A reduction of more than 10 mph in the speed limit should be used only when required by restrictive features in the work zone. Where restrictive features justify a speed reduction of more than 10 mph, additional driver notification should be provided. The speed limit should be stepped down in advance of the location requiring the lowest speed, and additional warning should be used.

POLICE PRESENCE

It was shown above that the average speed of free flow traffic in construction work zones often exceeds the posted speed limit. However, speeding motorists slow down when they see a police car patrolling the area or they perceive the threat of getting a speeding ticket. Limited studies of the effects of police presence in work zones have shown a positive effect on traffic operations. Police vehicle presence/police presence means at least one police vehicle was observed in the work zone during a period when a speed study was being conducted. With police presence and no change in the speed limit, the mean and 85th percentile speeds were about 4 mph less than without police presence. When the speed limit was reduced by 10 mph, police presence resulted in a 1-2 mph reduction in speed. Compliance with work zone speed limits improved by 15 percent where speed limits were not reduced, and approximately 5 percent when the speed limit was reduced 10 mph. In addition, police presence decreased speed variance by 6 percent where speed limits were not reduced and 20 percent where speed limits were reduced 10 mph. [9]

Respondents to a highway agency survey commented that police presence in work zones was the most effective speed control method available. [9] However, a survey of work zone contractors found the contractors felt the use of police officers for speed control was not effective because speeds increase when the police leave the work zone. [8] This belief was partially confirmed by a study conducted by Benekohal in Illinois. It was found that the "halo effect" of police presence was significant for trucks, but not for cars. During a one-hour period immediately following the departure of police in the work zone area, the average speed for cars increased by 2.4-3.0 mph, but that for trucks only increased by 0.3-0.4 mph. [5] Benekohal's recommendation, therefore, is that since the halo effect was sustained for trucks, the use of a police officer at adjacent work zones could be used to control vehicle speeds without a significant loss in the effectiveness on speed reduction.

Another belief expressed by work zone contractors was that speed control should be done by using established traffic control procedures and speed enforcement, including the issuance of speeding tickets by civilian flaggers. [8] A study conducted in Massachusetts evaluated the effectiveness of flaggers and police on federal-aid highway projects. Based on their findings, a guideline on when to use uniformed police officers or civilian flaggers was established as shown in Table 28. [7]

TABLE 28: GUIDELINE ON THE USE OF POLICE OFFICERS AND FLAGGERS

Work Activity	Low Speed & Low Volume	High Speed & High Volume
Work in median or roadside area (no infringement on roadway)	Neither flaggers nor uniformed officers required	Neither flaggers nor uniformed officers required
Shoulder closed (with concrete barrier)	Neither flaggers nor uniformed officers required	Neither flaggers nor uniformed officers required

Work Activity	Low Speed & Low Volume	High Speed & High Volume
Shoulder closed without concrete barrier (work adjacent to traffic)	Neither flaggers nor uniformed officers required	1 uniformed officer suggested
Setting up or removing lane closures, lane shifts, or other changes in traffic pattern	1 flagger per traffic approach suggested	1 uniformed officer per traffic approach suggested
Lane closed on multi-lane roadway (with concrete barrier)	Neither flaggers nor uniformed officers required	Neither flaggers nor uniformed officers required
Lane closed on multi-lane roadway without concrete barrier (active work adjacent to traffic)	Neither flaggers nor uniformed officers required	1 uniformed officer per traffic approach suggested
Survey crew - roadway center line	1 flagger per traffic approach suggested	1 uniformed officer per traffic approach suggested
Temporary road closure (15-20 minutes)	1 flagger per traffic approach suggested	1 uniformed officer per traffic approach suggested
Ramp work	1 flagger suggested	1 flagger suggested
Moving operation (in travel lane)	1 flagger suggested	1 uniformed officer suggested
One lane, alternating traffic (no signal)	1 flagger at each end and at each cross street suggested	1 uniformed officer at each end and 1 flagger at each cross street suggested
Work within intersection	flagger(s) suggested (number dependent upon field conditions)	flagger(s) suggested (number dependent upon field conditions)

Source: Report on the Use of Police Details for Traffic Control on Federally-aided Highway Construction Projects in the State of Massachusetts

In addition, it was suggested that additional consideration be given to night time operations. The use of a uniformed traffic officer with a marked patrol car and flashing lights was recommended for any night time construction operations that impact traffic flow in any way.

ENHANCED FINES

Many states have adopted a "double fines in work zones" policy in an effort to reduce vehicle speeds and improve safety. Table 29 lists enhanced fines for speeding or other violations in traffic work zones.

TABLE 29: ENHANCED FINES FOR TRAFFIC VIOLATIONS IN WORK ZONES

State	Chapter/ Section/Bill No.	Date Enacted	Violations Affected	Type of Enhanced Fine	
				Fine ($)	Multiple of Original Fine
AL	None				
AK	Proposed SB 304 - Amend Sec. 28.05.151	proposed	all traffic violations		2X
AR	AC Section 27-50-408	1995	speeding		2X
AZ	None [a]				
CA	MVC Section 42009	1994	numerous violations specified		2X
CO	CS 42-4-613 (HB 97-1003)	1997	speeding		2X
CT	CGS Vol 5. MVC 95-181 Sec. 1 (HB 6050)	1995	all moving vehicle violations		2X
DE	MVC Title 21, Sec. 4105	1990	numerous violations specified		no less than 2X for 1st infraction
FL	FAC Section 318.18 (SB 892)	1996	speeding		2X
GA	CGA Section 40-6-188(a)(b)(c) (SB 580)	1996	speeding	$100-$2000 up to 12 mo. jail	
HI	None				
ID	MVC Sec. 49-657		speeding	$50	

State	Chapter/ Section/Bill No.	Date Enacted	Violations Affected	Type of Enhanced Fine	
				Fine ($)	Multiple of Original Fine
IL	MVC Sec. 5. Sec. 11-605 (HB 0008)	1996	speeding	$150 min	
IN	IC 1993, 33-19 Chapter 6 Sec. 14 (HB 1154)	1993	speeding	$.50 + $25 if ordered by judge	
IA	IC 1993, Sec. 3. Sec. 805.8 New Subsec 2A (HF 193) rev. 1997)	1993 1997 [b]	all moving vehicle violations		2X
KS	KSA 8-2004(c) (HB 2781)	1994	all moving vehicle violations		lesser of 2X or $100
KY	KRS, Chapter 37, Sec. 2 189.2325 (SB 137)	1996	speeding		2X ($120-$200)
LA	LRS 32:57(G) (SB 1363)	1997	speeding		2X
MA	None				
MD	MVC Sec. 21-802.1	1991	speeding	$270	
ME	MS Sec. 1. 29-a, MRSA 2075, sub-2. (HP 134, LD 182)	1995	speeding		2X
MI	MVC Sec. 257.628, 257.629c, add Sec. 601b(1) (HB5123)	1996	all moving vehicle violations		2X
MN	MS 1994, Sec. 169.14, Subd. 5d(d)	1994	speeding		larger of 2X or $25
MO	RSM Sec. 304.580 (HB 1430)	1994	all moving vehicle violations	$35	
MS	Proposed House Bill 1253 - Amend MC Sec. 63-3-5106(1)	proposed	speeding		2X or $250

State	Chapter/ Section/Bill No.	Date Enacted	Violations Affected	Type of Enhanced Fine	
				Fine ($)	Multiple of Original Fine
MT	MVC. 61-8-314 (5)(a)	1997	all traffic violations		2X
NC	Section 1. GS 20-141(j2) (SB 30)	1997	speeding	$100-$250	
ND	MVL Sec. 39-09-02	1995	speeding	$40 + $1/mph when 10 mph+ over limit	
NE	RSN Sec. 11 Sec. 60-6, 190(1)(2) (HB 901)	1996	speeding		2X ($20-$400)
NH	VCS Sec. 265:6-a	1994	speeding	$250-$500	
NJ	RS, Title 39-Chapter 4-203.5 (HB 2262)	1993	all moving vehicle violations		2X
NM	None [a]				
NV	NRS Sec. 1, Chap. 484 new sec. 1(a)(b)2, 3(a)(b)(c) (AB 456)	1997	speeding		lesser of 2X or $1000, and/or 6 mo. jail or 120 hrs community service
NY	Vehicle & Traffic Law 1180(f)(g)(3)	1997	speeding		2X
OH	RC 4511.99(D)(3) (HB 247)	1991	speeding		2X
OK	47 OS, 1991, Sec. 11-806(c) (HB 1860)	1996	speeding		2X
OR	MVC Sec. 11.230 (3)(a)	1996	all moving vehicle violations		2X
PA	PaCS Sec. 33-3326 (c)	1989	numerous violations specified		2X
RI	MVC Sec. 31-14-12.1(a)(b)	1996	speeding		2X

State	Chapter/ Section/Bill No.	Date Enacted	Violations Affected	Type of Enhanced Fine	
				Fine ($)	Multiple of Original Fine
SC	MVC Sec. 56-5-1535(A)(B)(C)	1994	speeding	$75-$200, 30 days jail or both	
SD	MVC Sec. 32-25-19.1 (HB 1214)	1996	speeding		2X
TN	TCA Sec. 55-8-152 (g)(2) (SB 2075)	1996	speeding	$250-$500	
TX	MVC Sec. 472.022(d) (HB 981)	1997	all moving vehicle violations		2X of min. and max. applicable
UT	Proposed SB 20 - To amend UCA Chapter 138, Sec. 41-6-13	proposed	speeding		2X
VA	MVC Sec. 46-2-878.1	1992, 1995 [c]	speeding	$250 max.	
VT	VSA Sec.16.23, Section 1010	1997	speeding		2X
WA	RCW 46.61 Sec.1 (SB 5995)	1994	speeding		2X
WI	WS Sec.1. 346.60 (SB 48 and SB 44)	1995	numerous violations specified		2X of min. and max. applicable
WV	MVC Subsec.17C-3-4b, 17C-3-4a	1994	numerous violations specified	$200 max., 20 days jail or both	
WY	None [d]				

a. Bill was submitted but did not pass in the 1997 legislative session
b. Original bill passed in 1993 with a fine structure of double fines or $100 whichever is less, if the violation occurred within any road construction zone. This was revised in 1997 (HF 704) to eliminate the $100 whichever is less portion of the fine structure and expand the work activity to include road construction, maintenance, survey, or utility work.
c. Original bill passed in 1992 applied to only "reduced" maximum speed limits in work zones. This requirement was eliminated in 1995 to allow it to be applied to all maximum speed limits in work zones (even those not reduced from the normal speed limit).
d. Wyoming has a separate (higher) fine structure for speeding at locations where a speed limit has been established based on an engineering study rather than the blanket speed limits defined in the motor vehicle code. This includes construction zones, school zones, transition zones, etc.

HB = House Bill; SB = Senate Bill / Source: National Work Zone Safety Information Clearinghouse

In summary, enhanced fines for violations in work zones are covered in state legislation are as follows: 28 states (56%) cover speeding only; 9 states (18%) cover all violations; and 5 (10%) cover numerous violations specified. Three states (Alabama, Hawaii, and Massachusetts) have no laws for work zones. Wyoming does not have a specific law, but they do have a separate higher fine structure for speeding at locations where a speed limit has been established based on an engineering study. Three states submitted proposed bills in the 1997 legislative session which did not pass:

- Alaska - Double fines for violations of speeding, reckless driving, and negligent driving through construction, repair, or maintenance work zones. The DOT indicated they would resubmit in the 1998 legislative session.

- Arizona - Double fines for speeding violations through construction, repair, or maintenance work zones. The DOT indicated they would resubmit a new bill in 1999.

- New Mexico - Double fines and points for all violations in construction work zones. The DOT stated they hoped to resubmit in the 1999 legislative session.

In addition, three states proposed bills in the 1998 legislation.

- Alaska - Double fines for all traffic violations driving through construction, repair, or maintenance work zones. Advance signing required; work activity is not necessary.

- Mississippi - Proposed HB 1253; double fines, but not to exceed $250, for speed violations within a highway work zone where construction or maintenance work is being conducted and workers are present.

- Utah - Proposed SB 20; double fines for speeding violations in a highway construction or maintenance site. [3]

Additional Legislation

In addition to the above enhanced fine legislation, some states have enacted other work zone legislation as shown below.

TABLE 30: OTHER WORK ZONE LEGISLATION

State	Type of Law	Chapter/ Section/Bill No.	Date Enacted	Comments
Indiana	Reduce WZ speed limits without traffic and engineering investigation	IC 9-21, Chapter 5, Sec. 11(a)(b) (HB 1151)	1993	Speed limit must be 10 mph below normal speed limit. Max WZ speed limit is 45 mph
Kentucky	Reduce WZ speed limits without traffic and engineering investigation	KRS, Chapter 37, Sec. 4.189.390(4) (b) (HB 137)	1996	Effective when and where signs are posted

State	Type of Law	Chapter/ Section/Bill No.	Date Enacted	Comments
Maine	Reduce WZ speed limits without traffic and engineering investigation	MS Sec. 1.29-A MRSA 2027, sub(2)	1997	WZ speed limits can be set between 25 and 55 mph. Max speed limit reduction allowed is 10 mph
Minnesota	Reduce WZ speed limits without traffic and engineering investigation	MVL Sec. 169.15 Sudd.5d(a)	1996	WZ speed limits can be set between 20 and 40 mph. Max speed limit reduction allowed is 15 mph
Montana	Reckless endangerment of highway workers	MVC 61-8-315(1)(2) (defined); MVC 61-8-715(1) (penalty)	1997	First conviction up to 90 days imprisonment or $25-300 fine, or both; 2nd conviction imprisonment 10 days to 6 months or $50-500 fine, or both.
Nebraska	Reduce WZ speed limits without traffic and engineering investigation	Sec. 9-Sec. 60-6 188(1)(2)(3)(4)	1996	Statutory speed limits in WZ are 25 and 35 mph in urban and rural areas, respectively. DOT supervisors can raise limits above statutory levels (up to normal speed limits for that roadway) as they deem appropriate
Oregon	Reckless endangerment of highway workers	MVC 11.231(1)(2)	1996	Class A misdemeanor - max fine of $5000 or 1 year jail
Oregon	Refusing to obey a flagger	MVC 11.232(1)(2)	1996	Class A misdemeanor - max fine of $5000 or 1 year jail
South Dakota	Authorize agents of employees of DOT to issue citations for speeding violations within WZ	Section 1, Chapter 32-33 new section (HB 1273)	1997	Workers must be present and signs indicating work area required
Utah (proposed)	Proposed - obedience to peace officer or other traffic controllers in construction or maintenance zones	To amend Chapter 138, section 1, Sec. 41-5-13(1)	1998	A person may not willfully fail or refuse to comply with any lawful order or direction of peace officer, fireman, flagger at a highway WZ

State	Type of Law	Chapter/ Section/Bill No.	Date Enacted	Comments
Washington	Reckless endangerment of highway workers in a roadway construction zone	RCW 46.61, Sec. 1(4)(5)	1994	Gross misdemeanor - max fine of $5000 or 1 year jail, or both

Source: National Work Zone Safety Information Clearinghouse [4]

Five states (Indiana, Kentucky, Maine, Minnesota, and Nebraska) have laws which reduce speed limits in work zones without requiring traffic and engineering investigation; 3 states (Montana, Oregon, and Washington), have laws regarding reckless endangerment of highway workers; 1 state (Oregon) has a law for refusing to obey a flagger; and 1 state (South Dakota) authorizes agents of employees of DOT to issue citations for speeding violations within the work zone. In addition, Utah has proposed legislation relative to obedience to peace officer or other traffic controllers in a construction or maintenance zone. Another bill was submitted in Ohio, but did not pass (HB 615). This bill would have created the traffic offense of failing to merge into a merging zone at a construction zone. In addition, it would use a photographic camera or videotape to record vehicles that violate the failing to merge offense and speeding offenses and send the owner of those violations a citation. [4]

Effectiveness of Enhanced Fines

The ultimate goal of enacting work zone-related legislation is to improve safety in the work zone for both the workers and the motoring public. Consequently, the most direct measure of the effectiveness of such legislation is whether or not accidents that occur within a work zone are reduced in frequency and/or severity after the enactment of such legislation. A study of the effectiveness of enhanced fines was conducted by the Texas Transportation Institute in September 1997. Obtaining similar data from all 50 states was nearly impossible due to differences in data collection methods. As a result, they utilized the Fatal Accident Reporting System (FARS) maintained by the National Highway Traffic Safety Administration (NHTSA) of the U.S. Department of Transportation. Only fatal accidents occurring in construction zones were extracted for evaluation since some states' legislation was limited to construction zones rather than all work zones. Researchers conducted a before-and-after analysis using a control group and a check for comparability. FARS data was available only through 1995; therefore, only 14 states had passed and implemented laws early enough to capture at least one year of after data from the FARS database. The control group was all of the other states that did not have work zone legislation passed between 1984 and 1995. A cross-product ratio was used to estimate the number of fatal work zone accidents expected to occur in the test state in the after period as shown below.

$$E\,[\text{Test State}_{\text{after}}] = \frac{(\text{Test State before})(\text{Control States after})}{(\text{Control States}_{\text{before}})}$$

Table 31 lists the accident data utilized in the study.

TABLE 31: Fatal Accidents in Construction Zones										
State	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Alabama	14	5	17	18	12	16	14	10	9	6
Alaska	1	2	2	0	3	3	2	0	1	1
Arizona	10	12	24	20	15	7	9	18	16	14
Arkansas	8	10	5	6	7	6	12	8	8	14
California	35	32	48	57	60	73	54	57	50	52
Colorado	6	3	3	1	5	6	1	8	2	5
Connecticut	7	2	4	7	8	7	6	5	11	4
Delaware	4	2	1	1	0	3	3	2	1	3
Florida	14	5	36	19	31	17	19	26	27	18
Georgia	22	24	7	11	12	7	8	49	48	53
Hawaii	0	1	0	1	3	3	1	3	1	2
Idaho	1	0	1	1	3	2	2	2	1	3
Illinois	25	18	18	23	38	31	21	17	31	34
Indiana	20	6	12	10	18	16	17	14	13	15
Iowa	1	8	7	4	4	4	7	3	7	3
Kansas	1	3	6	4	8	3	10	6	5	20
Kentucky	6	5	6	5	3	4	3	6	2	2
Louisiana	11	9	15	14	25	10	5	10	8	5
Maine	2	6	6	2	1	2	3	2	4	0
Maryland	12	15	2	7	4	10	5	7	4	4
Massachusetts	1	2	3	4	5	4	3	2	4	9
Michigan	10	4	19	8	6	9	8	3	12	9
Minnesota	10	8	13	12	9	6	7	5	8	6
Mississippi	3	3	3	1	4	3	0	2	7	4
Missouri	17	10	11	7	10	5	14	10	13	11
Montana	7	1	2	2	6	5	1	5	4	4
Nebraska	4	7	13	6	5	6	5	7	9	8

TABLE 31: Fatal Accidents in Construction Zones										
State	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Nevada	3	7	5	8	10	5	7	7	6	4
New Hampshire	2	3	1	0	1	1	0	1	0	2
New Jersey	7	8	17	19	29	37	12	9	10	3
New Mexico	7	7	6	10	5	2	6	1	6	5
New York	4	11	9	9	12	14	10	12	26	18
North Carolina	2	2	5	1	6	14	5	9	11	5
North Dakota	1	0	2	4	2	1	0	1	0	0
Ohio	18	21	21	14	7	9	19	10	13	10
Oklahoma	9	10	9	7	5	7	6	10	5	12
Oregon	6	5	19	11	3	8	3	9	11	5
Pennsylvania	9	14	8	9	8	11	11	20	15	12
Rhode Island	1	0	3	1	0	1	0	2	0	1
South Carolina	2	4	3	3	4	12	5	7	7	0
South Dakota	0	3	1	1	0	1	3	2	4	4
Tennessee	11	10	11	11	7	13	9	15	8	12
Texas	128	127	126	142	126	73	93	90	97	99
Utah	3	1	1	0	2	0	0	1	0	0
Vermont	1	1	1	0	0	0	0	0	1	3
Virginia	2	8	2	5	3	3	6	11	14	10
Washington	4	2	0	9	4	11	7	6	12	10
West Virginia	2	7	0	2	4	3	3	3	0	3
Wisconsin	4	8	9	12	10	7	11	9	8	11
Wyoming	6	2	6	5	4	3	3	2	2	2

Source: Work Zone-Related Traffic Legislation: A Review of National Practices and Effectiveness

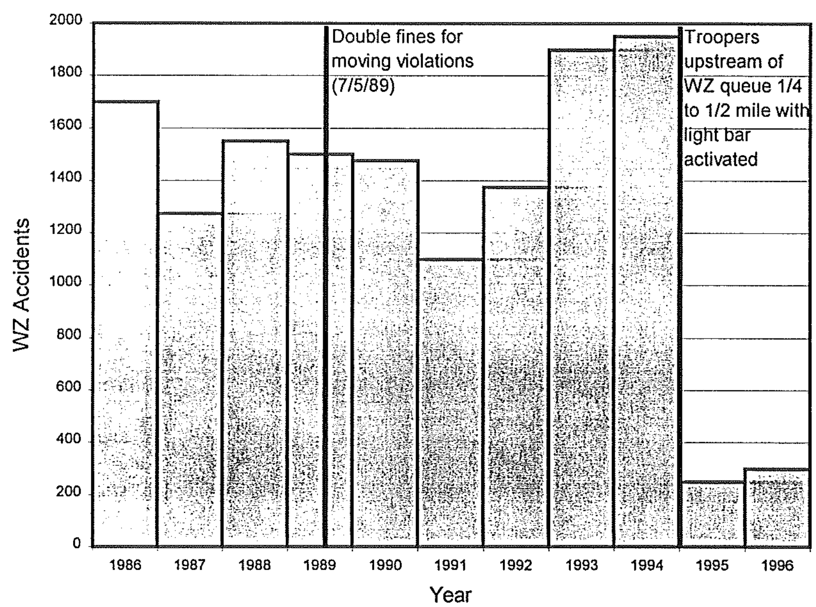
NOTE: Shaded cells denote when increased work zone fine legislation was passed in that state

The results of the analysis indicated that overall, states that enacted legislation to increase fines in work zones did not experience significantly lower fatal accident rates than states without fines. Fatal accident experiences in those states after implementation of a law were not significantly different than those of the states that did not enact any work zone-related legislation. Changes in fatal accident frequencies after implementation of an increased fine law (relative to changes that occurred in states without legislation) varied from an 87% decrease to a 299% increase. However, the frequencies in 12 of the 14 states after implementation of the law were not significantly different from the frequencies before implementation. It was determined that a low sample size associated with fatal accident analysis made it difficult to identify any subtle impacts that a treatment such as increased fine legislation may have upon safety, and analysis of other types (non-fatal) of work zones accidents was recommended. [14]

SPEED LIMIT ENFORCEMENT

Figure 6 presents evidence from a case study of Pennsylvania, which has had increased fine legislation in effect the longest. As shown, the implementation of increased fines in 1989 had very little impact on work zone accidents. When combined with the presence of police and enforcement in 1995, however, there was a dramatic effect.

FIGURE 6: WORK ZONE ACCIDENT HISTORY IN PENNSYLVANIA



Source: Work Zone-Related Traffic Legislation: A Review of National Practices and Effectiveness [14]

Obviously, enforcement and work zone legislation are highly interdependent. The intent of work zone legislation has increased the enforcement threat by making an individual violation more expensive to motorists. However, if enforcement is not carried out, it stands to reason that the legislation is largely ineffective.

Enforcement can generally be categorized in one of two ways: circulating patrols through the work zone and stationary patrols. Past research has shown that both methods can be effective, although stationary patrols appear to reduce speeds by a slightly greater amount on average [14]. Regardless of the method utilized, however, several problems were commonly heard by the TTI researchers when conducting their work zone-related laws study. These included the following:

- difficulties in apprehending violators within the work zone (due to a lack of shoulders, restricted lane widths, etc.),
- difficulties in keeping track of whether work zone personnel are present at a work zone (relevant in states with legislation requiring workers to be present in order to impose higher fines for traffic violations),
- difficulties in remembering to mark that a traffic infraction was incurred in a work zone, and
- difficulties in enforcing laws that were viewed as particularly "complex" (i.e., requiring workers be present, special traffic controls, certain speed limit restrictions).

Funding Mechanism

Another difference among states pertaining to enforcement and increased work zone fine legislation is the way in which the enforcement is funded. Three general funding approaches were found nationwide:

- as part of normal duty,
- through contractor (DOT), or
- through payback arrangements from the increased fine revenues generated.

The most prevalent method nationwide is where work zone enforcement is part of normal duty, but this generally comes at the expense of reduced enforcement activities elsewhere. The second approach - where funding comes from the DOT - essentially provides overtime funding for officers. The final approach (presently used by Kentucky and Indiana) is to establish a special fund or account in which work zone fine revenues are deposited and then managed by the transportation agency to fund and hire off-duty police officers to patrol and enforce traffic laws in the work zones [14].

Court Support of Enforcement

Although many states have implemented an "enhanced fine for speeding in work zones" policy, it was found that police officers are hesitant to issue double-fine speeding tickets and failed to enforce speed limits when work was off the traveled way or workers were not present. This was primarily due to uncertainty as to whether the courts would uphold the double fine [9]. Several issues were discovered by TTI researchers:

- Citations are dismissed due to the belief that an officer does not have the authority to influence the fine that is being imposed.

- Fines reduced when the driver does not have a means to pay the additional fines.

- Citations dismissed because the drivers stated they were not adequately warned of the additional fine for work zone violations.

- Lower fines issued by the courts when the citation is issued in a work zone.

Regardless of the reason, state officials mentioning this type of problem noted its adverse consequence upon officer morale and efforts to enforce traffic violations in work zones. There was a perception that officers tended to avoid work zone areas because of these problems and concentrated their efforts elsewhere [14].

PHOTO-RADAR

According to a 1991 article, Michigan developed a photographic device which accompanied the "Give 'Em a Brake" campaign. The license plate of a speeding vehicle was photographed and the owner received a letter advising that the work zone speed limit was exceeded. [9] According to comments from the National Work Zone Safety Information Clearinghouse, although several states are using photo-radar for enforcement of speed limits on general roadways, none are currently using this method in work zones and don't anticipate its use in the near future. Minnesota is currently using photo-radar to count violations and collect data in order to demonstrate the reliability of the equipment, but does not issue tickets. They have found that the problem is much more widespread than expected with 60% of vehicles in work zones exceeding posted speed limits in metropolitan test areas.

CHANGEABLE MESSAGE SIGNS

Several studies have been conducted as to the effectiveness of changeable message signs (CMS) in the reduction of vehicle speeds in work zones.

New York - A study done in New York found that the CMS can reduce work area speeds; however, the average speeds were still 10 mph above the speed limit. In addition, the standard deviation of speeds in the work zone increased. Therefore, although speeds decreased, safety problems may increase due to the increased variance of vehicle speeds. [8]

Illinois - An Illinois study evaluated the speed reduction effects of using a changeable message sign (CMS) at work zones to display speed limit and information messages. The study utilized three experiments: one experiment in which the CMS was located outside the work zone, a second in which the CMS was located within the work zone, and a third in which two CMS' were located within the work zone. The CMS in each case displayed two alternating messages, "WORKERS AHEAD" and "SPEED LIMIT 45 MPH." Data was collected at stations located prior to the CMS and after passing the CMS.

Experiment 1 utilizing the CMS in advance of the work zone reduced the average speed of cars by 2.8 mph and trucks by 1.4 mph. Displaying the messages on one CMS located in the work area (experiment 2) reduced the average speed of cars by 1.7 mph within about 1000 ft of the sign, but was no longer effective at the third station about 2 miles down the road (but still within the work zone). The effect on trucks in experiment 2 resulted in no decrease near the CMS, but reduced average speeds by 3.7 mph at the 2-mile station. Experiment 3 in which two CMS were located within the work zone further reduced the speeds of both cars and trucks; however, it was felt that this was related in some way to the initial speed of the vehicle as it passed the CMS (e.g., the closer the vehicle was to the speed limit, the less the reduction in speed). The findings from this study indicate that the messages on the CMS only affected the speeds of vehicles close to the CMS. Further study was recommended to determine the optimal distance from the CMS to the work area. [5]

Virginia - A two-phase study was conducted in Virginia. The first phase found that the CMS was more effective in reducing vehicle speeds in work zones than conventional static signing procedures (using regulatory or advisory speed signs). The second phase concentrated on the effect of duration of exposure of the CMS with radar on its effectiveness in reducing speeds and influencing speed profiles in work zones. The data were collected at the beginning, middle, and end of each work zone in order to study the behavior of high speed drivers who triggered the CMS by exceeding the threshold speed and to compute their average speed reduction in response to the warning messages.

The results of this study indicated that the duration of exposure of the CMS does not have a significant impact on speed characteristics and driver behavior; the CMS with radar remained effective up to seven weeks. Therefore, it continues to be effective in controlling speeds in work zones for projects of long duration. In contrast to the Illinois study, it was found that there were no distinctive differences among types of vehicles with regard to speed reduction. Drivers exceeding the speed limit reduced their speeds by an average of 8-10 mph at the middle of the work zone, and speed variances tended to reduce with the CMS operating in the work zone. As with the Illinois study, drivers had a tendency to speed back up in work zones longer than 3500 ft; therefore, the introduction of a second CMS was recommended so speed reductions could be maintained throughout the work zone. Virginia also recommended further study to analyze how speed reductions vary with increasing distance from the CMS and compare the results with the benefits/problems of introducing a second CMS in long work zones. [12]

RADAR-ACTIVATED HORN SYSTEM

A radar-activated audible message system was a technique used in an Illinois study to evaluate the speed reduction effects of providing an audible message to the speeding motorists approaching a highway striping crew. The audible message system consisted of a directional radar unit and a radar-activated horn which had a maximum audible range of three miles and a minimum audibility of one mile. The horn system was set up so a vehicle which was approaching at a speed of 60 mph or more would trigger the horn. The data was grouped into three categories which were based on the speed of the vehicle and the status of the horn: (1) the horn was activated by vehicles traveling faster than 60 mph; (2) the horn was not activated because the vehicle was traveling slower than 60 mph; and (3) the horn was off and was not activated by speeding vehicles (control data). In addition, these three groups were further broken down into subgroups as to the detection distances from the horn. The detection distances tested were 1000, 750, 500, 400, 300, 200, and

100 feet from the horn. Data was collected for 118 vehicles and a speed reduction profile was generated. [5]

The data results indicated a similar decreasing relationship between the average speed reduction and the detection distance before the horn. The average speed reductions were less when the detection distance was further from the horn. For example, in the horn-activated case, the average speed reduction at a distance of 750 ft was 9.71 mph (range of 4-17 mph); however, this same group averaged a speed reduction of only 0.9 mph (range of 0-2 mph) when the distance was 200 ft from the horn.

Of note was the decrease seen for both the group in which the horn was not activated due to their slower speed and the control group. Both groups showed a similar decreasing speeds even though the horn was not activated. This was felt to be in part due to drivers seeing the striping vehicles or receiving a warning from radar detectors set off by the horn system.

Overall, the horn system appeared to have some speed reduction effect on the motorists. It was recommended that a detection distance of 750 ft gave the drivers enough time to slow down before passing the work crew. An additional factor which should be considered when using the horn system is the noise problem and human factor considerations which may limit application of the device to very special cases. Further studies were recommended. [5]

DRONE RADAR

A drone radar system is a passive or unmanned radar which is used to reduce the speed of vehicles traveling through highway work zones by activating the drivers' radar detectors and thus influencing a change in driver behavior. A study to determine the effects of using this device was conducted through three experiments. Experiment 1 evaluated the immediate (less than one hour) speed reduction effects when motorists were traveling at excessive speeds both inside and outside of the work zone. Experiments 2 and 3 evaluated the effects of sending a continuous radar signal transmission for extended periods of time (several hours) using one radar gun (experiment 2) and two guns (experiment 3) within the work zone. The use of two radar guns was intended to increase the perceived "threat" of police in the work zone and make it difficult for the drivers to determine the location of and who was activating the radar. [5]

Experiment 1 used two station points to determine the speed of vehicles approaching the drone radar system and then the speed once they had passed the system. During the control period, it was found that both cars and trucks were traveling at about 10 mph over their respective speed limit. Once the radar system was activated, the net speed reduction for cars was 8.0 mph and for trucks it was 9.8 mph. It was concluded that the drone radar was effective in reducing the speed in a very short period of time and simulated a short-term maintenance job where a work crew spent less than an hour in one location.

Experiment 2 using only one radar gun within the work zone found only small decreases in speed during the radar transmission period. Three stations were used which found a decrease of 7%, 4%, and 0% at stations 1, 2, and 3 respectively for cars. Trucks decreased speed even less with changes of 1%, 5%, and -1% (an increase), respectively. It was concluded that the continuous transmission allowed the drivers to determine the location of the radar and who was activating it.

In fact, in as little as a half an hour, some drivers were aware that there were no police present and may not have felt threatened by the radar transmission.

Experiment 3 used two radar guns with three testing stations. During the control period with the radar not activated, results showed minimal speed reductions at stations 1 and 3, and station 2 showed considerable reductions which decreased over time. Once the radar was activated, however, noticeable reductions were seen at station 2, and reductions of as much as 21% were seen for cars and 40% for trucks were seen at station 3.

The conclusion from these three experiments was that drone radar may be used effectively to reduce the speed of vehicles which have a radar detector. However, the use of the device diminishes its effectiveness when used over extended periods of time because drivers become aware that it is not police radar. The drone radar was found to be most effective in short periods of time and the location of radar-transmitting stations should be selected to provide the maximum threat of police presence. The use of drone radar in conjunction with police enforcement is recommended in order to keep the drivers off-balance. [5]

DISPLAY LICENSE PLATE NUMBER AND SPEED OF SPEEDING VEHICLE

A British study [16] demonstrated the effectiveness of displaying the license plate number and the speed of a speeding vehicle in real time. In one sense, the system is similar to photo-radar in that a visual image of the vehicle is captured. In photo radar (described previously) the feedback to the driver occurs a few days later when the driver receives a letter or ticket in the mail. In contrast, the British system provides immediate feedback to the driver while driving through the work zone. Unlike photo radar, the British system uses two video cameras to determine vehicle speed. Thus, the system is not "detectable" by the driver, as is drone radar. The British system uses a changeable message sign to present the message to the driver.

The British system has been demonstrated and thoroughly documented. The effectiveness of the system has been clearly shown.

The Speed Violation Detection / Deterrent was deployed on the M 1 Motorway in Leicestershire from May 31 to October 19, 1994 as part of a long-term roadway construction project. Two video cameras were deployed on overpasses 738 feet apart. Each video camera was connected to a license plate reader. The reader used image processing technology to recognize the characters on the license plate. The character recognition was accomplished in about 0.7 seconds. License plates from both camera locations were matched, along with the exact time that the vehicle passed each location. The 225 foot baseline allowed for computation of vehicle speed.

The license plate of each vehicle whose speed exceeded the posted speed limit (50 mph) and the speed at which that vehicle was traveling were then displayed on a large changeable message sign about 1600 feet beyond the second camera (see Figure 7). The message was displayed with very adequate time for the offending driver to see and read the message before passing by the sign. All of this processing (plate reading, license plate matching, computation of travel speed, and display of the license plate and speed) was done automatically. The system operated during the day under a variety of weather conditions and at night using infrared illumination to read the license plates.

FIGURE 7: DISPLAY OF LICENSE PLATE NUMBER AND SPEED OF SPEEDING VEHICLE

The effectiveness of this system was impressive. Before and after speed studies were conducted to observe changes in driver behavior. Comparing data collected eight days prior to deployment with data collected 20 weeks after deployment showed that average speed decreased by 10.0 mph (from 57.2 mph before to 47.2 mph after). Eighty-fifth percentile speed decreased by 11.7 mph (from 67.3 mph before to 55.6 mph after). It is notable that this deterrent effect continued to exist after 20 weeks of operation. This is in contrast, for example, to studies of drone radar, where the drone radar quickly lost its effectiveness. It is also noteworthy that these reductions were achieved without the presence of enforcement or any explicit threat of enforcement. Neither violation letters nor tickets were sent to offending motorists. No extra police resources were deployed in the work zone.

The before data indicate that 75.9 percent of vehicles were exceeding the 50 mph speed limit. The after data indicate that only 32.5 percent of vehicles were exceeding the 50 mph speed limit. This change in driver behavior is further illustrated in Figure 8.

A decrease in vehicle speed suggests that safety may have improved. To more clearly demonstrate whether safety was improve, a before and after accident study was conducted. A before period of 299 days was compared to a 142 day period when the Speed Violation Detection / Deterrent was in operation. Changes in accident experience are summarized as follows.

	Before	**After**
Number of property damage only accidents (daily average)	0.2642	0.2887
Number of injury accidents (daily average)	0.0268	0.0141
Number of persons injured (daily average)	0.0468	0.0282

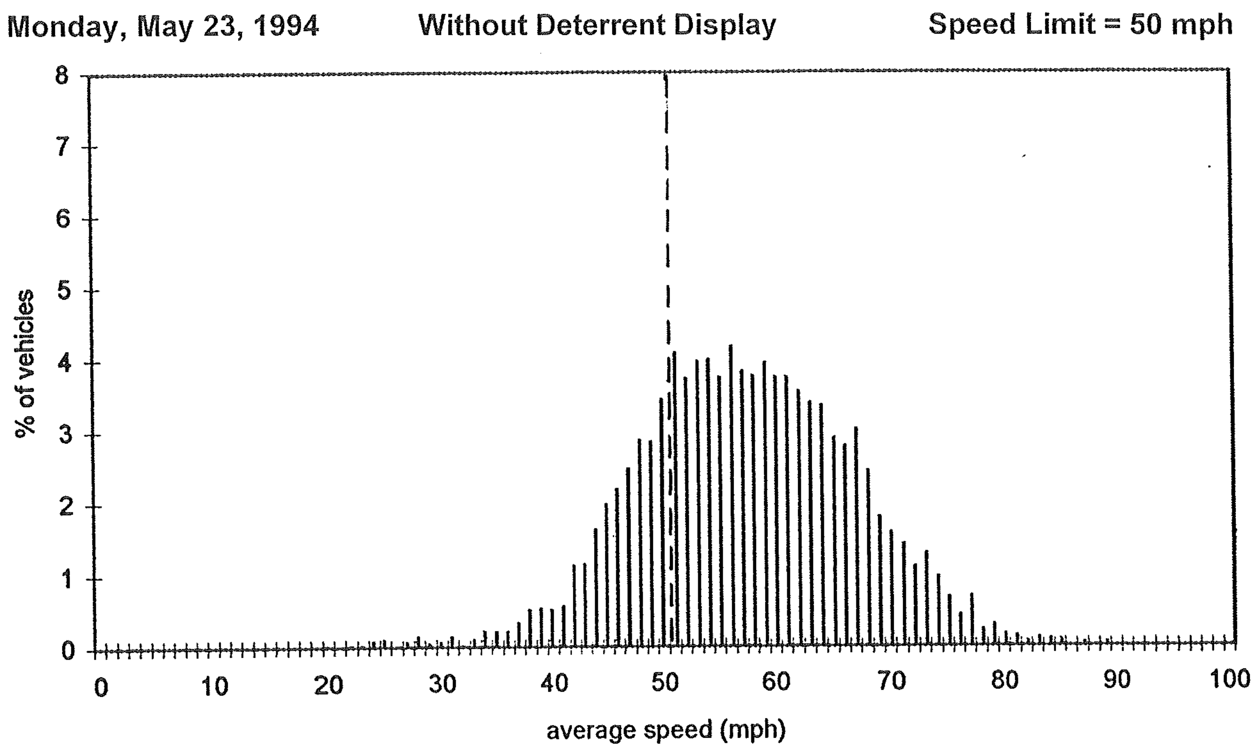
The daily average number of property damage only accidents was virtually unchanged while the daily average number of injury accidents and number of persons injured declined to about one-half of the before condition. These changes in accidents are consistent with the widely held view that accident severity reduces with reductions in speed.

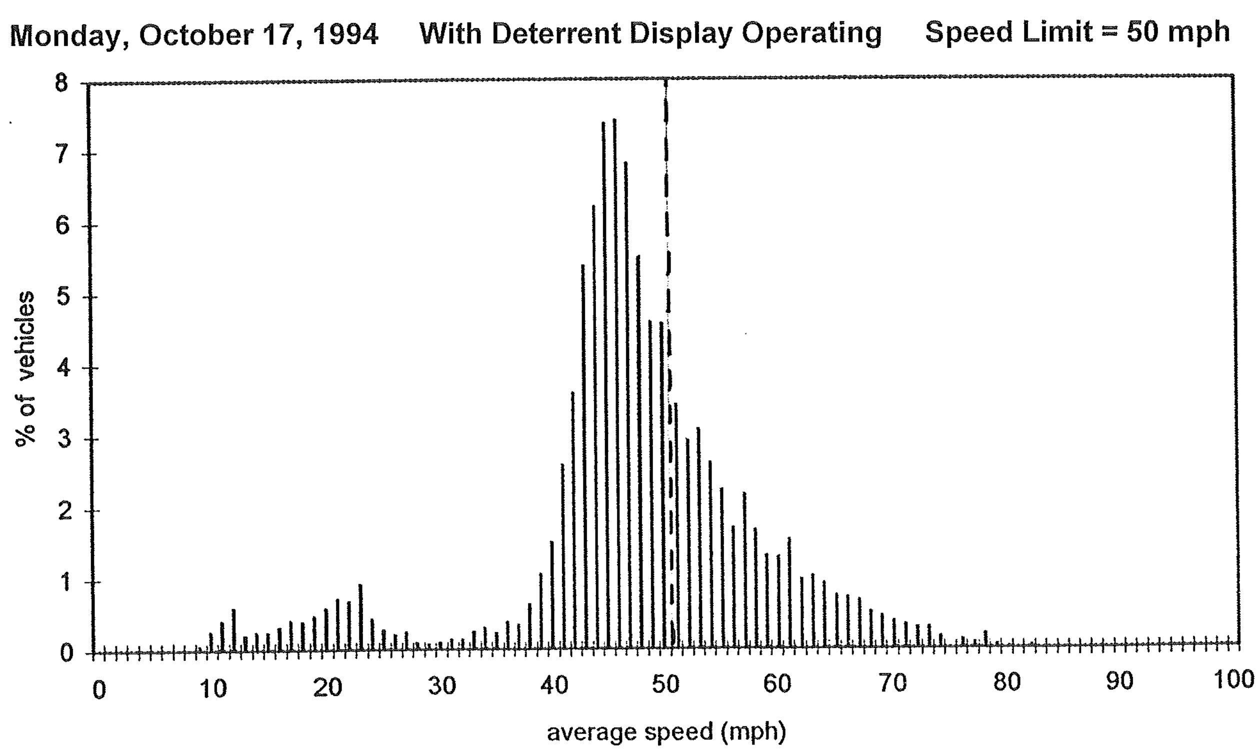
An economic assessment of accidents showed that accident costs were reduced by British Pounds 505 per day. The savings in accident costs were about twice the deployment cost of the Speed Violation Detection / Deterrent system at this demonstration.

SMART WORK ZONES - USING ITS

A 1997 study conducted by the Iowa Department of Transportation (DOT) designed a smart work zone system utilizing Intelligent Transportation System (ITS) components for an interstate reconstruction project. The traffic on the reconstruction project was rerouted head-to-head on two lanes of the interstate roadway while the other two lanes were being reconstructed. This traffic control strategy works until the traffic volumes exceed the roadway capacity of the open lanes. At that point, high-speed interstate traffic quickly comes to a halt and creates the potential for severe rear-end-type crashes. The smart work zone system was designed to monitor approaching traffic speeds and volumes, determine when traffic backups occur, activate the warning devices, and inform surveillance personnel of the problem in real-time and without human intervention. The four components of the system included incident detection units, changeable message signs, highway advisory radios, and video cameras.

FIGURE 8: CHANGE IN VEHICLE SPEEDS BEFORE AND AFTER IMPLEMENTATION OF SPEED VIOLATION DETECTION / DETERRENT





The microwave traffic detector was located approximately 500 ft in advance of the beginning of the lane closure taper. Video cameras were attached and positioned so one camera was looking upstream and one camera was pointed downstream. The detector collected traffic volumes and speeds for each of the two approaching traffic lanes. The information was processed by a computer and compared to predetermined thresholds established by Iowa DOT staff. When traffic volumes reached a threshold, the computer used a cellular modem to activate the appropriate warning message on the CMSs and the Highway Advisory Radio (HAR). Three types of messages were used on the CMS and on the HAR. A "normal" message was transmitted over the HAR at all times except when a traffic backup occurred. The message on the CMS was: RT LANE CLOSED 2 MILES / MERGE LEFT. This message told the motorist where the work zone was, that traffic was currently flowing smoothly, and some tips on safe driving through a work zone. A congested message was sent when traffic backups occurred without mandatory diversion. The CMS message was: CMS - TRAFFIC DELAY AHEAD / PREPARE TO STOP. This message informed the motorist that delays were occurring and that an alternate route was available for motorists who wished to bypass the traffic delays. A diversion message was transmitted over the HAR when traffic backups occurred. The CMS message was: I-80 CLOSED AHEAD / USE EXIT 133.

The detection units were first generation devices which caused operational problems. One problem was that just after a traffic backup began, the unit started calling the warning devices (CMS and HAR). If, during the time the detection unit was calling the warning devices, traffic became free-flow again (e.g., traffic was delayed just enough to go over a threshold, but dissipated in the next minute), the system stopped calling the devices and failed to recognize the current free-flow conditions.

The motorists were able to listen to the messages on the HAR for a range of 3 to 12 miles. The range was affected by the quality of the AM radio in the vehicle and weather and atmospheric conditions. Overall, the HAR's were well-received by motorists, contractors, DOT staff, and local businesses.

The video equipment providing remote traffic surveillance to the Iowa DOT staff was well-received and was found to have many applications in a work zone environment where portability is required. The conclusion of the study was that much valuable information was gained on several new and innovative work zone devices. It was found that ITS devices are only as good as the company that manufactures and supports the systems; however, the overall system was determined to be a valuable tool for traffic control in a work zone area. [6]

SHRP SAFETY DEVICES

To make work zones safer, the Strategic Highway Research Program (SHRP) has investigated dozens of suggestions for new safety devices. Devices which were chosen to be developed were intended to improve highway safety in several ways:

- Give workers more warning of, and protection from, errant vehicles or inattentive drivers;
- Help motorists navigate confusing work zones; and/or
- Alert drivers of changing traffic conditions.

SHRP developed ten devices which can be grouped into three areas: signs (flashing stop/slow paddle, opposing traffic lane divider, direction indicator barricade, and portable all-terrain sign stand), detectors (intrusion alarm and queue-length detector), and protective devices (portable crash cushion, portable rumble strip, and remotely driven vehicle). A brief summary and test results are given below.

Flashing Stop/Slow Paddle

Typically, flaggers have used signs with the word "stop" on one side and "slow" on the other to control traffic in temporary work zones. Drivers, distracted by sights along the road, don't always heed the signs, with potentially dangerous consequences for maintenance workers. To better get the motorists' attention, the flashing stop/slow paddle features high-intensity quartz halogen lights that are visible during both day and night. If a motorist does not appear to be following the flagger's instructions, the flagger can press a button on the handle that switches on the flashing lights, thus alerting the driver to the message on the paddle and possibly preventing an accident. Several different models of the flashing stop/slow paddle are now commercially available. [1]

Studies of the flashing stop/slow paddle have been conducted in Alabama, Iowa, Kentucky, Maine, New Mexico, North Dakota, Ohio, Oklahoma, Pennsylvania, Puerto Rico, and South Dakota. Tests were conducted in both urban and rural areas and on roadways with a variety of average annual daily traffic volumes. Iowa tested the paddles extensively in conjunction with other traffic control devices. In a surveys of motorists passing through work zones, the paddles rated second (behind portable rumble strips, see below) as "most effect" at getting the driver's attention and the device "observed" most often when passing through the zone. Reported benefits included the following:

! The flashing paddles get drivers' attention more effectively than conventional devices, particularly at night.

! Flaggers using flashing paddles were more successful at getting drivers to slow down.

! Work crews using the flashing paddles feel better protected from traffic.

Problems included interference from two-way radios and a short battery life - both of which are being addressed by manufacturers of the paddle. Another problem encountered involved the workers' habit of throwing paddles onto the back of their trucks which caused the lights to break.

Opposing Traffic Lane Divider

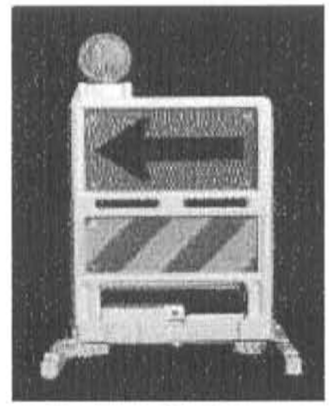
When highway maintenance operations force crews to temporarily convert one-way roads to two-way traffic, the modified traffic patterns can be both confusing and dangerous because motorists fail to realize that the lane next to them now carries oncoming traffic. The opposing traffic lane divider helps guide motorists through work zones and keep the vehicles in their proper lanes. The divider is a small, portable sign with two-way arrows on its face. Signs are placed in sequence to indicate the temporary centerline of the road which separates the opposing traffic flows. The arrows on the divider clearly show motorists that traffic on both sides of the sign is moving in opposite directions. The divider is easy to install and remove, and cannot be blown over by high winds or gusts from passing vehicles. If it is struck by a vehicle, it is designed to either spring back to an upright position or be easily restored by a maintenance crew member. The device is commercially available from a number of manufacturers. [1]

The opposing traffic lane divider has been tested in Georgia, Indiana, Mississippi, and Texas. Mississippi DOT was able to see an immediate safety benefit once the dividers were installed - drivers passing the dividers tended to stay further from the centerline than they did when passing the delineator tube traditionally used. Mississippi surveyed motorists and found that 95 percent indicated the correct response as to what message the dividers conveyed, compared to 51 percent when the delineator tubes were used. In addition, although the opposing traffic lane divider signs were spaced twice as far apart as the delineator tubes, most drivers said that both devices were spaced equally. Mississippi DOT crews also made speed checks at three points to see if drivers would speed up or slow down when passing from sections marked by delineator tubes to sections marked by opposing traffic lane dividers. They found almost no change in speed which indicates that the new devices did not disrupt traffic flow.

Texas tested the opposing traffic lane dividers in place of concrete barriers. They found set-up of the dividers required far less time, could easily be performed by one person, reduced the risk of injury to workers, and required no special equipment to transport, set up, or remove, as compared to the concrete barriers which required cranes to set up and caused longer interruptions in traffic flow during installation and removal.

All states indicated that the opposing traffic lane dividers allowed for better traffic flow and clearer instructions for drivers that traffic on the roadway is traveling in both directions.

Direction Indicator Barricade



The direction indicator barricade provides motorists with clear instruction on new traffic patterns in work zones where workers have closed a lane. The device features a 60 cm by 30 cm (24 in by 12 in) horizontal arrow panel and a 60 cm by 20 cm (24 in by 8 in) bias-striped panel mounted on a plastic barricade. Work crews place a series of direction indicator barricades along the roadway to direct motorists out of the lane that tapers to a close ahead and into the temporary travel lane. The arrow panel is reversible, making the barricade suitable for closing the left or right lane. The direction indicator barricade is commercially available from several manufacturers. [1]

Studies of the direction indicator barricade have been conducted in Alabama, Arkansas, Georgia, Illinois, and South Dakota. Tests ranged from two months to a year in duration. Alabama maintenance crews used the barricades on two-lane and undivided four-lane rural highways with a range of speeds and with average annual daily traffic ranging from 150 vehicles to 15,000 vehicles. Reported benefits from all states include the following:

- Work zones are less confusing to motorists. The motorists appear to understand the device better than traffic cones or other barricade devices.
- Motorists' attention is successfully attracted and traffic flow improved.
- Motorists and workers are at less risk.
- The device is sturdy and durable, easy to install and remove, and has no significant maintenance problems. Maintenance crews reported high satisfaction, and, although the barricade costs more than traditional barricades, the shorter set-up time and its maintenance-free operation promise long-term savings.

Several of the DOTs have recommended or are considering recommendation of the direction indicator barricade for routine use. Alabama DOT has also recommended further testing to determine the device's nighttime effectiveness and long-term safety record.

All-Terrain Sign and Stand

To ensure that drivers have advance notice of highway work zones, signs are often set up warning of "Road Work Ahead". This warning ensures that drivers are prepared for the possibility of new traffic patterns, slower speed limits, or other changes. The signs are placed on the shoulder of the highway, where there is usually plenty of space for a sign to stand; however, when the shoulder is too narrow or the road borders a steep slope, this can be difficult. The portable all-terrain sign and stand uses adjustable legs which allow the sign to stand on almost any surface. The part of the device that holds the sign itself can also be adjusted so the sign is always vertical and easy to read. Stakes are driven through the legs to keep the base from tipping, sliding, or blowing over. The sign and stand can be set up by one worker using a hammer to drive in the leg stakes. The portable all-terrain sign and stand is commercially available.

The all-terrain signs were tested by Tennessee DOT in locations with high winds or on roads that carry a great deal of truck traffic. Initially, crews felt the sign was awkward and cumbersome; however, use and experience made set-up less difficult, and the DOT has increased the usage to sites with narrow shoulders, ditches, and steep banks. The crews now report that the signs have been found to be durable and reliable, and the DOT is planning on expanding their usage.

Intrusion Alarm

The intrusion alarm improves worker safety in highway work zones by monitoring the buffer area between work crews and passing vehicles. If a vehicle accidentally enters this buffer area, the intrusion alarm almost instantly sounds a piercing siren. The siren gives workers a few seconds to move out of the path of the oncoming vehicle. The intrusion alarm is commercially available from several manufacturers. Various models use pneumatic tubes, infrared beams, or microwave beams to detect vehicles. [1]

The intrusion alarm has been tested by New York and Vermont. New York preferred the microwave beam model with an optional drone radar. This model covered a large area and sent a false signal to drivers' radar detectors which prompted them to slow down. Both states reported satisfaction with the intrusion alarm and are currently using it for jobs involving small work crews or jobs of short duration where it is difficult to justify using a flagger. Benefits include:

- Several seconds warning when vehicles intrude into work area, giving workers a chance to move to safety.
- Better sense of security for work crews.
- Less risk of injury.
- Siren is loud enough to be heard even over the sound of generators or jackhammers.

Problems encountered involved proper set-up of the device, especially at job sites which lacked shoulders wide enough to place the two parts of the alarm.

Queue-Length Detector

The queue-length detector monitors traffic backups in work zones. If traffic slows to a preset level or stops, the detector activates a message board or other device to warn approaching drivers of the changing travel conditions ahead. [13] A study currently underway in Pennsylvania is using the detector in conjunction with 15 variable message signs placed along the roadway in advance of the work zone. The message signs change in response to signals from eight queue-length detectors and alert drivers if traffic ahead is stopped, slowed down, or if a lane is blocked by an accident. The estimated length of any delay is also provided. The detector is also being used to help travelers plan their route by automatically sending updates to a travelers advisory radio station, area police and emergency services, and an Internet web site. The project manager says the cost of the system is more economical (about half as much) as it would have cost to hire people to monitor traffic conditions 24 hours a day. [11]

Portable Rumble Strip

The portable rumble strip warns drivers when they are approaching a highway work zone. Driving over the strip produces an audible rumble and a vibration in the steering wheel, alerting the driver to changing traffic conditions ahead. The commercially-available device works best when deployed in a series in work zones controlled by flaggers. It is designed primarily for operations where moderate-speed traffic may need to be stopped intermittently.

Kentucky found the rumble strip to be easy to use and install. It weighs about 34 kg (75 lb) and can be deployed from the back of a pickup truck by one or two workers. They felt the strip worked well on low-volume roadways and in the city. [1]

Iowa tested the rumble strip in conjunction with several other traffic control devices. When surveying motorists, the rumble strip received the highest ranking as the device being "most effective" in getting their attention. It also scored the highest in the "observed" category where motorists were asked to check boxes of devices which they noticed when passing through the work zone. However, Iowa reported that the operational aspects of the rumble strip caused problems. Each vehicle that passed over the strip moved it down the roadway and the strip tended to buckle in the middle. This required constant monitoring and adjustment to prevent the strips from becoming a traffic hazard. In addition, twice during the period of three days of evaluation, a strip was picked up and rolled down the roadway after a semi-trailer passed over it. As a result, Iowa has determined the portable rumble strips to be unsafe for use and suspended further testing. [2]

Remotely-Driven Shadow Vehicle

To protect workers as they slowly move down the pavement patching potholes and filling cracks, highway agencies often send out a "shadow vehicle" which travels behind the workers, providing a moving barrier between the workers and passing vehicles. This improves the safety of the work crew, but the driver can be severely injured if the shadow vehicle is hit. The remotely driven vehicle is a truck customized to allow it to be operated by remote control from a safe location up to 370 m (1200 ft) away. The operator uses a radio-control box to control the vehicle's speed, direction, lights, and other components. Inside the truck, a computer and a system of motors, switches, and pneumatic cylinders control the steering, brakes, engine, and other controls. The remote-control system can be installed on any vehicle without extensive modifications, which allows the truck to be operated normally when not being used as a shadow vehicle. The remotely driven vehicle is nearing commercial production. A kit to convert a truck to remote-control operation will be available for about $35,000.

The remote-control shadow vehicle concept was developed by the Minnesota DOT research department. Once SHRP built a prototype, Minnesota began field testing. The shadow truck is kept at a distance of about 60 to 90 m (200 to 300 ft) behind the work crew. If it is closer, it doesn't protect the crew if a vehicle hits it, and if it is further, it leaves room for passing vehicles to pull in between the shadow vehicle and the work crew. The remote-control vehicle also protects motorists who run into it because it is equipped with an energy-absorbing cushion which softens the impact should a vehicle crash into the back of the truck. Although initially skeptical, Minnesota DOT's operations staff now appreciate the remote-controlled vehicle. The prototype conversion cost was $75,000; however, the accident which led to the vehicle's development cost the DOT about $2 million in workers- compensation costs. [1]

Economic Benefits

A panel of safety experts from the Texas Transportation Institute was convened to review the case studies and provide a consensus estimate of accident reductions that could be reasonably expected from additional implementation of the SHRP work zone safety products. The panel felt the devices had not been in use long enough or used widely enough to permit developing a safety improvement estimate on each one individually. However, taken as a group, it was felt that implementation over the next 20 years should contribute up to a five percent savings in the number of work zone accidents each year. [11]

ONGOING RESEARCH

Several research projects are listed on the National Academy of Sciences Internet web site (www3.nas.edu) which are currently underway. Project title, source, and estimated completion date are shown below for future follow-up.

TABLE 32: ONGOING RESEARCH

Title	Source of Document	Estimate Date of Completion
Design and Operation of Work Zone Traffic Control	Federal Highway Administration	September 1, 1998
Work Zone Safety for Maintenance and Operations on Rural Highways	Federal Highway Administration	September 15, 1998
Traffic Management Strategies for Merge Areas in Work Zones	Iowa State University	December 1998
Evaluation of Remote-Controlled Flagman	Federal Highway Administration	December 1998
Automated Speed Enforcement for Work Zones	South Dakota Department of Transportation	December 1998
Development of Guidelines for Nighttime Road Work to Improve Safety and Operations	National Cooperative Highway Research Program	January 14, 1999
Improving Night Work Zone Traffic Control	Virginia Transportation Research Council	2nd Quarter 1999
Design and Development of GIS Tools to Improve Pedestrian and Bicycle Safety	Federal Highway Administration	2000
Lateral Protect Short-Term Work Zones	New York State Department of Transportation	2000
Work Zone Accident Exposure Analysis	Federal Highway Administration	None Given
Deployment of Laser Intrusion Warning System for Highway Work Zone Safety	National Cooperative Highway Research Program	None Given
Development of Portable Stop Line for Traffic Control	Connecticut Department of Transportation	None Given

CHAPTER 4

RECOMMENDED COUNTERMEASURES

The third objective of this project is to recommend countermeasures which should be implemented in Arizona to improve work zone safety and to reduce accidents. Recommended countermeasures are presented in this chapter. Recommendations for implementation of countermeasures are presented in Chapter 5.

A variety of countermeasures to reduce accidents in work zones were reported in Chapter 3. To identify which countermeasures are most appropriate for use in Arizona, a panel of 21 experts was convened on May 24, 1999. The panel included representatives with a variety of perspectives on the work zone accident problem. ADOT personnel dealing with construction operations, maintenance, traffic operations, safety, and research were present, as well as personnel from District offices. Department of Public Safety officers, construction industry representatives, a traffic control contractor, a Federal Highway Administration representative, and university researchers also attended. The variety of disciplines and expertise helped to insure that a balance of viewpoints was involved in selecting countermeasures.

The panel reviewed and commented on the countermeasures reported in Chapter 3. In addition, the participants identified many other issues and factors that affect work zone safety. Extensive, and very valuable, discussion and dialogue took place during the panel meeting.

In a consensus-building process, the panel selected six principal countermeasures for implementation in Arizona.

WORK ZONE SPEED LIMITS

As described in Chapter 3, research has shown that large reductions in the speed limit through a work zone substantially increases the accident rate. No reduction in speed limit, or a minimal reduction in speed limit (a reduction of 10 mph or less), results in a smaller increase in accident rate. At the national level, a recommendation has been made to include guidance in the Manual on Uniform Traffic Control Devices (see Chapter 3). It is recommended that ADOT and other jurisdictions in Arizona follow this guidance when developing traffic control plans and selecting speed limits to apply in work zones. Although a recommended practice, the MUTCD guidance does allow flexibility of application in special situations.

POLICE PRESENCE

The opinion of the panel is that police presence at the start of the work zone is a deterrent to speeding. Research has shown that police presence does result in a small reduction in speed and a reduction in speed variance. Construction projects currently have provisions to pay for police presence to help with traffic control (Standard Specification for Road and Bridge Construction, item 701-4.04F).

SPEED LIMIT ENFORCEMENT

The panel believed that speed limit enforcement is essential. An enforcement activity within the work zone would reinforce the deterrent created by police presence at the beginning of the work zone. Research has demonstrated that enforcement can have a very significant impact on work zone accidents.

PUBLIC EDUCATION

Although not covered in Chapter 3, there was strong sentiment on the panel to recommend various public education activities as a countermeasure. Public education activities have been widely used in other states, but a review of the literature did not find any evidence of the effectiveness. This is likely due to the difficulty in proving a cause-and-effect relationship between public education activities and work zone accidents.

It was pointed out that the ADOT Motor Vehicle Division Driver's License Manual has only one page devoted to traffic control devices used in work zones and work zone safety. This needs to be expanded. The panel believed that public service messages about work zone safety can be very effective and should be emphasized. As an analogy, it was pointed out that public service messages promoting swimming pool safety and the prevention of drownings have received great visibility and have been effective. The number of victims of work zone accidents is very comparable to swimming pool drownings and deserves equal public exposure.

SIGN CREDIBILITY

Another major issue identified by the panel, but not discussed in Chapter 3, is sign credibility. It is common on construction projects for various construction signs to be in place when there is no hazard apparent to the public. These include both speed limit signs (showing a reduced speed limit) and other warning signs. A reduction in the speed limit for miles and miles, when there is no construction activity, will be ignored by the public. Such signing will also degrade motorist compliance with signing at other work zone locations where a reduction in speed is needed to provide adequate safety.

The remedy to this problem is proper application of signing. The opinion of the panel is that construction projects must have someone designated on-site to be responsible for traffic control. To ensure proper training, this person should be ATSSA-certified (ATSSA is the American Traffic Safety Services Association). ADOT could require this as a standard provision and contractors would include this as a cost in their bid. This person should be responsible for proper traffic control and making sure that construction signing is displayed only when it is needed. Traffic control devices must be checked two to three times per day to insure their effectiveness.

TEMPORARY PAVEMENT MARKINGS IN WORK ZONES

The absence of striping was noted on 16 (19.5 percent) of the fatal accident reports in 1992 through 1996 (see Fatal Accident Analysis in Chapter 2). Although these accidents were also noted as being caused by speed and/or DUI, or driver inexperience, the lack of roadway striping combined with those factors could have contributed to the occurrence of the accident.

Temporary pavement markings in work zones received considerable attention at the national level during the latter 1980's and early 1990's. In 1993 the Federal Highway Administration issued a new edition of Part VI of the Manual on Uniform Traffic Control Devices (Part VI deals with traffic control for construction and maintenance zones). The new edition provides standards for the use of pavement markings in work zones. Important provisions include the following.

"Adequate pavement markings shall be maintained along paved streets and highways in temporary traffic control zones."

"Markings shall be placed, along the entire length of any surfaced detour or temporary roadway, before such detour or roadway is opened to traffic."

Provisions for interim markings are also included.

A copy of the MUTCD provisions is shown in Figure 9. If not already a standard practice, ADOT and local jurisdictions in Arizona should implement these MUTCD provisions.

ADDITIONAL PANEL RECOMMENDATIONS

Several other issues were discussed by the panel and additional recommendations made.

Maintenance personnel on the panel said that changeable message signs have been effective for maintenance activities and said they would like to have more of them available. There was a strong consensus among the panel that changeable message signs are useful and that it is desirable to have more available.

Several panel members supported Enhanced Fines, i.e., that fines be double in work zones. The panel understood, however, that ADOT had repeatedly sought legislation to allow enhanced fines and had not been successful in the state legislature.

Several panel members liked the British system of displaying the license plate number and speed of each speeding vehicle. There was a recognition, however, that additional research to determine its effectiveness in Arizona would be worthwhile.

All construction projects should include partnering sessions between ADOT, the Department of Public Safety, and the contractor to discuss and plan work zone traffic control and to promote work zone safety. As is done in the normal construction partnering activities of the agency, sessions should be held both prior to construction and periodically during construction to identify any problems, remedies, and to review traffic control for the next phase of construction.

The panel identified an institutional issue related to maintenance activities. When a maintenance activity is scheduled, maintenance personnel will inform ADOT's Traffic Operations unit. Word of the maintenance activity does not always reach the Department of Public Safety. If the maintenance personnel want the DPS to provide some presence at the maintenance site, they need to make sure that the DPS gets the word. ADOT Maintenance units do have the ability to pay for DPS officers on their work sites. However, tight maintenance budgets limit the widespread usage of DPS officers.

Oversize vehicles (extra-wide or extra-long vehicles) were raised as an issue. They are frequently a major problem at construction zones because lane widths are often narrowed and confined by concrete barriers. The current process of issuing permits for oversize vehicles does not (apparently) provide a way to inform oversize vehicles that there is restricted lane width on a route. Permits are not generally sold individually for an individual trip. Rather, the Motor Vehicle Division sells a book of permits and the hauler simply fills out a permit when it is needed. Thus, there is no opportunity to link information on a roadway restriction to an individual oversize vehicle trip.

FIGURE 9: MUTCD PROVISIONS FOR TEMPORARY PAVEMENT MARKINGS IN WORK ZONES

6F-6. MARKINGS

a. Pavement Marking Applications

Adequate pavement markings shall be maintained along paved streets and highways in temporary traffic control zones obliterated markings shall be unidentifiable as pavement markings under day or night, wet or dry conditions. The work should be planned and staged to provide the best possible conditions for the placement and removal of the pavement markings.

It is intended, to the extent possible, that motorists be provided markings within a work area comparable to the markings normally maintained along adjacent roadways, particularly at either end of the work area. The following guidelines set forth the level of markings and delineation for various work area situations.

(1) All markings shall be in accordance with part III A and part III B, except as indicated under 6F-6b (Interim Markings) of this manual.
(2) Markings shall be maintained in long-term stationary work areas and shall match and meet the markings in place at both ends of the work area.
(3) Markings shall be placed, along the entire length of any surfaced detour or temporary roadway, before such detour or roadway is open to traffic
(4) Centerline/lane lines should be placed, replaced, delineated where appropriate before the roadway is opened to traffic.
(5) Markings should be provided in intermediate-term stationary work areas, to the extent practicable.
(6) In any work area where it is not practical to provide a clear path by markings, appropriate warning signs, channelizing devices, and delineation shall be used to indicate the required vehicle path.

All markings and devices used to delineate vehicle and pedestrian paths shall be carefully reviewed during daytime and nighttime periods to avoid inadvertently leading drivers or pedestrians from the intended.

Proper pavement marking obliteration leaves a minimum of pavement scars and completely removes old marking materials. Obliterated markings shall be unidentifiable as pavement markings under day or night, wet or dry conditions. Overlaying existing stripes with black paint or asphalt does not meet the requirements of covering, removal or obliteration; however, the use of removable, nonreflective, preformed tape is permitted where markings need to be covered temporarily.

FIGURE 9: MUTCD PROVISIONS FOR TEMPORARY PAVEMENT MARKINGS IN WORK ZONES (Continued)

b. Interim Markings

Interim pavement markings are those that may be used until it is practical and possible to install pavement markings that meet the full MUTCD standards for pavement markings. Normally, it should not be necessary to leave interim pavement markings in place for more than 2 weeks. All interim pavement markings, including pavement markings for no-passing zones, shall conform to the requirements of sections 3A and 3B with the following exceptions:

(1) All interim broken-line pavement markings shall use the same cycle length as permanent markings and be at least 4 feet long, except that half-cycle lengths with a minimum of 2-foot stripes may be used for roadways with severe curvature. (See section 3A-6.) This applies to white lane lines for traffic moving in the same direction and yellow center lines for two-lane roadways when it is safe to pass

(2) For those interim situations of 3 calendar days or less for a two- or three-lane road, no-passing zones may be identified by using signs rather than pavement markings. (See sections 3B-4, 3B-5, and 3B-6.) Also, signs may be used in lieu of pavement markings on low- volume roads for longer periods, when this practice is in keeping with the State's or highway agency's policy. These signs should be placed in accordance with Sections 2B-21, 2B-22, and 2C-38.

(3) The interim use of edgelines, channelizing lines, lane reduction transitions, gore markings and other longitudinal markings, and the various non-longitudinal markings (stop line, railroad crossings, crosswalks, words, symbols, etc.) should be in keeping with the state's or highway agency's policy

The recent implementation of the Highway Closure and Restriction System (HCRS) provides an opportunity for haulers to check for restricted clearances before starting a trip. HCRS is a computer based system available to anyone via the Internet. ADOT posts information on all highway closures or restrictions on the State Highway System due to construction, maintenance, flooding, snow, or other reasons. ADOT should publicize the Highway Closure and Restriction System to oversize vehicle haulers.

There are two additional ways of accommodating oversize vehicles. Signing with the message "Oversize Trucks Not Allowed" can be posted far enough in advance so that the hauler is informed and the truck can take an alternate route. The other option is to stop oversize vehicles and escort them through the restricted area. One or both of these options should be used at any construction site that has narrowed lane width.

There is a continuing need to ensure that ADOT and local public agency employees are well trained in work zone traffic control. The work force changes as time goes by and it is important that new employees be trained. Continuing employees can benefit from periodic refresher training.

CHAPTER 5

IMPLEMENTATION OF COUNTERMEASURES

Recommended countermeasures were presented in Chapter 4. Recommendations for implementation of those countermeasures are presented in this chapter.

WORK ZONE SPEED LIMITS

ADOT and other jurisdictions in Arizona should follow the proposed MUTCD guidance on work zone speed limits (Figure 5 in Chapter 3) when developing traffic control plans and selecting speed limits to apply in work zones. This guidance should be included in the ADOT policies that guide development of traffic control plans. ADOT should also distribute this guidance to local jurisdictions in Arizona as an advisory. Application of the MUTCD guidance will result in safer work zones. Although a recommended practice, the MUTCD guidance does allow flexibility of application in special situations.

POLICE PRESENCE

ADOT, in cooperation with the Department of Public Safety, should explore ways to provide police presence at the upstream end of each work zone. Although there are currently provisions to pay for police presence to help with traffic control, there are still issues that need to be addressed (availability of DPS manpower, funding, and institutional issues) The types of work zones where police presence is desirable should also be identified. These might be specified as a function of traffic speed, traffic volume, or functional classification of roadway.

As noted in Chapter 4, a request for police presence on maintenance projects must be communicated from ADOT Maintenance to DPS. ADOT Maintenance units do have the ability to pay for DPS officers on their work sites, but tight budgets limit the use of DPS officers. These institutional issues must be overcome.

Local jurisdictions in Arizona should be encouraged to provide police presence for the same types of work zones as are selected by ADOT.

SPEED LIMIT ENFORCEMENT

ADOT, in cooperation with the Department of Public Safety, should explore ways to provide speed limit enforcement in each work zone. Availability of DPS manpower, funding, and institutional issues need to be addressed. The types of work zones where speed limit enforcement is desirable should also be identified. These might be specified as a function of traffic speed, traffic volume, or functional classification of roadway.

As noted in Chapter 4, a request for police assistance on maintenance projects must be communicated from ADOT Maintenance to DPS. ADOT Maintenance units do have the ability to pay for DPS officers on their work sites, but tight budgets limit the use of DPS officers. These institutional issues must be overcome.

For construction projects, ADOT and DPS should identify a mechanism for funding speed limit enforcement. The possible use of federal aid highway construction funds for this purpose should be investigated.

Local jurisdictions in Arizona should be encouraged to provide speed limit enforcement for the same types of work zones as are selected by ADOT.

Radar or other speed measuring system should be installed in every Department of Public Safety patrol car so that it is always available for an officer's use.

PUBLIC EDUCATION

Coverage of work zone safety and traffic control devices used in work zones should be expanded in the ADOT Motor Vehicle Division Driver's License Manual. The written test for driver licensing should include questions on work zones.

Through ADOT's Community Relations Office, any existing public education campaigns on work zone safety should be continued and expanded. The campaign could include public service announcements on radio and television and print media. ADOT should partner with industry, FHWA, and DPS to develop and initiate additional public service announcements on work zone safety. ADOT should work with the media to promote a television spokesperson for work zone safety.

SIGN CREDIBILITY

ADOT should require that construction projects have someone designated on-site to be responsible for traffic control. To ensure proper training, ADOT should require this person be ATSSA-certified (ATSSA is the American Traffic Safety Services Association). ADOT can require this as a standard provision and contractors would include this as a cost in their bid. This provision should also require that traffic control devices must be checked three times per day (twice during daylight and once at night) to insure their effectiveness.

ADOT should encourage local jurisdictions to have similar requirements.

For maintenance projects, ADOT and local agency employees must be well trained and qualified in work zone traffic control. Existing training programs should be continued and expanded to serve both ADOT and local agency staff.

TEMPORARY PAVEMENT MARKINGS IN WORK ZONES

If not already a standard practice, ADOT and local jurisdictions in Arizona should implement the MUTCD provisions for temporary pavement markings in work zones shown in Figure 9. These guidelines should be followed on both federally funded and locally funded projects.

PARTNERING SESSIONS ON CONSTRUCTION PROJECTS

All construction projects should include partnering sessions between ADOT, the Department of Public Safety, and the contractor to discuss and plan work zone traffic control and to promote work zone safety. As is done in the normal construction partnering activities of the agency, sessions should be held both prior to construction and periodically during construction to identify any problems, remedies, and to review traffic control for the next phase of construction.

INCREASE USE OF CHANGEABLE MESSAGE SIGNS ON WORK ZONE PROJECTS

ADOT should acquire additional changeable message signs for use on maintenance projects. ADOT should develop traffic control plans for construction projects that take advantage of changeable message signs and their flexibility in presenting messages. The types of work zones where Changeable Message Signs can be effectively used should be identified.

HIGHWAY CLOSURE AND RESTRICTION SYSTEM – USE BY OVERSIZE VEHICLES

ADOT should publicize the Highway Closure and Restriction System to oversize vehicle haulers and encourage its use prior to each oversize vehicle trip. This information should be included in the books of oversize vehicle permits that are sold by the Motor Vehicle Division.

ADOT should partner with FHWA, DPS and the Arizona Motor Transport Association to identify ways to reduce the number of oversize vehicles that travel through construction zones.

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