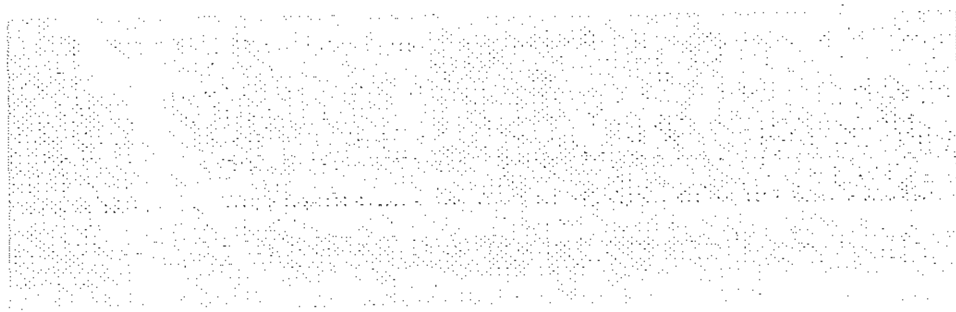
AN EVALUATION OF THE 1965-66
SKIDPROOFING PROGRAM

TSD-SS-126-70

TRAFFIC and
SAFETY
DIVISION

DEPARTMENT OF STATE HIGHWAYS
STATE OF MICHIGAN



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MICHIGAN DEPARTMENT OF STATE HIGHWAYS

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Seventy-three locations completed under seven statewide contracts, let during the 1965-66 fiscal year.

Prepared By

Safety & Surveillance Section
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February, 1970

Abstract

This report is an evaluation of the accident information at 73 locations, throughout Michigan, where relatively smooth roadway surfaces were covered with skidproofing material to improve vehicle stopping capabilities in the fiscal year 1965-1966.*

The total number of accidents was reduced by 17.1 percent (from 2,191 to 1,817) and is attributed to the Skidproofing Program. Wet surface accidents were reduced by 54.7 percent (935 to 423).

A cost-benefit analysis showed that a savings of $645,000 accrued during the one year "after" period. This savings, resulting from the reduction in accidents, is sufficient to repay the total construction costs ($1,006,353) in slightly less than two years.

*Fiscal year runs from July 1, 1965 to June 30, 1966.

General Discussion

Traffic accidents, in general, are a complex phenomena resulting from a multiplicity of factors involving both physical and mental conditions. Among the physical elements, the roadway, itself, may be a significant contributor to its relative safety (or lack thereof).

The safety of a particular section of roadway is determined by numerous individual aspects including: geometric configuration of intersections; capability of the roadway to handle an adequate flow of traffic; operational devices, such as signs and signals; and the condition of the roadway surface. It is the roadway surface which is the subject of this report.

After a period of service, roadway surfaces tend to lose their abrasiveness. This is especially true at signalized intersections where constant vehicular stopping and starting tends to polish the pavement and minimize the frictional characteristics necessary for effective braking action. The rectification of this "polishing" by applying a fine aggregate bituminous emulsion is referred to as skidproofing.*

The study recognizes only the addition of skidproofing at 73 locations and takes no cognizance of other factors that might possibly affect accident potential. The majority of these locations are intersections. Because of the relatively large number of locations involved, it was deemed prohibitive, in terms of available time, to investigate the specific histories of each site as would be done with fewer locations. It is reasonalbe to assume that the other positive and negative safety influences would tend to cancel each other in the long run.

* For Skidding and Skid Tests information, see Appendix "A"

The 73 locations covered by this report were skidproofed in 1965 and 1966. The study period in every case includes one year prior to the start of construction (the "before" period) and one year after the project completion (the "after" period).

The total cost of the seven contracts which covered all of the work was $1,006,353.

Project Location Reference Number	List of Project Locations
1.	US-23 At Linwood Road, Bay County
2.	US-23 at Grove Street, Bay County
3.	M-25 at Wagner Road, Bay County
4.	M-54 at Carpenter Road, City of Flint
5.	M-54 at Coldwater Road, Genesee County
6.	M-54 at M-54BR (Saginaw Highway), Genesee County
7.	M-121 at Fenton Road, Genesee County
8.	I-96 at Grand River Avenue (old US-16) Off Ramp, Livingston County
9.	US-12, Neblo Road to Lima Center Road, Washtenaw County
10.	US-24 at Fenkell Road, Wayne County
11.	US-24 at W. Chicago Road, Wayne County
12.	US-24 at M-14 (Plymouth Road), Wayne County
13.	US-24 at Schoolcraft Road, Wayne County
14.	M-78, I-75 to Ballenger Road, Genesee County
15.	M-21 at Center Road, Genesee County
16.	M-54 at Mt. Morris Road, Genesee County
17.	M-21 at Graham Road, Genesee County
18.	M-15 at Lapeer Road, Genesee County
19.	M-81 at Center Road, Saginaw County
20.	US-24 at Joy Road, City of Dearborn Heights, Wayne County
21.	US-24 at Vanborn Road, City of Dearborn Heights, Wayne County
22.	US-24 at Annapolis Road, City of Dearborn Heights, Wayne County
23.	M-17 at Inkster Road, Wayne County
24.	M-17 at Middlebelt Road, Wayne County
25.	M-17 at Beech Daly Road, Wayne County
26.	US-24 at Sibley Road, Wayne County
27.	BS-96 at Kinloch Road, Wayne County
28.	US-12 from Eloise to Henry Ruff, Cities of Inkster and Westland
29.	US-12 at Sheldon Road, Wayne County
30.	US-12 at Canton Center Road, Wayne County
31.	US-24 at M-153 (Ford Road), Cities of Dearborn and Dearborn Heights
32.	US-24 at Oxford Road, City of Dearborn
33.	BS-96 at M-102 (8 Mile), Wayne County
34.	BS-96 at 7 Mile Road, Wayne County
35.	US-25 at Stewart Road, Monroe County
36.	US-25 at Stewart Road, Monroe County
37.	US-10 at 10 Mile Road, Oakland County
38.	US-10 at Woodland Road, Oakland County
39.	US-10 at Andersonville Road, Oakland County
40.	US-10 at Drayton Plains Shopping Center, Oakland County
41.	US-10 at Quarton Road - Big Beaver Road, Oakland County
42.	US-24 at Quarton Road, Oakland County
43.	US-24 at Lone Pine Road, Oakland County
44.	US-24 at Exeter Road to W. Long Lake Road, Oakland County

Project Location Reference Number	List of Project Locations
45.	US-10 at Pontiac Lake Road, City of Pontiac
46.	US-10 at Miracle Mile Shopping Center, Oakland County
47.	US-10 at Frembes Road, Oakland County
48.	US-10 at Oakland Park Road and Sylvan Street, City of Pleasant Ridge, Oakland County
49.	BS-96 at Middlebelt Road, Oakland County
50.	M-59 at M-150, Oakland County
51.	US-25 at Eastgate Boulevard, City of Roseville, Macomb County
52.	US-25 at 11 Mile Road, City of Roseville, Macomb County
53.	US-25 at 12 Mile Road, City of Roseville, Macomb County
54.	US-25, Martin Street to Utica Road, City of Roseville, Macomb County
55.	US-25 at 15 Mile Road, Macomb County
56.	M-59 at Dequindre Street, Macomb County
57.	M-59 at Parkdale Street, Macomb County
58.	M-53 at Gates Road, Macomb County
59.	M-97 at Metro Beach Road, Macomb County
60.	M-97 at Harrington Road, Macomb County
61.	US-25, M-136 to north of Kraft Road, St. Clair County
62.	US-10 at M-15, Oakland County
63.	M-17 at Carpenter Road, Washtenaw County
64.	US-12BR at Harris Road, Washtenaw County
65.	M-59 at Old US-23, Livingston County
66.	M-139 at Napier Avenue, Berrien County
67.	M-139 at Empire Avenue, Berrien County
68.	M-96 at Hussey Avenue, Calhoun County
69.	M-96 at River Street, Calhoun County
70.	US-131 at 4 Mile Road, Kent County
71.	M-44 at Cascade Road, Kent County
72.	US-31 at M-131, Emmet County
73.	M-54 at M-57, Genesee County

Compilation of Accident Data

The accident data compiled in the Accident Record Table represents 146 years of traffic accident records (i.e.: 73 one year "before" periods and 73 one year "after" periods). To obtain these records utilization of several sources was made. Twenty-three locations were checked using information from Michigan Department of State Highways computer printout lists while the remaining 50 locations were checked with Michigan State Police records in Lansing. Supplemental checks were made with local police agencies in numerous localities to obtain as accurate records as possible.

The accidents recorded represent only those which occurred on the skidproofing mat or those which involved braking on the skidproofed surface.

ACCIDENT RECORD TABLE

Loc. Ref. No.	BEFORE PERIOD				AFTER PERIOD				% Change ADT
	Total Accs.	Injury Accs. (Persons Injured)	Fatal Accs. (Persons Killed)	Wet Accs.	Total Accs.	Injury Accs. (Persons Injured)	Fatal Accs. (Persons Killed)	Wet Accs.	
1.	32	13(42)	1(1)	20	14	3(9)	1(1)	8	+ 8.9
2.	7	4(6)	0(0)	4	13	5(12)	0(0)	1	+ 6.4
3.	4	2(7)	0(0)	2	4	1(2)	0(0)	0	+ 8.8
4.	11	6(8)	0(0)	5	28	17(34)	1(1)	8	+ 5.2
5.	22	10(18)	0(0)	8	14	10(26)	0(0)	1	+ 5.2
6.	20	6(13)	0(0)	3	17	7(20)	1(1)	5	- 5.7
7.	15	3(4)	0(0)	4	14	10(15)	0(0)	2	+11.9
8.	0	0(0)	0(0)	0	0	0(0)	0(0)	0	+ 7.2
9.	15	6(19)	1(1)	9	12	7(8)	0(0)	2	+ 6.5
10.	59	18(31)	0(0)	12	51	22(32)	3(3)	14	+ 7.2
11.	30	11(17)	0(0)	10	24	8(13)	0(0)	8	+ 8.3
12.	52	16(27)	0(0)	15	43	15(27)	0(0)	5	+10.4
13.	121	43(67)	0(0)	47	67	26(41)	0(0)	6	+10.2
14.	96	42(74)	0(0)	24	69	36(69)	0(0)	10	+ 7.7
15.	17	11(23)	0(0)	4	11	11(21)	0(0)	2	+ 8.9
16.	11	4(8)	0(0)	5	13	8(24)	0(0)	1	- 0.7
17.	12	6(8)	0(0)	4	6	3(7)	0(0)	2	+ 6.2
18.	11	6(12)	0(0)	3	5	3(6)	0(0)	0	+31.5
19.	30	12(19)	0(0)	11	19	4(8)	0(0)	3	+ 8.0
20.	36	12(23)	2(2)	9	33	10(17)	1(1)	5	+ 6.0
21.	61	22(35)	1(1)	18	51	19(37)	0(0)	5	+ 9.2
22.	13	6(10)	0(0)	6	18	10(20)	0(0)	5	+ 9.2
23.	27	12(26)	0(0)	5	33	14(28)	0(0)	4	+ 6.8
24.	8	6(8)	0(0)	5	6	2(3)	0(0)	2	+ 6.8
25.	14	6(15)	0(0)	7	23	8(13)	0(0)	2	+ 4.8
26.	7	4(13)	0(0)	1	8	5(16)	0(0)	0	+ 2.2
27.	6	2(3)	0(0)	5	3	1(1)	0(0)	3	+ 8.8
28.	40	15(24)	0(0)	18	40	11(11)	0(0)	11	+14.8
29.	5	2(2)	0(0)	4	8	5(15)	0(0)	1	+ 3.8
30.	25	8(13)	0(0)	14	21	6(12)	0(0)	5	+ 3.8
31.	58	19(32)	1(1)	31	57	18(46)	1(1)	13	+ 5.7
32.	23	9(11)	0(0)	9	10	8(12)	0(0)	3	+ 8.8
33.	102	40(48)	1(1)	48	56	19(29)	0(0)	10	+ 3.4
34.	97	35(61)	0(0)	71	23	7(11)	0(0)	7	+ 7.2
35.	7	4(5)	0(0)	3	19	8(18)	0(0)	6	+19.5
36.	6	5(9)	0(0)	3	11	5(9)	0(0)	2	- 1.5
37.	37	22(32)	0(0)	27	26	8(12)	0(0)	8	+ 0.5

ACCIDENT RECORD TABLE

Loc. Ref. No.	BEFORE PERIOD Total Accs.	Injury Accs. (Persons Injured)	Fatal Accs. (Persons Killed)	Wet Accs.	AFTER PERIOD Total Accs.	Injury Accs. (Persons Injured)	Fatal Accs. (Persons Killed)	Wet Accs.	% Change ADT
38.	72	19(36)	0(0)	47	33	9(13)	0(0)	4	+ 0.5
39.	15	5(8)	0(0)	6	20	9(14)	0(0)	11	+ 3.3
40.	9	4(7)	0(0)	3	20	5(6)	0(0)	6	+ 3.3
41.	50	24(47)	0(0)	31	33	12(29)	1(1)	10	+18.3
42.	16	6(13)	0(0)	10	12	4(11)	0(0)	6	+17.0
43.	40	19(44)	0(0)	30	11	6(13)	0(0)	3	+17.0
44.	33	13(26)	0(0)	8	45	17(25)	0(0)	21	+17.0
45.	23	11(18)	0(0)	9	20	12(16)	0(0)	6	+ 6.3
46.	33	20(36)	1(1)	17	10	4(8)	0(0)	1	- 9.8
47.	9	4(7)	0(0)	2	24	7(16)	1(1)	5	+ 3.6
48.	29	18(23)	0(0)	16	26	7(9)	0(0)	6	+ 0.6
49.	37	19(25)	0(0)	17	43	21(41)	1(1)	6	+ 5.9
50.	12	6(12)	0(0)	5	33	16(41)	0(0)	9	+25.8
51.	21	9(13)	0(0)	6	25	7(10)	0(0)	6	+ 4.1
52.	81	30(47)	0(0)	40	58	35(59)	0(0)	15	+ 4.1
53.	51	17(23)	0(0)	13	56	17(27)	0(0)	17	+ 4.1
54.	128	54(80)	0(0)	50	100	44(63)	0(0)	19	+ 4.1
55.	29	17(37)	0(0)	13	33	13(21)	0(0)	5	+22.7
56.	28	10(16)	0(0)	8	11	3(7)	0(0)	0	+24.8
57.	0	0(0)	0(0)	0	1	0(0)	0(0)	0	+24.8
58.	5	3(6)	0(0)	2	9	2(4)	0(0)	6	+28.4
59.	35	20(44)	1(1)	11	36	13(29)	1(1)	9	- 6.6
60.	9	4(13)	1(1)	4	17	8(12)	0(0)	5	- 6.6
61.	30	11(19)	0(0)	12	29	11(20)	0(0)	10	+15.0
62.	13	9(21)	0(0)	7	12	4(10)	1(1)	6	+ 6.6
63.	22	9(16)	0(0)	9	29	7(11)	0(0)	6	- 4.2
64.	52	18(36)	0(0)	12	44	17(38)	0(0)	6	- 2.8
65.	4	4(7)	0(0)	1	6	3(7)	0(0)	1	+ 7.6
66.	61	15(33)	0(0)	25	54	5(6)	0(0)	13	+ 7.5
67.	11	3(3)	0(0)	3	20	6(8)	0(0)	9	+ 2.6
68.	12	6(9)	0(0)	11	4	3(3)	0(0)	1	+ 2.2
69.	10	1(2)	0(0)	5	7	2(3)	0(0)	3	+ 2.6
70.	42	14(29)	0(0)	17	44	22(25)	0(0)	20	- 0.8
71.	6	1(1)	0(0)	3	4	2(5)	0(0)	0	+ 6.4
72.	6	3(4)	0(0)	0	4	1(1)	0(0)	0	+ 1.4
73.	20	6(13)	0(0)	8	14	6(19)	0(0)	2	+ 8.6
TOTALS	2191	880(1547)	10(10)	935	1817	720(1314)	13(13)	423	+10.8

RESULTS OF SKID TESTS

(40 mph coefficients of wet sliding friction)

Location Reference Number	Co-efficient "Before"	Co-efficient "After"	Loc. Ref. No.	Co-efficient "Before"	Co-efficient "After"
1.	0.19	0.69	37.	0.29	-
2.	0.23	0.72	38.	0.17	0.39
3.	0.27	0.70	39.	0.26	0.41
4.	0.26	0.69	40.	0.26	-
5.	0.25	0.65	41.	0.25	-
6.	0.28	0.65	42.	0.32	-
7.	0.24	0.65	43.	0.18	-
8.	0.31	0.57	44.	0.17	-
9.	0.28	0.57	45.	0.31	-
10.	0.27	0.55	46.	0.29	-
11.	0.27	0.55	47.	0.23	-
12.	0.25	0.56	48.	0.29	-
13.	0.21	0.47	49.	0.29	-
14.	0.26	0.58	50.	0.26	-
15.	0.29	0.51	51.	0.37	-
16.	0.26	0.61	52.	0.34	-
17.	0.18	0.55	53.	0.30	-
18.	0.22	0.54	54.	0.29	-
19.	0.28	0.51	55.	0.25	-
20.	0.26	0.51	56.	0.29	-
21.	0.26	0.49	57.	0.21	-
22.	0.27	0.51	58.	0.25	-
23.	0.32	0.53	59.	0.28	0.49
24.	0.27	0.44	60.	0.28	0.48
25.	0.28	0.56	61.	0.20	-
26.	0.30	0.49	62.	0.24	-
27.	0.25	0.51	63.	0.27	0.41
28.	0.27	0.49	64.	0.27	0.43
29.	0.22	0.47	65.	0.28	0.70
30.	0.22	0.48	66.	0.18	0.41
31.	0.29	0.51	67.	0.36	0.43
32.	0.30	0.48	68.	0.21	0.48
33.	0.29	0.49	69.	0.20	0.47
34.	0.17	0.53	70.	0.30	0.41
35.	0.18	0.65	71.	0.23	0.42
36.	0.20	0.65	72.	0.24	-
			73.	0.18	0.65

Results

In the year "after" the skidproofing was in place, 1,817 accidents occurred at the treated areas (see attached table, pp. 7 and 8). This represented a decrease of 374 (or 17.1 percent) from the 2,191 occurring during the year "before".

Injury accidents also decreased from 890 "before" to 733 "after", resulting in 230 fewer persons being either killed or injured (1,557 "before" and 1,327 "after").

The greatest reduction was noted in accidents occurring on wet pavement where a reduction from 935 "before" to 423 "after" was noted (54.7 percent fewer "wet" accidents).

Forty-three of the 73 locations showed a decrease in total accidents, while 54 of the locations showed a reduction in "wet" accidents.

All the above reductions were achieved despite a 10.8 percent increase in the aggregate average daily traffic at the 73 locations (64 locations showed an increase in average daily traffic volume).

Conclusion

The 17.1 percent reduction of accidents from 2,191 "before" to 1,817 "after" was found to be statistically significant at the 99 percent confidence level. This reduction was found to be attributable to the only known safety improvement factor common to all 73 locations, the addition of a skidproofed surface.

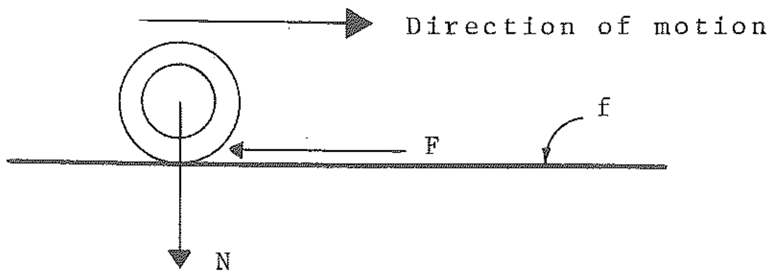
It is important to note that the reduction in accidents occurring on wet pavement was numerically larger than the overall reduction in accidents. It is seen that reduction of "wet" accidents is responsible for preventing an aggregate increase in accidents.

The benefit to the motoring public was calculated to be $645,000 resulting from the reduction in accidents during the year "after". This rate is sufficient to repay the projects' costs ($1,006,353) in slightly less than two years.

APPENDIX "A"

Skidding and Skid Tests

The treatment of pavements to provide for safer stopping distances takes advantage of a basic principle of physics (illustrated below).



F = friction force acting to stop vehicle

N = ¼ weight of a four-wheeled vehicle

f = coefficient of friction between a rubber tire and roadway pavement

where

$$F = f \times N$$

Stopping distance (once the process has been initiated) is a function of three basic variables:

(1) condition of the vehicle's braking system

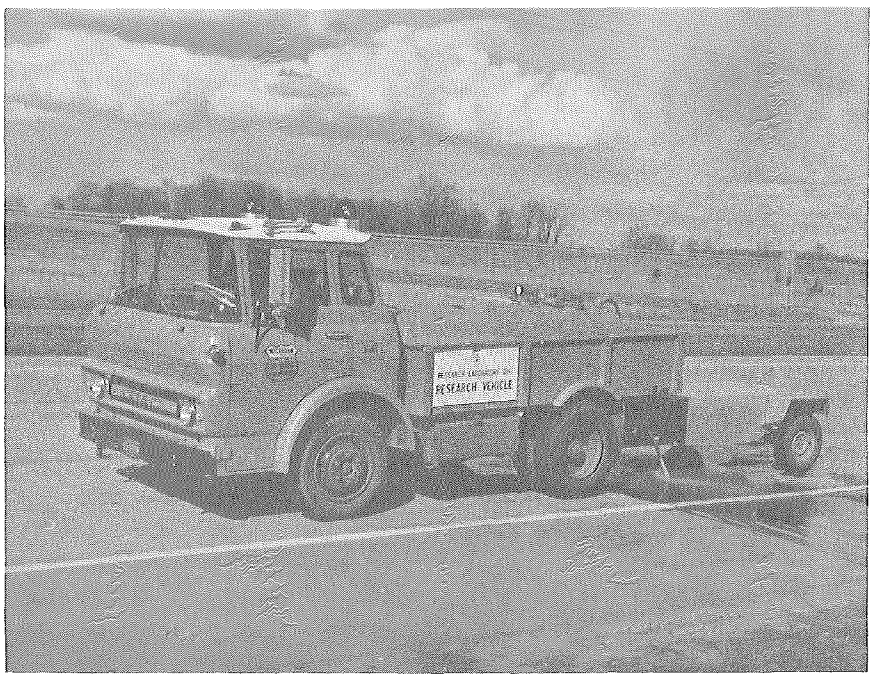
(2) frictional capabilities of the vehicle's tires

(3) frictional capabilities of the roadway surface

The Michigan Department of State Highway has no control over the first two variables and must, therefore, confine its efforts to improving the frictional role contributed by the roadway surface. In essence it must increase the frictional coefficient between the road surface and the vehicle's tires.

The Department of State Highways performs thousands of skid tests each year through its Testing and Research Division. Many of the tests are performed in response to requests from other divisions, including the Traffic & Safety Division, in an attempt to pinpoint locations where an unusual number of accidents involved skidding, particularly when the pavement was wet.

For a description of the actual skid testing procedure (see photo of skid testing device below) reference is made to Research Report No. R-585 ("Summaries of Michigan Pavement Skid Resistance: 1965 Test Program").



The skid test is initiated by actuating an electrically controlled test cycle. The cycle of events which occur is as follows:

1. Solenoids open water valves, spilling approximately 3.5 gallons of water directly into the wheel path of the skid trailer.
2. Trailer brakes are automatically locked. At this point the operator of the towing vehicle must exercise care in maintaining the specified

test speed (40 mph).

3. A reading is taken which indicates the force required to pull the trailer.

4. After dragging the skidometer trailer for approximately 60 feet, the water solenoids are closed and the brakes are released simultaneously.

Skid test values are expressed as 40 miles per hour, wet, sliding coefficients of friction. A value of 0.40 is generally considered the dividing point between "satisfactory" and "unsatisfactory". Surfaces below 0.35 could be dangerous under wet conditions, depending on vehicle speeds and road alignment. Surfaces with coefficients of 0.20 or less are in the category of packed snow or ice.

APPENDIX "B"

The Significance of Accident Reduction

To test the aggregate accident reduction for statistical "significance" reference is made to the "Null Hypothesis" (H_0)* stating that there is no change in "before" and "after" accident numbers.

Where

	"Before"	"After"
Traffic Volume	A	B
Number of Accidents	C	D

Assume

$$A/B = C/D \qquad (H_0)$$

using Chi-square statistics

$$\chi^2 = \frac{(AD - BC)^2 N}{(A + B)\ (C + D)\ (A + C)\ (B + D)}$$

Where $N = A + B + C + D$

From Chi-square "2 x 2" Table

$\chi_{.99,1}$ (read Chi-square at the 99% confidence level, with 1 degree of freedom) = 6.63

and using

A = 1,926,325
B = 2,134,805
C = 2,191
D = 1,817

then

$$\chi^2 = 83.99 > 6.63$$

* Reference is made to "Statistical Inference" by Helen M. Walker, page #100.

Therefore, the original hypothesis, H_0, (stating that the number of accidents during the "after" period could have been equal to the number of accidents in the "before" period) is rejected within a 99percent level of confidence and the reduction is shown to be statistically significant.

APPENDIX "C"

Computed Benefits Derived Through Accident Reduction

Cost Analysis

The method of evaluating accident costs, used below is given on page 67 of Roy Jorgensen's report of Highway Safety Improvement Criteria, 1966 edition. This same method is given in the Bureau of Public Roads IM21-3-67.

In the following analysis the costs provided by the National Safety Council are:

Death - $34,400

Non-fatal Injury - $1,800

Property Damage Accident - $310

$$B = \frac{ADT_a}{ADT_b} \times (Q\ R_1{*} \times 310\ R_2{*})$$

where

B = annual benefit in dollars

ADT_a = average traffic volume after the improvement (2,134,805)**

ADT_b = average traffic volume before the improvement (1,926,325)**

R_1 = reduction in fatalities and injuries combined (1557-1327 = 230)

R_2 = reduction in property damage accidents (1301-1084 = 217)

and $$Q = \frac{34{,}400 + (I/F \times 1{,}800)}{1 + I/F}$$

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* In the above noted reference, R_1 is listed as $A_{fi} \times P_{fi}$. It is evident upon inspection that $P_{fi} = \frac{R_1}{A_{fi}}$ (see definition above)

so that $A_{fi} \times P_{fi} = A_{fi} \times \frac{R_1}{A_{fi}} = R_1$

Similarly R_2 replaces $A_{pd} \times P_{pd}$

** Sum of individual trunkline ADTs for all 73 locations.

where

I/F = ratio of injures to fatalities that occurred statewide on all streets, highways, and freeways during 1965.

$$= \frac{155,258}{2,129} = 73.0$$

therefore

$$Q = \frac{34,400 + (73.0 \times 1,800)}{1 + 73.0} = 2,240$$

The computed benefits to the motoring public accrued during the year "after" period is then:

$$B = \frac{2,134,805}{1,926,325} (2,240 \times 230 + 310 \times 217) = \$645,000$$