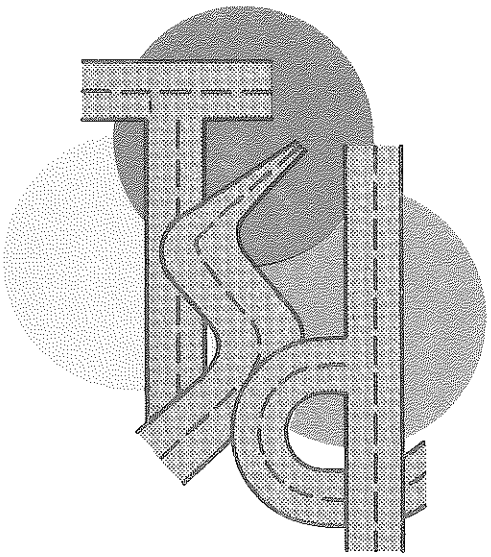
A Safety Evaluation of Three-Foot Paved Shoulder Projects in 1977

TSD 517-82



TRAFFIC and SAFETY DIVISION

MICHIGAN DEPARTMENT OF TRANSPORTATION

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A Safety Evaluation of Three-Foot Paved Shoulder Projects in 1977

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By

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This document was prepared to furnish information concerning the effect of shoulder edge treatments on accident experience. The opinions and conclusions implied or expressed herein do not necessarily reflect the official views or policies of the Michigan Department of Transportation.

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ABSTRACT

This report evaluates the effect on accident experience of providing three-foot paved shoulders. Fifteen project locations were selected from five of the department's nine highway district areas. Control sites selected for comparison had similar operational, geometric, and geographic characteristics. These rural roadway segments were high speed, two-lane, two-way roadways. Approximately 111 miles of three-foot paved shoulder projects and 97 miles of non-paved shoulder control sites were evaluated. The average daily traffic ranged from about 1,300 to 8,300 vehicles for the project locations and control sites. The accident experience for two years "before" and "after" was reviewed for each project and for the corresponding control site. Only accident information for mid-block locations was used for analytical purposes with intersection-related accidents excluded. The selection of both project locations and control sites were non random samples.

The total number of accidents, property damage accidents and injuries for the project locations increased. The number of injury accidents was unchanged while the number of fatal accidents and fatalities decreased.

The total number of accidents, property damage accidents, injury and fatal accidents increased for the selected control sites.

Accident types (i.e. run-off-road, head-on, sideswipe, rear-end) increased in some categories and decreased in others for both project and control sites. Statistical tests to determine the significance of the changes were utilized and are discussed within the text.

It is concluded that this shoulder treatment had a statistically significant impact on reducing the frequency of run-off-roadway, vehicle overturn, side-swipe-opposite and fixed-object (sign) accidents. Although total accidents at the test sites increased 6 percent, this was 19 percent less than the expected value for total accidents predicted using the 29 percent increase at the control sites. Volume changes at the control and test sites were similar.

INTRODUCTION

The creation of the Michigan State Highway Department in 1905 was the initial step in developing Michigan's network of modern highways. The innovations and accomplishments are many from those original dirt roadways to todays' paved highway system. The birth of Michigan's 3R program began in 1973 when the concept of highway Resurfacing was expanded to include some road Reconstruction and Restoration for capacity and maintenance purposes. In 1974, a program was developed to focus on shoulder edge treatments for heavily commercialized highways in order to reduce maintenance activity and increase safety.

The practice of constructing a three-foot bituminous edge strip along the right-hand side of state highways was incorporated into resurfacing of rural highways in 1978. This practice continues today.

The type of improvement for the 15 locations selected for study in this report included only the addition of a three-foot paved strip along the edge of high-speed, two-lane, two-way rural roadways. No other improvements, such as resurfacing, joint repairs, or spot safety improvements, were accomplished in conjunction with these shoulder projects. There were no improvements at the various control site locations during the study period. Strict control was maintained in order to fully determine the effect shoulder projects had on accident experience. Refer to Appendix A for listing of the project locations and control sites.

The number of project miles and the mileage of control sites were as close as possible while retaining similar operational, geometric, and geographic characteristics (see Appendix A).

The control sites, in effect, represent the "do nothing" alternative which shows what would have happened if no paved shoulder treatments were instituted.

GENERAL DISCUSSION

With the ever-increasing demand for the transportation dollar, it is evident that all agencies from the local to the federal level, must examine and allocate the expenditure of funds. As funds become limited, the competition is keen as to what types of programs/projects should continue to be funded.

Do maintenance activities continue to outweigh construction demands? Should greater attention be given to a series of minor roadway improvements, such as shoulder ribbon or highly cost-effective spot safety improvements supported by a continuing accident experience? If the need is to accomplish all of these, how much funding should be delegated to each? Every agency is faced with the question of prioritization. The answer to these questions, of course, largely depend on the agency itself and on the funding sources available. The key element is how effective the program/ project is in terms of dollars spent. What is the benefit relative to the investment?

There are various measures of effectiveness (M.O.E.) to determine the benefit of a program/project. Such factors include accident reduction, vehicle operating cost, travel time, fuel consumption, air quality, and others.

This report evaluates the effect on accident experience of providing a three-foot bituminous shoulder along various state trunkline highway sections. It must be reemphasized that the intent of shoulder edge treatments was to reduce maintenance activity and increase overall traffic safety on trunkline roadways where a large number of trucks in the traffic stream was evident. The systematic inclusion of this treatment in most rural resurfacing projects in 1978 was prompted by earlier litigation against the department.

ACCIDENT FREQUENCY

For the typical high-speed, two-lane, two-way, rural highway segment, it seemed reasonable to assume that the addition of paved shoulders would improve highway safety through the reduction of certain accident types, such as ran-off-roadway, head-on, and sideswipe collisions. This additional available pavement could provide the motorist a greater opportunity to either recover from or minimize out-of-control maneuvers. Analysis of the two years' "before" and two years "after" accident data is interesting with respect to these expectations.

The total number of accidents at the project locations increased by 45, and the number of property damage accidents increased by 47. There was no change in the number of personal injury collisions but the number of injuries increased by 27. The number of fatal collisions and fatalities decreased by two and three, respectively (Table 1).

The total number of accidents at the control sites increased by 108, and the number of property damage accidents increased by 70. The number of injury accidents and injuries increased by 33 and 74, respectively, and the number of fatal collisions and fatalities increased by five and 12, respectively (Table 2).

A review of the accident types for the project locations showed decreases in ran-off-roadway collisions by 32, sideswipe-opposite direction by 12, and sideswipe-same direction by nine. Head-on collisions increased by 24 and rear-end accidents by 15, along with an increase noted in several other accident types (Table 1). It should be noted that the number of "parking" related collisions appears to be higher than expected for two-lane, two-way rural highways. However, it is hypothesized that this pattern was influenced by the practice of assigning a "parking" designation to vehicles involved in either entering or leaving driveways. A similar review of the "before" and "after" accident data for the control site locations showed an increase in most accident types (Table 2).

Since a sizeable decrease in ran-off-roadway accidents occurred, a closer examination of these for the project locations was conducted. Table 3 shows the various type of ran-off-roadway collisions investigated. Overturn accidents were reduced by 17, collisions involving ditches were reduced by 13, mailboxes by nine, signs by three, and poles by two. A similar review for "before" and "after" accidents at the control sites showed an increase in all of the same accident types (Table 4).

Chi-square tests were used to determine whether the changes at the project locations versus the control sites were significant (Appendix B). The increase in total accidents at the control sites was significant at the 97.3 percent confidence level when compared to the increase of total accidents at the project locations. The decrease in ran-off-roadway accidents at the project locations was significant at the 99.4 percent confidence level when compared to the increase of these accidents at the control sites. Sideswipe-opposite accidents at the project sites were reduced significantly (94.6% confidence level) compared to the increase at the control locations. Additionally, accidents involving signs at the project sites were reduced significantly (97.5% confidence level) compared to the increase at the control locations. The reductions in the remaining patterns were not statistically significant which may be due, in part, to the low numbers involved.

Table 1

ALL ACCIDENTS BY TYPE
(fatal, injury & property damage)

Three-foot Paved Shoulder Project Locations
2 Years "Before" & 2 Years "After"

	BEFORE				AFTER				CHANGE				
Type	PD	Injury (Injrd)	Fatal (Kld)	Total	PD	Injury (Injrd)	Fatal (Kld)	Total	PD	Injury (Injrd)	Fatal (Kld)	Total	%
Ran-off-road	147	92(113)	4(4)	243	126	81(118)	4(4)	211	-21	-11(5)	0	-32*	-13
Head-on	26	16(50)	7(9)	49	37	31(82)	5(6)	73	11	15(32)	-2(-3)	24	49
Sideswipe Same	10	2(2)	0	12	2	1(1)	0	3	- 8	-1(-1)	0	-9	-75
Sideswipe Opposite	17	8(14)	0	25	6	7(8)	0	13	-11	-1(-6)	0	-12*	-48
Rear-end	47	32(54)	0	79	77	38(76)	0	115	30	6(22)	0	36	46
Right Angle	0	0	0	0	7	2(2)	0	9	7	2(2)	0	9	
Right Turn	0	0	0	0	3	1(1)	0	4	3	1(1)	0	4	
Left Turn	5	3(8)	0	8	15	8(12)	0	23	10	5(4)	0	15	188
Backing	2	0	0	2	3	0	0	3	1	0	0	1	50
Parking	57	35(70)	1(1)	93	65	19(40)	1(1)	85	8	-16(-30)	0	-8	- 9
Overhead Object	3	0	0	3	1	0	0	1	- 2	0	0	-2	-67
Multi-Vehicle Other	5	1(4)	0	6	8	1(1)	0	9	3	0(-3)	0	3	50
Animal	181	4(4)	0	185	198	6(6)	0	204	17	2(2)	0	19	10
Pedestrian	0	4(4)	0	4	0	3(5)	0	3	0	-1(1)	0	-1	-25
Bike	0	4(5)	1(1)	5	1	3(3)	1(1)	5	1	-1(-2)	0	0	0
Misc.	6	2(2)	0	8	4	2(2)	0	6	- 2	0	0	-2	-25
Total	506	203(330)	13(15)	722	553	203(357)	11(12)	767	47	0(27)	-2(-3)	45	6

* Statistically significant changes when compared to control sites
(-) Frequency/percentage decrease

Table 2

ALL ACCIDENTS BY TYPE
(fatal, injury & property damage)

Non-Paved Shoulder Control Sites
2 Years "Before" & 2 Years "After"

	BEFORE				AFTER				CHANGE				
TYPE	PD	Injury (Injrd)	Fatal (Kld)	Total	PD	Injury (Injrd)	Fatal (Kld)	Total	PD	Injury (Injrd)	Fatal (Kld)	Total	%
Ran-off-road	64	52(73)	2(2)	118	94	62(81)	2(2)	158	30	10(8)	0	40	34
Head-on	13	10(25)	0	23	16	16(39)	3(9)	35	3	6(14)	3(9)	12	52
Sideswipe Same	4	1(2)	0	5	5	0	0	5	1	-1(-2)	0	0	0
Sideswipe Opposite	3	0	0	3	3	5(10)	0	8	0	5(10)	0	5	167
Rear-end	27	11(14)	0	38	27	15(27)	1(2)	43	0	4(13)	1(2)	5	13
Right Angle	1	0	0	1	6	1(3)	0	7	5	1(3)	0	6	600
Right Turn	1	0	0	1	0	2(3)	0	2	- 1	2(3)	0	1	100
Left Turn	4	0	0	4	7	4(9)	0	11	3	4(9)	0	7	175
Backing	1	0	0	1	2	0	0	2	1	0	0	1	100
Parking	23	11(18)	0	34	17	14(35)	1(1)	32	- 6	3(17)	1(1)	- 2	- 6
Overhead Object	0	0	0	0	1	0	0	1	1	0	0	1	100
Multi-Vehicle Other	0	2(2)	0	2	1	0	0	1	1	-2(-2)	0	- 1	-50
Animal	130	3(3)	0	133	164	4(4)	0	168	34	1(1)	0	35	26
Pedestrian	0	3(3)	0	3	0	3(3)	0	3	0	0	0	0	0
Bike	1	0	0	1	0	2(2)	0	2	- 1	2(2)	0	1	100
Misc.	2	3(3)	0	5	1	1(1)	0	2	- 1	-2(-2)	0	- 3	-60
Total	274	96(143)	2(2)	372	344	129(217)	7(14)	480	70	33(74)	5(12)	108	29

(-) Frequency/percentage decrease

Table 3

RAN-OFF-ROAD ACCIDENTS BY OBJECT HIT
(Fatal, Injury, & Property Damage)

Three-Foot Paved Shoulder Project Locations
2 Years "Before" & 2 Years "After"

	BEFORE				AFTER				CHANGE				
TYPE	PD	Injury (Injrd)	Fatal (Kld)	Total	PD	Injury (Injrd)	Fatal (Kld)	Total	PD	Injury (Injrd)	Fatal (Kld)	Total	%
Overturn	26	44(59)	2(2)	72	22	32(43)	1(1)	55	-4	-12(-16)	-1(-1)	-17*	-24
Ditch	32	16(17)	0	48	25	10(15)	0	35	-7	-6(-2)	0	-13	-27
Tree	17	7(8)	2(2)	26	12	16(23)	3(3)	31	-5	9(15)	1(1)	5	19
Mailbox	20	5(5)	0	25	14	2(2)	0	16	-6	-3(-3)	0	- 9	-36
Guardrail	17	6(7)	0	23	15	9(14)	0	24	-2	3(7)	0	1	4
Sign	14	6(9)	0	20	14	3(7)	0	17	0	-3(-2)	0	- 3*	-15
Pole	8	0	0	8	4	2(5)	0	6	-4	2(5)	0	- 2	-25
Fence	4	3(3)	0	7	8	3(5)	0	11	4	0(2)	0	4	57
Off Road Object	1	1(1)	0	2	0	2(2)	0	2	-1	1(1)	0	0	0
Other Object	8	4(4)	0	12	12	2(2)	0	14	4	-2(-2)	0	2	17
Total R-O-R	147	92(113)	4(4)	243	126	81(118)	4(4)	211	-21	-11(5)	0	-32*	-13

* Statistically significant changes when compared to control sites
(-) Frequency/percentage decrease

Table 4

RAN-OFF-ROAD ACCIDENTS BY OBJECT HIT
(Fatal, Injury, & Property Damage)

Non-Paved Shoulder Control Sites
2 Years "Before" & 2 Years "After"

	BEFORE				AFTER				CHANGE				
TYPE	PD	Injury (Injrd)	Fatal (Kld)	Total	PD	Injury (Injrd)	Fatal (Kld)	Total	PD	Injury (Injrd)	Fatal (Kld)	Total	%
Overturn	14	21(35)	0	35	16	32(42)	0	48	2	11(7)	0	13	37
Ditch	14	9(11)	0	23	15	10(13)	0	25	1	1(2)	0	2	9
Tree	5	10(13)	2(2)	17	10	6(7)	1(1)	17	5	-4(-6)	-1(-1)	0	0
Mailbox	9	1(1)	0	10	13	1(1)	0	14	4	0	0	4	40
Guardrail	12	4(4)	0	16	12	3(3)	0	15	0	-1(-1)	0	-1	-6
Sign	2	0	0	2	9	2(2)	1(1)	12	7	2(2)	1(1)	10	500
Pole	2	4(6)	0	6	5	4(7)	0	9	3	0(1)	0	3	50
Fence	4	2(2)	0	6	7	1(1)	0	8	3	-1(-1)	0	2	33
Off Road Object	0	1(1)	0	1	3	0	0	3	3	-1(-1)	0	2	200
Other Object	2	0	0	2	4	3(5)	0	7	2	3(5)	0	5	250
Total R-O-R	64	52(73)	2(2)	118	94	62(81)	2(2)	158	30	10(8)	0	40	34

(-) Frequency/percentage decrease

ACCIDENT ANALYSIS - EXPECTED VS OBSERVED FREQUENCIES

Further analysis of accident frequency was accomplished by determining the change in accident patterns for control sites, calculating the after expected accident frequency for the project location and comparing them to the actual after observed frequencies (Table 5). Again, chi-square tests were used to determine whether the difference in the expected accident frequency at the project location and the observed frequency for various accident patterns was significant. Table 6 shows the change in total accidents for those types that decreased and increased. The analysis of all accident types that decreased for the project locations were statistically significant at the 99 percent confidence level. The major contributors to this were both ran-off-roadway and sideswipe-opposite accidents. The analysis those types that increased was also statistically significant at the 99 percent confidence level with the major contributors being rear-end, right-turn, and other multi-vehicle type collisions. It should be noted in the case of both right-angle and other multi-vehicle type accidents, that caution be used in recognizing statistical significance due to the small sample size of these categories. The increase in rear-end accidents at the project locations is not consistent with expected results found in the control sites. From a traffic engineering standpoint, it is not readily assumed that the addition of paved shoulders on a two-lane, two-way roadway would have much of an effect on rear-end type collisions. Perhaps, the increase found in this study could be related to roadside development. Unfortunately this aspect cannot be clarified due to the lack of appropriate information.

A description of ran-off-roadway accidents using similar analysis of expected and observed frequencies is included in Table 7. Chi-square test shown in Table 8 indicated that the analysis of ran-off-roadway type accidents that decreased was significant at the 99 percent confidence level. Further examination shows that overturn and sign-related collisions were principle factors. The analysis of ran-off-roadway accidents that showed increased frequencies was not significant as a group.

TABLE 5

ALL ACCIDENTS BY TYPE

Type	% Change @ Control Sites	After Expected for Project Locations	After Observed for Project Locations	% Change
Ran-off-roadway	+ 34	326	211	- 35
Head-on	+ 52	74	73	- 1
Sideswipe-Same	+ 0	12	3	- 75
Sideswipe-Opposite	+167	67	13	- 81
Rear-end	+ 13	89	115	+ 29
Right-angle	+600	6	9	+ 33
Right-turn	+100	1	4	+300
Left-turn	+175	22	23	+ 5
Backing	+100	4	3	- 25
Parking	- 6	87	85	- 2
Overhead Object	+100	6	1	- 83
Multi-vehicle				
Other	- 50	3	9	+200
Animal	+ 26	233	204	- 12
Pedestrian	0	4	3	- 25
Bike	+100	10	5	- 50
Miscellaneous	- 60	3	6	+100
Total		947	767	- 19

(-) Percentage Decrease

TABLE 6

ALL ACCIDENT TYPES THAT DECREASED

Type	Expected	Observed	E-0	$(E-0)^2$	$\frac{(E-0)^2}{E}$
Ran-off-roadway	326	211	115	13,225	40.57#
Head-on	74	73	1	1	0.01
Sideswipe-Same	12	3	9	81	6.75
Sideswipe-Opposite	67	13	54	2,916	43.52#
Backing	4	3	1	1	0.25
Parking	87	85	2	4	0.05
Overhead Object	6	1	5	25	4.17
Animal	233	204	29	841	3.61
Pedestrian	4	3	1	1	0.25
Bike	10	5	5	25	2.50
					101.68*
			df = 9	P <0.001	
			*Significant @ 99%		

ALL ACCIDENT TYPES THAT INCREASED

Type	Expected	Observed	E-0	$(E-0)^2$	$(E-0)^2/E$
Rear-end	89	115	26	676	7.60 #
Right-angle	6	9	3	9	1.50
Right-turn	1	4	3	9	9.00 #
Left-turn	22	23	1	1	0.05
Other Multi-vehicle	3	9	6	36	12.00 #
Miscellaneous	3	6	3	9	3.00
					33.15*
		df = 5	P < 0.001		
			*Significant @ 99%		

(#) denotes major contributors to statistical significance

TABLE 7

RAN-OFF-ROADWAY ACCIDENTS BY OBJECT HIT

Type	% Change @ Control Site	After Expected for Project Locations	After Observed for Project Locations	% Change
Overturn	+ 37	99	55	- 44
Ditch	+ 9	52	35	- 33
Tree	0	26	31	+ 19
Mailbox	+ 40	35	16	- 54
Guardrail	- 6	22	24	+ 9
Sign	+500	100	17	- 83
Pole	+ 50	12	6	- 50
Fence	+ 33	9	11	+ 22
Off-Road Object	+200	4	2	- 50
Other Object	+250	30	14	- 53
Total R.O.R.		389	211	- 46

(-) Percentage Decrease

TABLE 8

RAN-OFF-ROADWAY TYPES THAT DECREASED

Type	Expected	Observed	E-O	$(E-O)^2$	$(E-O)^2/E$
Overturn	99	55	44	1,936	19.56#
Ditch	52	35	17	289	5.56
Mailbox	35	16	19	361	10.31
Sign	100	17	83	6,889	68.89#
Pole	12	6	6	36	3.00
Off-Road Object	4	2	2	4	1.00
Other Object	30	14	16	256	8.53
					116.85*
		df = 6		P < 0.001	
				* Significant @ 99%	

RAN-OFF-ROADWAY TYPES THAT INCREASED

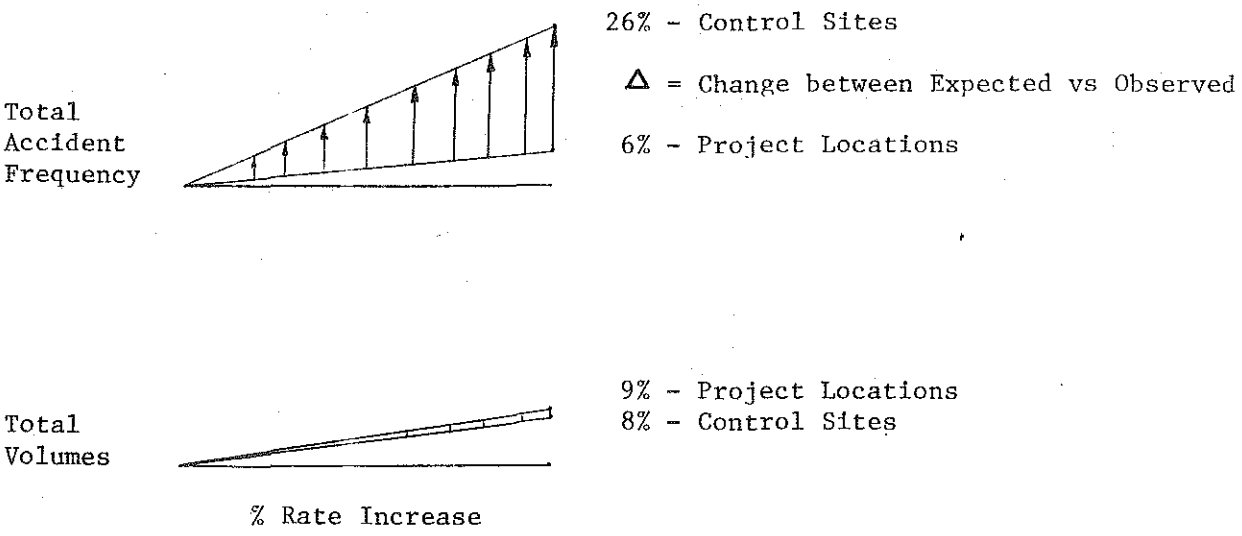
Type	Expected	Observed	E-O	$(E-O)^2$	$(E-O)^2/E$
Tree	26	31	5	25	0.96
Guardrail	22	24	2	4	0.18
Fence	9	11	2	4	0.44
					1.58
		df = 2		0.50 < P < 0.25	
				Not Significant	

(#) Denotes major contributors to statistical significance

Accident Rates

The initial data collection process did not provide for detailed information regarding specific accident rate analysis of either the project locations or the control sites. However, sufficient information was obtained to determine district-wide rates for all accident types which are shown on Table 9.

It is most interesting to see the general percent reduction between the expected and observed total accident frequencies for all but one district. This can be attributed to the percent increase in total accident frequency at the control sites which was much greater than the increase at the project location while the increase in total traffic volumes at both were about the same. The following graph depicts this situation:



Since the change in traffic volumes remained similar for both cases, it can be hypothesized that the paved shoulder treatment may have had some effect on total accident frequency at the project locations.

The determination of district-wide rates for ran-off-roadway accidents was also tabulated and shown in Table 10. There was a percent reduction in expected vs observed total ran-off-roadway accidents for all but one district.

TABLE 9

ALL ACCIDENT TYPES - ACCIDENT RATES (ACC/100MVM)
(Property Damage Only, Injury & Fatal, Total)

DISTRICT	TYPE	CONTROL SITES			PROJECT LOCATIONS			PERCENT CHANGE %
		BEFORE	AFTER	PERCENT CHANGE	BEFORE	AFTER EXPECTED	AFTER OBSERVED	
2	Total	78.61	108.39	38	89.77	123.88	68.72	- 45
	PDO	59.24	51.76	-12.6	66.23	57.89	51.23	- 11.5
	I&F	19.37	26.37	36.1	23.55	32.05	17.49	- 45.4
5	Total	72.71	74.77	3	57.21	58.93	56.97	- 3
	PDO	54.25	58.75	8.3	42.64	46.18	41.89	- 9.3
	I&F	18.47	16.02	-13.3	14.56	12.62	14.60	15.7
6	Total	74.10	64.95	-12	86.50	76.12	64.15	- 16
	PDO	55.57	43.30	-22.1	58.29	45.41	42.76	- 5.8
	I&F	18.52	21.65	16.9	28.21	32.98	21.38	- 35.2
7	Total	46.99	48.92	4	94.33	98.10	107.78	10
	PDO	32.43	32.41	- 0.1	75.93	75.83	79.04	4.2
	I&F	14.56	16.51	13.4	19.17	21.74	28.74	32.2
8	Total	21.94	29.84	36	48.57	66.06	47.37	- 28
	PDO	15.76	23.33	48	29.85	44.18	32.61	- 26.2
	I&F	61.89	92.33	49	18.90	28.16	15.09	- 46.4

(-) Percentage Decrease

TABLE 10

RAN-OFF-ROADWAY - ACCIDENT RATES (ACC/100MVM)
(Property Damage Only, Injury & Fatal, Total)

DISTRICT	TYPE	CONTROL SITES			PROJECT LOCATIONS			PERCENT CHANGE %
		BEFORE	AFTER	PERCENT CHANGE	BEFORE	AFTER EXPECTED	AFTER OBSERVED	
2	Total	29.62	52.73	78	52.98	94.30	34.99	- 63
	PDO	19.37	31.25	61	35.32	56.87	21.24	- 63
	I&F	10.25	21.48	110	17.66	37.09	13.74	- 63
5	Total	25.39	24.57	- 3	24.18	23.45	18.43	- 21
	PDO	11.54	12.82	11	13.52	15.01	10.05	- 33
	I&F	13.85	11.75	- 15	10.66	9.06	8.38	- 8
6	Total	34.73	25.59	- 26	37.61	27.83	17.82	- 36
	PDO	23.16	7.89	- 66	18.80	6.39	7.13	12
	I&F	11.58	17.71	53	18.80	28.76	10.69	- 63
7	Total	23.83	20.79	- 13	39.88	34.70	39.52	14
	PDO	14.56	11.62	- 20	28.38	22.70	22.99	1
	I&F	9.27	9.17	- 1	11.50	11.39	16.53	45
8	Total	9	16.82	87	23.67	44.26	21.25	- 52
	PDO	4.78	11.39	138	14.48	34.46	12.82	- 63
	I&F	4.22	5.43	29	9.18	11.84	8.44	- 29

(-) Percentage Decrease

TRAFFIC VOLUMES

Tables 11 and 12 show the traffic volume data for the three-foot paved shoulder project locations and the control sites, respectively. Two years of "before" and "after" information was gathered and averaged to provide estimated ADT values by district. The percentage change is listed. The total volume before and after ADT summaries and percent changes are also included. Vehicle speeds were not taken into consideration in this study since this information was not available throughout all project/control areas.

Table 11

TRAFFIC VOLUME DATA
Three-Foot Paved Shoulder Project Locations

DISTRICT	ROUTE	CONTROL SECTION	ESTIMATED AVERAGE DAILY TRAFFIC BEFORE	YEARS	AFTER	YEARS	CHANGE IN ADT %
2	US-2	21024	2600	1973-74	3200	1976-77	23
	US-2	75021	2600	1973-74	2925	1976-77	13
5	M-21	34061	2850	1973-75	2975	1976-78	4
	M-21	34062	3000	1973-74	3200	1976-77	7
	M-82	62011	5600	1975-76	6150	1978-79	10
	M-82	62022	2750	1975-76	3100	1978-79	13
6	M-21	44042	6300	1973-74	6600	1976-77	5
	M-57	73021	5450	1974-75	5800	1977-78	6
7	M-40	03072	4300	1974-75	4675	1977-78	9
	M-140	11071	3500	1975-76	3650	1978-79	4
8	M-50	38071	6500	1973-74	6900	1976-77	6
	US-223	46062	7800	1973-74	7650	1976-77	-2
	M-50	46082	7150	1974-75	7900	1977-78	10
	US-12	46101	4850	1974-75	6000	1977-78	24
	US-12	81031	1300	1973-74	1600	1976-77	23
Total			66550		72325		9

(-) Percentage decrease

Table 12

TRAFFIC VOLUME DATA
Non-Paved Shoulder Control Sites

DISTRICT	ROUTE	CONTROL SECTION	ESTIMATED ADT'S BEFORE	YEAR(S)	AFTER	YEAR(S)	CHANGE IN ADT %
2	US-2	21024	4550	1973-74	5500	1976-77	21
	M-94	75032	2650	1973-74	2900	1976-77	9
5	M-21	41043	5000	1974-75	6300	1977-78	26
	M-82	62021	3550	1975-76	2900	1978-79	-18
	M-46	62041	2000	1975-76	2200	1978-79	10
6	M-57	73021	5100	1974-75	6000	1977-78	18
7	M-89	03021	3100	1974-75	3350	1977-78	8
	M-140	11071	2750	1975-76	3100	1978-79	13
	M-140	11074	2050	1975-76	2100	1978-79	2
8	M-50	38071	5250	1973-74	5000	1976-77	-5
	US-223	46062	7800	1973-74	8250	1976-77	6
	M-50	46082	7125	1974-75	7375	1977-78	4
	US-12	46101	4050	1974-75	4500	1977-78	11
Total			54975		59475		8

(-) Percentage decrease

CONCLUSIONS

It is apparent that the provision of three-foot paved shoulders on rural, high-speed roadways had little effect on overall accident experience. Ran-off-roadway, sideswipe-same direction, and sideswipe-opposite direction collisions decreased while the remaining types generally increased.

The overall accident experience, as well as various accident types, increased at the control sites. These increases, when compared to the reduction in the accident types at the project locations, provide evidence to support the theory that three-foot paved shoulders have an impact on specific accident types.

In practice, however, careful attention must be placed on the specific type and expected accident reduction to be included in a cost/benefit analysis used for project justification. It is apparent that the anticipated savings due to expected reductions in accident types are not sufficient to warrant a shoulder treatment for safety alone. While such projects do yield safety benefits, continuation of such program should be based on other than safety-related factors (Table 13).

Table 13

RESURFACING PROGRAMS

FISCAL YEAR	MILES RESURFACED Mb	Mbr	TOTAL	Msh	AWARD + 15% Mb	Mbr	Msh	TOTAL Mb, Mbr, Msh Award +15%
1968	250				$ 6,602,000			$ 6,602,000
1969	251				5,826,240			5,826,240
1970	187				6,929,990			6,929,990
1971	260				8,434,270			8,434,270
1972	370				14,739,590			14,739,590
1973	336	78	414		11,430,060	$ 4,321,261		15,751,321
1974	425	219	644	136	18,103,694	13,753,058	$ 1,799,387	33,656,139
1975	409	89	498	168	16,574,387	6,307,961	1,782,359	24,664,707
1976	389	182	571	263	13,515,300	9,674,900	2,506,700	25,696,900
1977	257	70	327	198	13,349,200	8,459,400	3,275,200	25,083,800
* 1978	290	161	451	**162	21,753,000	15,934,000	4,764,000	42,451,000
* 1979	205	106	311	**232	14,300,000	10,717,000	4,523,000	29,540,000

*All resurfacing to include 3' bit shoulders
**Includes Mod 4' shoulders

Michigan Funded Projects (100% state funds)
Mb - Bituminous Resurfacing
Mbr - Bituminous Reconstruction
Msh - Shoulder Edge Treatment

FUTURE STUDY

Since this study addressed only two years of "before" and two years "after" data, it may be appropriate to obtain additional information to develop long-term accident trends in relation to shoulder edge treatments. The investigation of more specific accident rates and alternative statistical tests (i.e. regression analysis) may be beneficial, but is presently limited by the lack of available human resources.

It may also be desirable to address additional features, such as commercial development, vehicle speeds, horizontal and/or vertical alignment, in-state and/or out-state driver residency, motor-vehicle size, and travel trends to discover any useful generalizations.

Appendix A

Index of 3-Foot Paved Shoulder Projects
Index of Non-paved Shoulder Control Sites
Mileage Summaries by District

Index of Three-Foot Paved Shoulder Projects

District	Control Sections	Mile Points	Route	Location Description	Length (Miles	Letting Date
2	21024	20.65 to 25.43	US-2	Big Fishdam Rv. E'ly to WCL Manistique	4.8	8-22-74
	75021	0.00 to 12.07			12.1	
5	34061	4.93 to 12.95	M-21	Hawly Hwy to E. Co. Line	8.0	4-16-75
	34062	1.34 to 12.69			11.4	
5	34061	0.00 to 4.93	M-21	W. Co Line E'ly to Hawly Hwy.	4.9	1-21-76
5	62011	0.00 to 3.69	M-82	M-120 E'ly. to M-37	3.7	10-20-76
	62022	0.68 to 9.82			9.1	
6	44042	13.20 to 17.42	M-21	M-53 to E Co. Line	4.2	11-20-74
6	73021	10.19 to 12.19	M-57	M-52 E'ly 2.0 miles	2.0	1-21-76
7	03072	1.30 to 18.71	M-40	WCL Allegan NW'ly to I-196	17.4	7-21-76
7	11071	7.55 to 13.00	M-140	Napier Rd. N'ly to I-94	5.5	3-16-77
8	38071	4.34 to 5.38	M-50	US-127 to South St.	1.0	11-20-74
8	46062	2.79 to 4.06	US-223	M-52 to Treat Rd.	1.3	3-19-75
8	46062	13.72 to 18.55	US-223	Blissfield to E Co. Line	4.8	10- -74
8	46082	0.00 to 2.04	M-50	M-152 to WCL Tecumseh	2.0	4-21-76
8	46101	11.81 to 20.53	US-12	M-124 E'ly to N Co. Line	8.7	1-21-76
8	81031	2.51 to 8.54	US-12	McCollum Rd. To Dell Rd.	6.0	4-16-75
8	81031	12.41 to 16.69	US-12	NCL Saline to US-23	4.3	4-16-75

Index of Non-Paved Shoulder Control Sites

District	Control Section	Mile Point	Route	Location Description	Length (Miles)
2	21024	0.71 to 1.11	US-2	Near Rapid River to Co. Rd. I-19	
2	21024	3.10 to 4.43	US-2	Near M.S.T.P. RR to Co. Rd. J-7, J-31	
2	75032	6.50 to 21.50	M-94	Old M-94 to Island Lake Rd.	16.7
5	41043	6.89 to 12.02	M-21	Near Bennett St. to WCL Lowell	
5	62021	1.05 to 6.88	M-82	M-120, Baseline/Garfield Rds. to Skeels/Maple Island Rds.	
5	62041	0.70 to 12.19	M-46	Linden to Newcosta Ave.	22.5
6	73021	0.00 to 10.12	M-57	Gratiot/Saginaw Co Ln to M-52	
6	73021	13.40 to 14.85	M-57	Near Sunnyside St. to Stuart Rd.	11.6
7	03021	0.62 to 5.27	M-89	N of Blue Star Hwy. to 58th St.	
7	03021	6.46 to 11.49	M-89	Near ECL Fennville to 46th St.	
7	11071	0.22 to 7.47	M-140	Near M-62 Jct. to Napier Ave. (Co. Rd. 352)	
7	11074	0.07 to 9.34	M140	Near Jct. US-31,33 to Pipestone Rd.	22.6
8	38071	11.18 to 14.44	M-50	Near SVL Napoleon to Goose Creek	
8	38071	15.58 to 17.05	M-50	Near M124 (SCL Brooklyn) to Monrose Pike Rd.	
8	46062	9.45 to 2.66	US-223	Madison Twp. Line to Cadmus Rd.	
8	46082	4.34 to 8.60	M-50	ECL Tecumseh to Village of Britton	
8	46101	0.38 to 4.63	US-12	Near Jct. US-127, 223 to Miller Rd.	
8	46101	5.19 to 7.38	US-12	Near Miller Rd. to WVL Cambridge Jct.	20.1

Mileage Summaries by District

District	Three-Foot Paved Shoulder Projects (Miles)	Non-Paved Shoulder Control Sites (Miles)
2	16.9	16.7
5	37.1	22.5
6	6.2	11.6
7	22.9	26.2
8	28.1	20.1
Total	111.2	97.1

Appendix B

Statistical Tests

FILE ACC (CREATION DATE = 03/24/81) TOTAL ACCIDENTS SHLD + CONTROL SITES

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WORK BY AFTBEF
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WORK	COUNT / ROW PCT / COL PCT / TOT PCT	AFTBEF BEFORE, 1.	AFTER, 2.	ROW TOTAL
SHOULDER JOB,	3.	722	767	1489
		48.5	51.5	63.6
		66.0	61.5	
		30.8	32.8	
CONTROL SITE,	4.	372	480	852
		43.7	56.3	36.4
		34.0	38.5	
		15.9	20.5	
	COLUMN TOTAL	1094	1247	2341
		46.7	53.3	100.0

CORRECTED CHI SQUARE = 4.88015 WITH 1 DEGREE OF FREEDOM SIGNIFICANCE = 0.0272

FILE ACC (CREATION DATE = 03/24/81) RUN CFF ROADWAY ACCIDENTS SHLD + CONTROL SITES

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WORK BY AFTBEF
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WORK	AFTBEF COUNT ROW PCT COL PCT TOT PCT	BEFORE, 1.	AFTER, 2.	ROW TOTAL
SHOULDER JOB,	3.	243 53.5 67.3 33.3	211 46.5 57.2 28.9	454 62.2
CONTROL SITE,	4.	118 42.8 32.7 16.2	158 57.2 42.8 21.6	276 37.8
	COLUMN TOTAL	361 49.5	369 50.5	730 100.0

CORRECTED CHI SQUARE = 7.54084 WITH 1 DEGREE OF FREEDOM SIGNIFICANCE = 0.0060

FILE ACC (CREATION DATE = 03/26/81) HD-ON ACCIDENTS SHLD + CONTROL SITES

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WORK	AFTBEF COUNT / ROW PCT / COL PCT / TOT PCT	BEFORE, 1.	AFTER, 2.	ROW TOTAL
SHOULDER JOB,	3.	49 40.2 68.1 27.2	73 59.8 67.6 40.6	122 67.8
CONTROL SITE,	4.	23 39.7 31.9 12.8	35 60.3 32.4 19.4	58 32.2
	COLUMN TOTAL	72 40.0	108 60.0	180 100.0

CORRECTED CHI SQUARE = 0.00954 WITH 1 DEGREE OF FREEDOM SIGNIFICANCE = 0.9222

FILE ACC (CREATION DATE = 03/24/81) SS-SM ACCIDENTS SHLD + CONTROL SITES

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WORK	COUNT / ROW PCT / COL PCT / TOT PCT	AFTBEF: BEFORE, 1.	AFTER, 2.	ROW TOTAL
3. SHOULDER JOB,		12 80.0 70.6 52.2	3 20.0 50.0 13.0	15 65.2
4. CONTROL SITE,		5 62.5 29.4 21.7	3 37.5 50.0 13.0	8 34.8
	COLUMN TOTAL	17 73.9	6 26.1	23 100.0

FISHER'S EXACT TEST = 0.33382

FILE ACC (CREATION DATE = 03/24/81) SS-OP ACCIDENTS SHLD + CONTROL SITES

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WORK (rows) / AFTBEF (columns): COUNT, ROW PCT, COL PCT, TOT PCT	BEFORE, 1.	AFTER, 2.	ROW TOTAL
3. SHOULDER JOB,	25	13	38
	65.8	34.2	77.6
	89.3	61.9	
	51.0	26.5	
4. CONTROL SITE,	3	8	11
	27.3	72.7	22.4
	10.7	38.1	
	6.1	16.3	
COLUMN TOTAL	28	21	49
	57.1	42.9	100.0

CORRECTED CHI SQUARE = 3.71456 WITH 1 DEGREE OF FREEDOM SIGNIFICANCE = 0.0539

FILE ACC (CREATION DATE = 03/24/81) REAR END ACCIDENTS SHLD + CONTROL SITES

* C R O S S T A B U L A T I O N O F * * * * * * * * * * * *
WORK BY AFTBEF

WORK	AFTBEF: BEFORE (1.)	AFTER (2.)	ROW TOTAL
3. SHOULDER JOB	79	115	194
	40.7	59.3	70.8
	67.5	73.2	
	28.8	42.0	
4. CONTROL SITE	38	42	80
	47.5	52.5	29.2
	32.5	26.8	
	13.9	15.3	
COLUMN TOTAL	117	157	274
	42.7	57.3	100.0

CORRECTED CHI SQUARE = 0.80467 WITH 1 DEGREE OF FREEDOM SIGNIFICANCE = 0.3697

FILE ACC (CREATION DATE = 03/24/81) RT. ANGLE ACCIDENTS SHLD + CONTROL SITES

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WORK (COUNT / ROW PCT / COL PCT / TOT PCT)	AFTBEF: BEFORE, 1.	AFTER, 2.	ROW TOTAL
3. SHOULDER JOB.	0	9	9
	0.0	100.0	75.0
	0.0	81.8	
	0.0	75.0	
4. CONTROL SITE.	1	2	3
	33.3	66.7	25.0
	100.0	18.2	
	8.3	16.7	
COLUMN TOTAL	1	11	12
	8.3	91.7	100.0

FISHER'S EXACT TEST = 0.25000

FILE ACC (CREATION DATE = 03/24/81) LEFT TURN ACCIDENTS SHLD + CONTROL SITES

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WORK	AFTBEF: COUNT / ROW PCT / COL PCT / TOT PCT	BEFORE, 1.	AFTER, 2.	ROW TOTAL
SHOULDER JOB,	3.	8	23	31
		25.8	74.2	79.5
		66.7	85.2	
		20.5	59.0	
CONTROL SITE,	4.	4	4	8
		50.0	50.0	20.5
		33.3	14.8	
		10.3	10.3	
COLUMN TOTAL		12	27	39
		30.8	69.2	100.0

CORRECTED CHI SQUARE = 0.79612 WITH 1 DEGREE OF FREEDOM SIGNIFICANCE = 0.3723

FILE ACC (CREATION DATE = 03/24/81) ANIMAL ACCIDENTS SHLD + CONTROL SITES

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WORK	AFTBEF	1. BEFORE	2. AFTER	ROW TOTAL
3. SHOULDER JOB	COUNT	185	204	389
	ROW PCT	47.6	52.4	56.4
	COL PCT	58.2	54.8	
	TOT PCT	26.8	29.6	
4. CONTROL SITE	COUNT	133	168	301
	ROW PCT	44.2	55.8	43.6
	COL PCT	41.8	45.2	
	TOT PCT	19.3	24.3	
COLUMN TOTAL		318	372	690
		46.1	53.9	100.0

CORRECTED CHI SQUARE = 0.64668 WITH 1 DEGREE OF FREEDOM SIGNIFICANCE = 0.4213

FILE ACC (CREATION DATE = 03/24/81) OVER TURN ACCIDENTS SHLD + CONTROL SITES

* C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * *
WORK BY AFTBEF
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WORK	COUNT / ROW PCT / COL PCT / TOT PCT	AFTBEF BEFORE, 1.	AFTER, 2.	ROW TOTAL
SHOULDER JOB,	3.	72	55	127
		56.7	43.3	60.5
		67.3	53.4	
		34.3	26.2	
CONTROL SITE,	4.	35	48	83
		42.2	57.8	39.5
		32.7	46.6	
		16.7	22.9	
	COLUMN TOTAL	107	103	210
		51.0	49.0	100.0

CORRECTED CHI SQUARE = 3.67583 WITH 1 DEGREE OF FREEDOM SIGNIFICANCE = 0.0552

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WORK	AFTBEF COUNT / ROW PCT / COL PCT / TOT PCT	BEFORE, 1.	AFTER, 2.	ROW TOTAL
SHOULDER JOB,	3.	20 54.1 90.9 39.2	17 45.9 58.6 33.3	37 72.5
CONTROL SITE,	4.	2 14.3 9.1 3.9	12 85.7 41.4 23.5	14 27.5
	COLUMN TOTAL	22 43.1	29 56.9	51 100.0

CORRECTED CHI SQUARE = 5.02776 WITH 1 DEGREE OF FREEDOM SIGNIFICANCE = 0.0249

FILE ACC (CREATION DATE = 03/24/81) DITCH ACCIDENTS SHLD + CONTROL SITES

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WORK BY AFTBEF
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WORK	AFTBEF: COUNT / ROW PCT / COL PCT / TOT PCT	BEFORE, 1.	AFTER, 2.	ROW TOTAL
SHOULDER JOB,	3.	48	35	83
		57.8	42.2	63.4
		67.6	58.3	
		36.6	26.7	
CONTROL SITE,	4.	23	25	48
		47.9	52.1	36.6
		32.4	41.7	
		17.6	19.1	
	COLUMN TOTAL	71	60	131
		54.2	45.8	100.0

CORRECTED CHI SQUARE = 0.83802 WITH 1 DEGREE OF FREEDOM SIGNIFICANCE = 0.3600

FILE ACC (CREATION DATE = 03/24/81) MAILBOX ACCIDENTS SHLD + CONTROL SITES

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WORK	COUNT / ROW PCT / COL PCT / TOT PCT	AFTBEF: BEFORE, 1.	AFTBEF: AFTER, 2.	ROW TOTAL
3. SHOULDER JOB,	COUNT	25	16	41
	ROW PCT	61.0	39.0	63.1
	COL PCT	71.4	53.3	
	TOT PCT	38.5	24.6	
4. CONTROL SITE,	COUNT	10	14	24
	ROW PCT	41.7	58.3	36.9
	COL PCT	28.6	46.7	
	TOT PCT	15.4	21.5	
COLUMN TOTAL		35	30	65
		53.8	46.2	100.0

CORRECTED CHI SQUARE = 1.56059 WITH 1 DEGREE OF FREEDOM SIGNIFICANCE = 0.2116