Evaluation of TOPICS Project
INTERSECTION RECONSTRUCTION
M-143 (MICHIGAN AVENUE) AT HARRISON ROAD
EAST LANSING
Report TSD-295-76

TRAFFIC and SAFETY DIVISION

MICHIGAN DEPARTMENT OF STATE HIGHWAYS
AND TRANSPORTATION

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By
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June, 1976

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ABSTRACT

The intersection of Michigan Route 143 (Michigan Avenue) with Harrison Road in East Lansing was improved in 1974, within the federal TOPICS program, by realigning one leg to eliminate the offset crossing; widening, and adding a U-turn crossover and a right-turn lane. As a result, total accidents decreased 37 percent and injury accidents decreased 33 percent. Capacity analyses indicated a 21 percent increase of the intersection's traffic capacity, with a consequent 9.4 percent reduction in total stopped delay.

Approximate estimates for the cost of delays and operating costs at the intersection showed a yearly benefit of $38,800. Added to the yearly saving of $43,400 from accident reduction, a total yearly saving of $82,200 is equivalent to a return of 13.6 percent on the investment of $605,800 which was the total project cost.

CONTENTS

INTRODUCTION

For several years the intersection of Michigan Route 143 (Michigan Avenue) and Harrison Road in East Lansing has been a source of complaint because of its poor geometric layout. The north and south legs of Harrison Road were offset by 110 feet as shown in Figure 1. This created operational difficulties because of turning movements at this intersection, which serves a high proportion of the Michigan State University (M.S.U.) traffic and is adjacent to the campus. Poor operation and resulting congestion were reflected in the high number of accidents.

In 1974 the intersection was reconstructed, widened, and the south leg of Harrison Road was realigned to match the north leg. A westbound median left-turn lane and a directional median crossover were built west of the intersection, with left turns from the east and from the north routed via this facility. A channelized right-turn lane from eastbound Michigan to southbound Harrison was also added. A new signal was installed to control the traffic on eastbound Michigan at the median crossover. A bus turnout was provided on eastbound Michigan Avenue east of the intersection.

This improvement was implemented through the use of federal funds from the Traffic Operations Program to Increase Capacity and Safety (TOPICS). This report is an evaluation of the benefits obtained by this project.

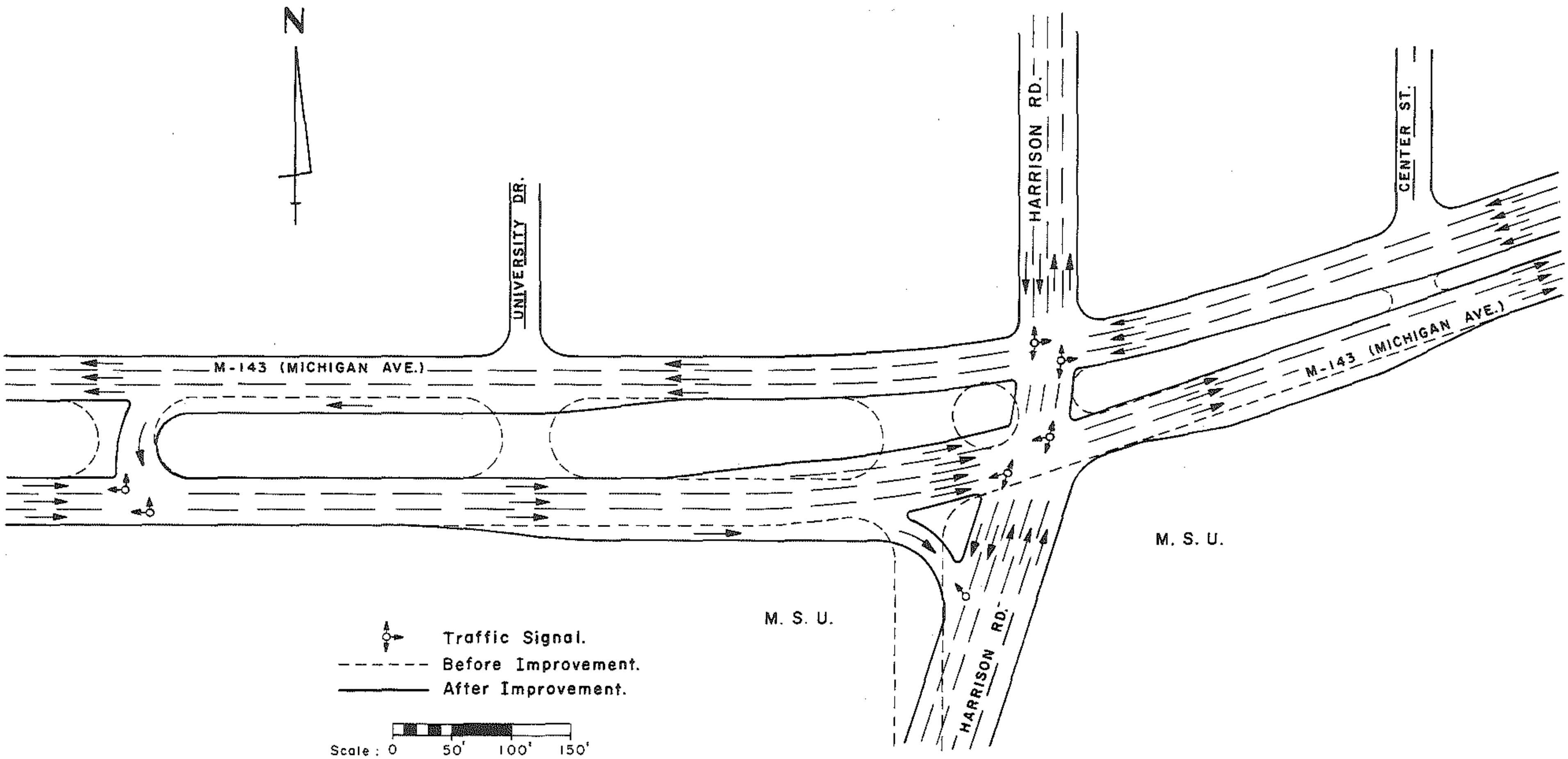
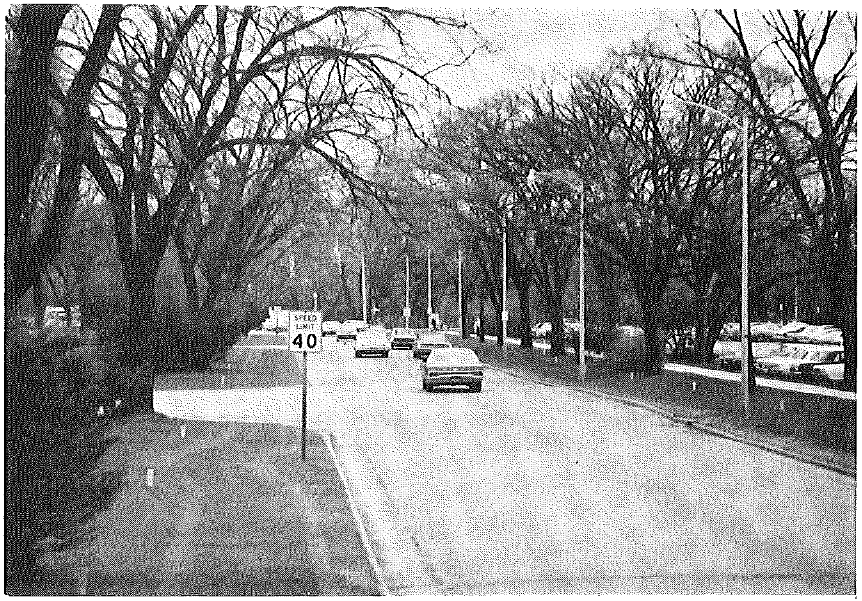
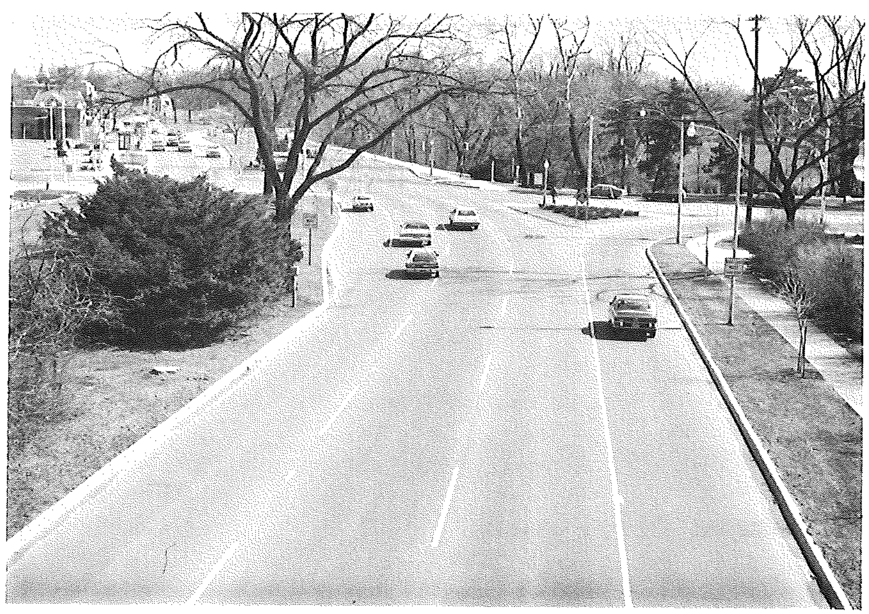


FIGURE 1 : MAIN GEOMETRIC CHANGES.



MICHIGAN AVENUE EASTBOUND APPROACH
BEFORE CONSTRUCTION



MICHIGAN AVENUE EASTBOUND APPROACH
AFTER CONSTRUCTION

SAFETY BENEFITS

Accident data for the location was provided by the city of East Lansing. Table 1 summarizes the accidents on a one-year before-and-after-construction basis, and on a calendar-year basis. Accident record for the whole city by years, since 1972, is also shown at the bottom of the table. A total accident reduction of 23, or 37 percent after construction at the Michigan-Harrison intersection is found to be statistically significant at the 98 percent confidence level. A reduction of 9, or 45 percent, in injury accidents was statistically significant at the 93 percent confidence level.

Comparing the experience of the intersection with that of the city as a whole, a reduction of 47 percent in injury accidents between the calendar years 1973 and 1975 for the location is much larger than the 13 percent for the city, showing the effectiveness of the improvement. Similarly, a reduction of 29 percent in total accidents between the two years compares favorably with the citywide reduction of only 8 percent.

Figures 2 and 3 are collision diagrams of the area one year before and one year after construction, respectively. It is apparent from these diagrams that considerable relief was effected at the intersection proper. A slight increase of accidents at the median crossover between Kensington and University Streets was not enough to diminish the overall accident improvement in the area.

The accident rate per million vehicles of traffic entering the intersection was 3.23 one year before construction, and was reduced to 2.06,

TABLE 1
Before and After Accident Data on That Part of
Michigan Avenue from Kensington to Beal That Was
Reconstructed during September, October, and November, 1974

Type of Accident	9-1-73 thru 8-31-74 (One Year Before)	12-1-74 thru 11-31-75 (One Year After)	Difference	% Reduction
Personal Injury	20	11	- 9	45%
Property Damage	43	29	-14	33%
Total Accidents	63	40	-23	37%

Type of Accident	Calendar Year 1973	Calendar Year 1975	Difference	% Reduction
Personal Injury	17	9	- 8	47%
Property Damage	45	35	-10	22%
Total Accidents	62	44	-18	29%

City of East Lansing Annual Accident Data

	1972	1973	1974	1975	% Reduction Between 1973 & 1975
Fatal Accidents	2	3	4	0	100%
Personal Injury	422	420	394	367	13%
Property Damage	997	875	859	830	5%
Totals	1,421	1,298	1,257	1,197	8%

or by 36 percent, one year after construction. Only those accidents directly attributable to the Michigan/Harrison intersection and to the crossover midway between Kensington and University Streets were considered in these rate calculations.

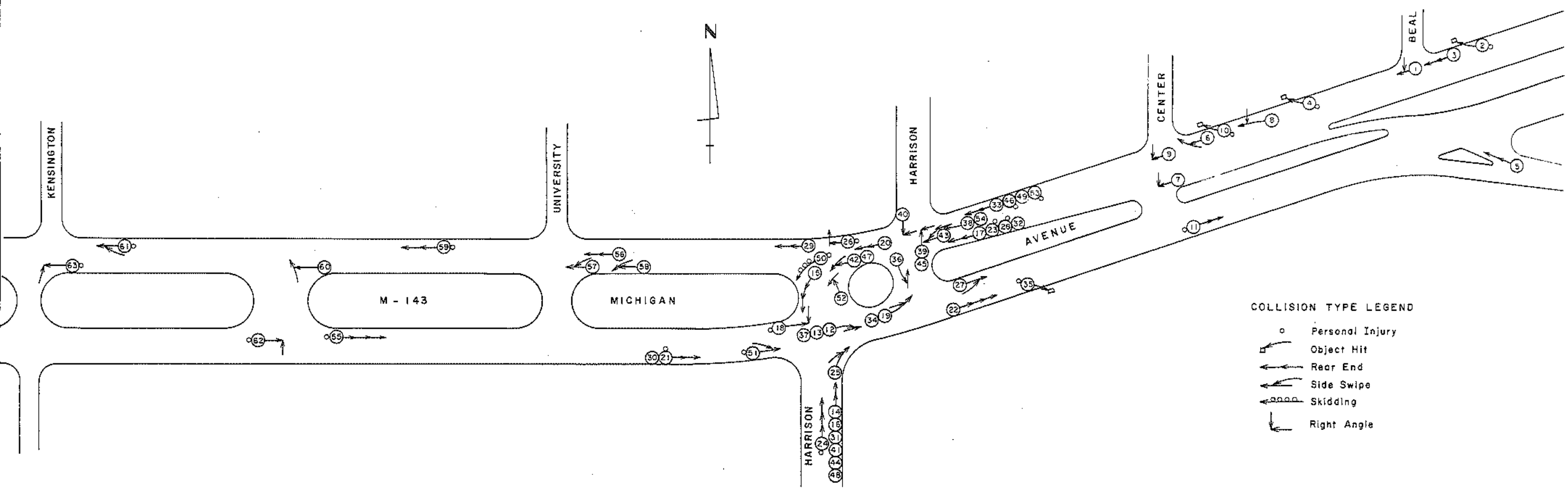


FIGURE 2: COLLISION DIAGRAM ONE YEAR BEFORE CONSTRUCTION - 9-1-73 Through 8-31-74.

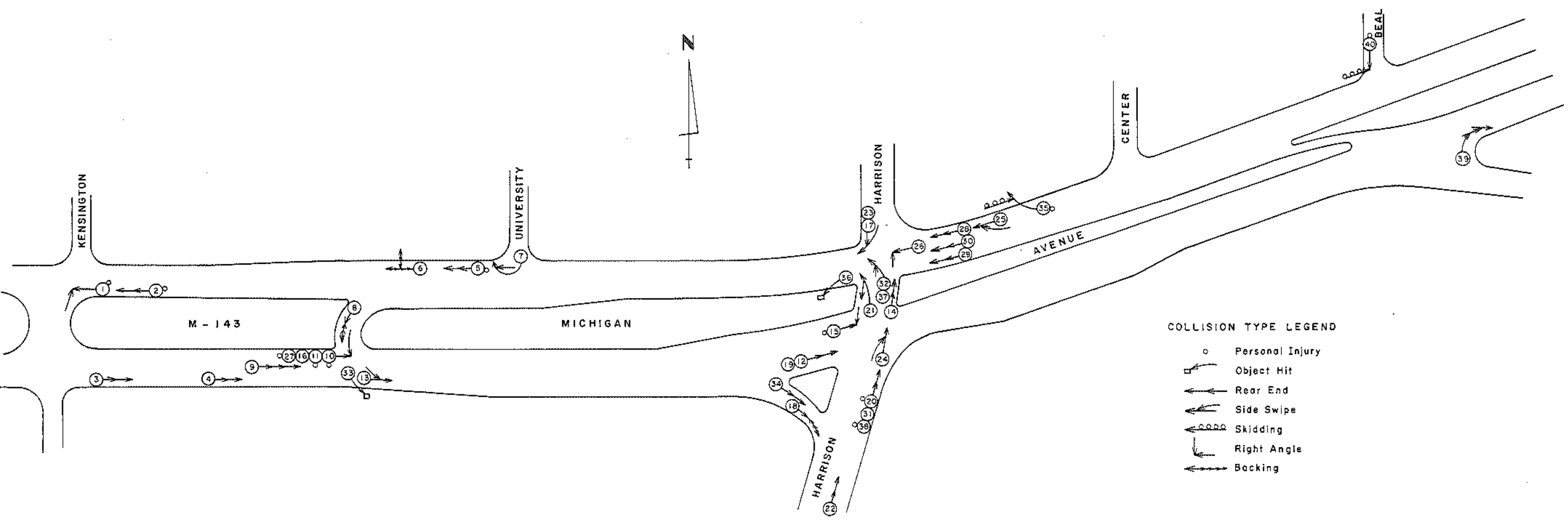
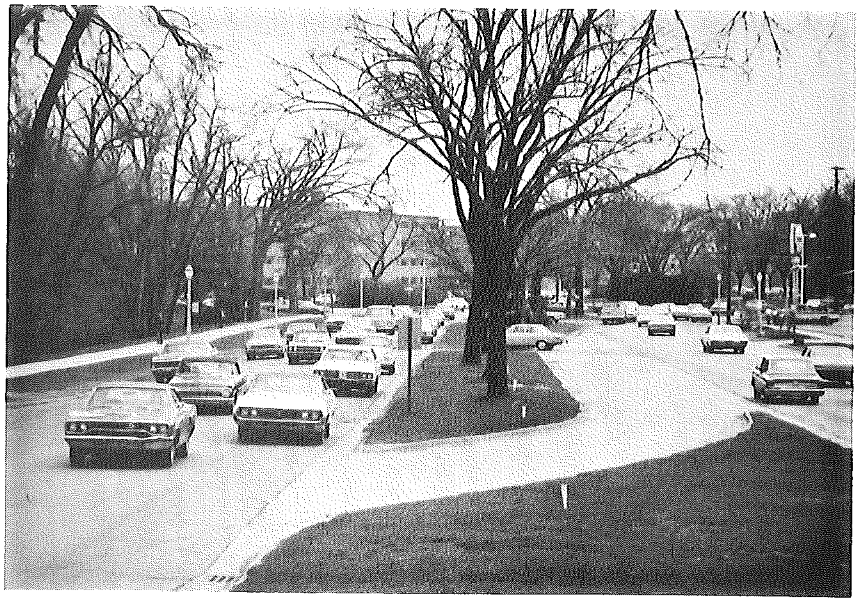
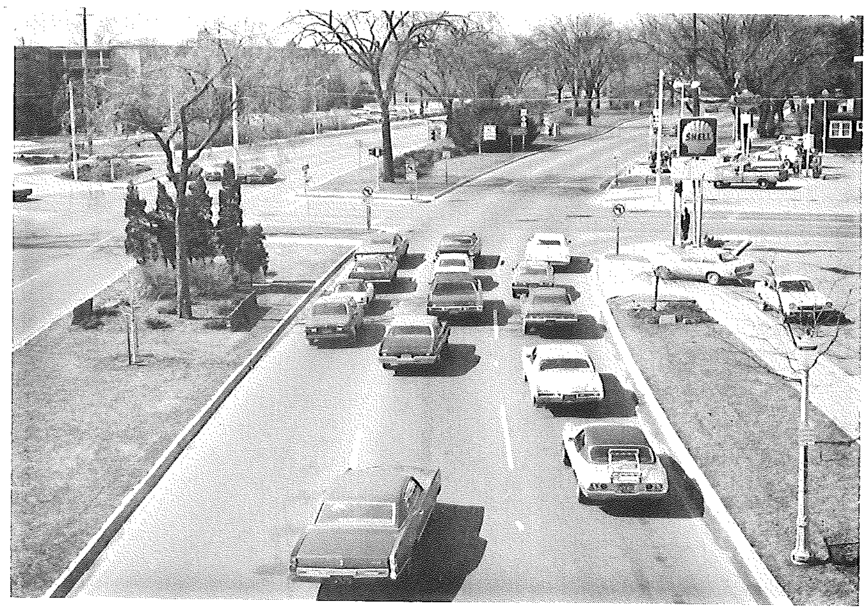


FIGURE 3: COLLISION DIAGRAM ONE YEAR AFTER CONSTRUCTION - 12-1-74 Through 11-30-75.



MICHIGAN AVENUE LOOKING WEST
TOWARD THE INTERSECTION BEFORE CONSTRUCTION



LOOKING WEST TO THE INTERSECTION
AFTER CONSTRUCTION

TRAFFIC CAPACITY IMPROVEMENT

The degree of utilization of the intersection's traffic capacity before and after reconstruction is analyzed in Appendix 1. This analysis shows a reduction of 21 percent in the overall congestion at the intersection. It should be recognized, however, that the analysis does not render itself fully applicable to the abnormal operation before reconstruction, because of the locking character of the turning movements. In reality, therefore, the congestion has been alleviated somewhat more than the analysis indicates.

Appendixes 2 and 3 show a method of intersection delay analysis recommended by the National Cooperative Highway Research Program (NCHRP) Report 133*. This is an approximate, theoretical approach for determining stopped delay at a signalized intersection. Eight-hour turning movement and 24-hour machine counts were used in Worksheet 5 of the NCHRP report. The capacity of each approach of the intersection was calculated according to the Highway Capacity Manual. The actual signal cycle length, split and green time was used in this worksheet to calculate (1) the average delay per vehicle and (2) proportion of vehicles that were stopped. These calculations were made for peak and off-peak traffic. Appendix 2 contains delay calculations before the improvement, and Appendix 3 contains the delays after the improvement. Delays at the signalized median crossover are also considered for the after period.

Appendixes 4 and 5 are derived from Appendixes 2 and 3, respectively, and show the daily totals for hours of stopped delay and the vehicles that stopped.

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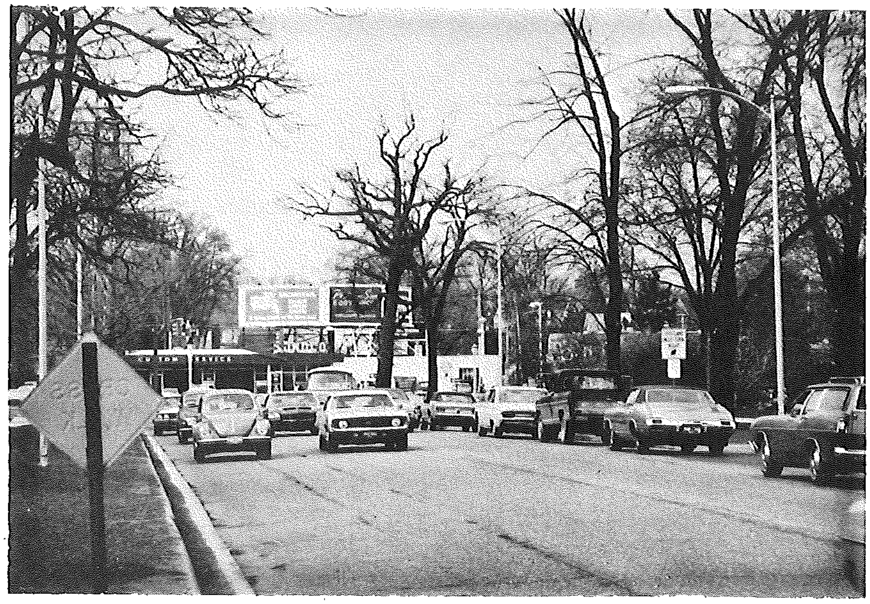
*"Procedures for Estimating Highway User Costs, Air Pollution, and Noise Effects"; by David A. Curry and Dudley G. Anderson, Stanford Research Institute, Menlo Park, California; 1972.



SOUTH LEG OF HARRISON ROAD
BEFORE CONSTRUCTION

SOUTH LEG OF HARRISON ROAD
AFTER CONSTRUCTION

COSTS AND BENEFITS

Calculation and comparison of the costs of the project and user benefits being derived from the improvement are shown in Appendix 6.

Total cost of construction, signal installation, landscaping and engineering was $605,800. Total yearly benefits to the public was estimated at $82,227 which is equal to a return of 13.57 percent on the investment.

Accident cost saving was estimated at $43,420 per year. This was based on the National Safety Council estimates for the year 1974 of $4,000 for each injury accident and $530 for each property-damage accident.

Delay reduction was estimated to be $25,601 per year. Cost of time saved was based on the value of time at $2.82 per person per hour, and vehicle occupancy of 1.2 persons per vehicle (2.82 x 1.2 = $3.38 per vehicle per hour), as used in a Department report* and recommended in the Stanford Research Institute study referred to in that report. The period for accrued benefits in time was considered to be 260 days a year. Delay reductions were analyzed in two categories: (1) stopped delay time, and (2) added delay due to decelerating from the initial speed to stop, and accelerating back to normal speed. Added delay time was taken from Table 5 of NCHRP Report 133 referred to earlier. Daily savings in stopped delay and daily totals of stopped vehicles were taken from Appendixes 4 and 5.

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*"Evaluation Study of the 1971-1972 Fiscal Year TOPICS Projects in Michigan", Michigan Department of State Highways and Transportation, September, 1973.

Operating-cost reduction was estimated to be $13,206 per year. Operating costs were analyzed in two categories: (1) engine idling, and (2) stopping and starting. Unit costs for these were also based on Table 5 of NCHRP Report 133. Daily totals of stopped vehicles were taken from Appendixes 4 and 5.

NORTH LEG OF HARRISON ROAD
BEFORE CONSTRUCTION

LOOKING SOUTH TO THE INTERSECTION
AFTER CONSTRUCTION

CONCLUSION

This TOPICS project has eliminated the congestion at the M-143 (Michigan Avenue) and Harrison Road intersection, which was being caused by narrow approach lanes and by two offset intersection legs that were difficult to negotiate by the driving public. Considerable savings in accident reduction, intersection delay and vehicle operating costs have accrued.

The traffic signals at the subject intersection are now connected to the Lansing area computerized signal control system. Without the improvement project, this intersection would have constituted a serious bottleneck in the new signal system.

A P P E N D I X

APPENDIX 1
UTILIZATION OF INTERSECTION CAPACITY
(Based on 90-second signal cycle)

<u>1973</u>

Michigan green time = $\frac{1330}{3390} \times 90 =$ 35.3 sec./cycle

Harrison green time = $\frac{650}{1700} \times 90 =$ 34.4 sec./cycle

Clearance interval = 10% of cycle = <u>9.0</u> sec./cycle

Total time needed 78.7 sec./cycle

Percent of capacity utilized = $\frac{78.7}{90} \times 100 = 87\%$

<u>1975</u>

Michigan green time = $\frac{1300}{4300} \times 90 =$ 27.2 sec./cycle

Harrison green time = $\frac{920}{3500} \times 90 =$ 23.6 sec./cycle

Clearance interval = 10% of cycle = <u>9.0</u> sec./cycle

Total time needed 59.8 sec./cycle

Percent of capacity utilized = $\frac{59.8}{90} \times 100 = 66\%$

Decrease in capacity utilization = 87 – 66 = 21%

Note: This analysis does not consider the additional improvement in operation as a result of the new uncomplicated intersection geometrics.

Worksheet 5

INTERSECTION DELAY

Project No. ________ Intersection Identification ________

Year 1973 Time 4-6 PM

Intersection Approach Identification	(1) EB Michigan Peak	(1) EB Michigan Off-Peak	(2) WB Michigan Peak	(2) WB Michigan Off-Peak
1. Demand volume, veh/hr (W2, 10.)	1,250	690	1,330	840
2. Demand volume duration, hrs (W2, 10.)	2	16	2	16
• 3. Saturation flow, veh/hr (S)	3,390	3,390	3,390	3,390
• 4. Effective green time of signal, sec (G)	45	34	45	34
• 5. Cycle length of signal, sec (C)	90	70	90	70
6. Green to cycle time ratio (λ) (4. ÷ 5.)	0.50	0.49	0.50	0.49
7. Capacity of approach, veh/hr (3. x 6.)	1,690	1,660	1,690	1,660
8. Degree of saturation (χ) (1. ÷ 7.) (if χ is greater than 1, do the queueing worksheet, W5A)	0.740	0.416	0.787	0.506
9. Delay per vehicle, sec/veh (7. and 8. to Figure 16)	14	10	15	11
10. Correction Factor, sec/veh (5. and 6. to Figure 16 insert)	3	2	3	2
11. Average Delay per vehicle, sec/veh (9. + 10., or enter from W5A)	17	12	18	13
12. Time to dissipate queue (if any) during Off-Peak period, hrs. (W5A, line 12.)				
13. Difference in delay between Peak and Off-Peak period, sec/veh (Peak 11. - Off-Peak 11.)				
14. Increase in average delay due to queueing that extends into Off Peak period, sec/veh (12. ÷ 2. x 13.)				
15. Average delay per vehicle, sec/veh (11. + 14.)*	17	12	18	13
16. Proportion of vehicles that were stopped. MIN (1, (1 - 6) + (1 - 1. ÷ 3.))*	0.792	0.641	0.822	0.678

* These results are utilized for Worksheet 3, lines 10.2 and 10.3

Worksheet 5

INTERSECTION DELAY

Project No. ______________ Intersection Identification ______________

Year 1973 Time 4-6 PM

Intersection Approach Identification	(1) NB Harrison Thru & L.T. Lane		(2) NB Harrison R.T. Lane	
	Peak	Off-Peak	Peak	Off-Peak
1. Demand volume, veh/hr (W2, 10.)	650	360	150	90
2. Demand volume duration, hrs (W2, 10.)	2	16	2	16
3. Saturation flow, veh/hr (S)	1700	1700	1700	1700
4. Effective green time of signal, sec (G)	36	27	36	27
5. Cycle length of signal, sec (C)	90	70	90	70
6. Green to cycle time ratio (λ) (4. ÷ 5.)	0.40	0.39	0.40	0.39
7. Capacity of approach, veh/hr (3. x 6.)	680	663	680	663
8. Degree of saturation (χ) (1. ÷ 7.) (if χ is greater than 1, do the queueing worksheet, W5A)	0.956	0.543	0.221	0.136
9. Delay per vehicle, sec/veh (7. and 8. to Figure 16)	70	16	13	12
10. Correction Factor, sec/veh (5. and 6. to Figure 16 insert)	5	2	5	2
11. Average Delay per vehicle, sec/veh (9. + 10., or enter from W5A)	75	18	18	14
12. Time to dissipate queue (if any) during Off-Peak period, hrs. (W5A, line 12.)				
13. Difference in delay between Peak and Off-Peak period, sec/veh (Peak 11. - Off-Peak 11.)				
14. Increase in average delay due to queueing that extends into Off Peak period, sec/veh (12. ÷ 2. x 13.)				
15. Average delay per vehicle, sec/veh (11. + 14.)*	75	18	18	14
16. Proportion of vehicles that were stopped. MIN (1, (1 - 6.) + (1 - 1. ÷ 3.)*	0.971	0.774	0.658	0.644

* These results are utilized for Worksheet 3, lines 10.2 and 10.3

Worksheet 5

INTERSECTION DELAY

Project No. ____________ Intersection Identification ____________

Year 1973 Time 4-6 PM

Intersection Approach Identification	(1) SB Harrison		(2)	
	Peak	Off-Peak	Peak	Off-Peak
1. Demand volume, veh/hr (W2, 10.)	270	210		
2. Demand volume duration, hrs (W2, 10.)	2	16		
• 3. Saturation flow, veh/hr (S)	1,790	1,790		
• 4. Effective green time of signal, sec (G)	36	27		
• 5. Cycle length of signal, sec (C)	90	70		
6. Green to cycle time ratio (λ) (4. ÷ 5.)	0.40	0.39		
7. Capacity of approach, veh/hr (3. x 6.)	716	694		
8. Degree of saturation (χ) (1. ÷ 7.) (if χ is greater than 1, do the queueing worksheet, W5A)	0.377	0.303		
9. Delay per vehicle, sec/veh (7. and 8. to Figure 16)	14	13		
10. Correction Factor, sec/veh (5. and 6. to Figure 16 insert)	5	2		
11. Average Delay per vehicle, sec/veh (9. + 10., or enter from W5A)	19	15		
12. Time to dissipate queue (if any) during Off-Peak period, hrs. (W5A, line 12.)				
13. Difference in delay between Peak and Off-Peak period, sec/veh (Peak 11. - Off-Peak 11.)				
14. Increase in average delay due to queueing that extends into Off Peak period, sec/veh (12. ÷ 2. x 13.)				
15. Average delay per vehicle, sec/veh (11. + 14.)*	19	15		
16. Proportion of vehicles that were stopped. MIN (1, (1 - 6) + (1 - 1. ÷ 3.)*	0.708	0.692		

* These results are utilized for Worksheet 3, lines 10.2 and 10.3

APPENDIX 3

Worksheet 5

INTERSECTION DELAY

Project No. ______________ Intersection Identification ______________

Year 1975 Time 4-6 PM

Intersection Approach Identification	(1) EB Michigan Thru & L.T. Lanes		(2) EB Michigan R.T. Lane	
	Peak	Off-Peak	Peak	Off-Peak
1. Demand volume, veh/hr (W2, 10.)	900	400	350	170
2. Demand volume duration, hrs (W2, 10.)	2	16	2	16
• 3. Saturation flow, veh/hr (S)	5,500	5,500	3,160	3,160
• 4. Effective green time of signal, sec (G)	47	27	58	37
• 5. Cycle length of signal, sec (C)	90	70	90	70
6. Green to cycle time ratio (λ) (4. ÷ 5.)	0.52	0.39	0.64	0.53
7. Capacity of approach, veh/hr (3. x 6.)	2,860	2,150	2,050	1,700
8. Degree of saturation (χ) (1. ÷ 7.) (if χ is greater than 1, do the queueing worksheet, W5A)	0.315	0.186	0.171	0.100
9. Delay per vehicle, sec/veh (7. and 8. to Figure 16)	9	12	5	8
10. Correction Factor, sec/veh (5. and 6. to Figure 16 insert)	3	2	2	1
11. Average Delay per vehicle, sec/veh (9. + 10., or enter from W5A)	12	14	7	9
12. Time to dissipate queue (if any) during Off-Peak period, hrs. (W5A, line 12.)		____		____
13. Difference in delay between Peak and Off-Peak period, sec/veh (Peak 11. - Off-Peak 11.)		____		____
14. Increase in average delay due to queueing that extends into Off Peak period, sec/veh (12. ÷ 2. x 13.)		____		____
15. Average delay per vehicle, sec/veh (11. + 14.)*	12	14	7	9
16. Proportion of vehicles that were stopped. MIN (1, (1 - 6.) ÷ (1 - 1. ÷ 3.)*	0.574	0.658	0.404	0.496

* These results are utilized for Worksheet 3, lines 10.2 and 10.3

Worksheet 5

INTERSECTION DELAY

Project No. ____________ Intersection Identification ______________

Year 1975 Time 4-6 PM

Intersection Approach Identification	(1) WB Michigan		(2) WB Michigan U-turn	
	Peak	Off-Peak	Peak	Off-Peak
1. Demand volume, veh/hr (W2, 10.)	1,300	700	250	130
2. Demand volume duration, hrs (W2, 10.)	2	16	2	16
• 3. Saturation flow, veh/hr (S)	4,300	4,300	1,700	1,700
• 4. Effective green time of signal, sec (G)	47	27	27	24
• 5. Cycle length of signal, sec (C)	90	70	90	70
6. Green to cycle time ratio (λ) (4. ÷ 5.)	0.52	0.39	0.30	0.34
7. Capacity of approach, veh/hr (3. x 6.)	2,240	1,680	510	578
8. Degree of saturation (χ) (1. ÷ 7.) (if χ is greater than 1, do the queueing worksheet, W5A)	0.580	0.417	0.490	0.225
9. Delay per vehicle, sec/veh (7. and 8. to Figure 16)	10	13	19	16
10. Correction Factor, sec/veh (5. and 6. to Figure 16 insert)	3	2	7	3
11. Average Delay per vehicle, sec/veh (9. + 10., or enter from W5A)	13	15	26	19
12. Time to dissipate queue (if any) during Off-Peak period, hrs. (W5A, line 12.)				
13. Difference in delay between Peak and Off-Peak period, sec/veh (Peak 11. - Off-Peak 11.)				
14. Increase in average delay due to queueing that extends into Off Peak period, sec/veh (12. ÷ 2. x 13.)				
15. Average delay per vehicle, sec/veh (11. + 14.)*	13	15	26	19
16. Proportion of vehicles that were stopped. MIN (1, (1 - 6.) ÷ (1 - 1. ÷ 3.))*	0.688	0.729	0.821	0.714

* These results are utilized for Worksheet 3, lines 10.2 and 10.3

Worksheet 5

INTERSECTION DELAY

Project No. ____________ Intersection Identification ____________

Year 1975 Time 4-6 PM

Intersection Approach Identification	(1) NB Harrison Peak	(1) NB Harrison Off-Peak	(2) SB Harrison Peak	(2) SB Harrison Off-Peak
1. Demand volume, veh/hr (W2, 10.)	920	400	270	180
2. Demand volume duration, hrs (W2, 10.)	2	16	2	16
3. Saturation flow, veh/hr (S)	3,500	3,500	2,040	2,040
4. Effective green time of signal, sec (G)	34	34	13	17
5. Cycle length of signal, sec (C)	90	70	90	70
6. Green to cycle time ratio (λ) (4. ÷ 5.)	0.38	0.49	0.14	0.24
7. Capacity of approach, veh/hr (3. x 6.)	1,330	1,710	286	490
8. Degree of saturation (χ) (1. ÷ 7.) (if χ is greater than 1, do the queueing worksheet, W5A)	0.692	0.234	0.944	0.368
9. Delay per vehicle, sec/veh (7. and 8. to Figure 16)	16	9	90	20
10. Correction Factor, sec/veh (5. and 6. to Figure 16 insert)	6	2	--	3
11. Average Delay per vehicle, sec/veh (9. + 10., or enter from W5A)	22	11	90	23
12. Time to dissipate queue (if any) during Off-Peak period, hrs. (W5A, line 12.)				
13. Difference in delay between Peak and Off-Peak period, sec/veh (Peak 11. - Off-Peak 11.)				
14. Increase in average delay due to queueing that extends into Off Peak period, sec/veh (12. ÷ 2. x 13.)				
15. Average delay per vehicle, sec/veh (11. + 14.)*	22	11	90	23
16. Proportion of vehicles that were stopped. MIN (1, (1 - 6.) ÷ (1 - 1. ÷ 3.)*	0.841	0.576	0.990	0.833

* These results are utilized for Worksheet 3, lines 10.2 and 10.3

APPENDIX 4

CALCULATION OF DELAYS AND STOPS - 1973

Approach	Duration (Hours)	Volume (Veh./Hr.)	Volume (Veh./Day)	Delay (Sec./Veh.)	Total Delay (Hours/Day)	Proportion Stopped	Vehicles Stopped
EB Michigan:							
Peak period	2	1,250	2,500	17	11.8	0.792	1,980
Off peak	16	690	11,040	12	36.8	0.641	7,077
WB Michigan:							
Peak	2	1,330	2,660	18	13.3	0.822	2,187
Off peak	16	840	13,440	13	48.5	0.678	9,112
Total Michigan					110.4		20,356
NB Harrison thru & L.T.:							
Peak	2	650	1,300	75	27.1	0.971	1,262
Off peak	16	360	5,760	18	28.8	0.774	4,458
NB Harrison R.T.:							
Peak	2	150	300	18	1.5	0.658	197
Off peak	16	90	1,440	14	5.6	0.644	927
SB Harrison:							
Peak	2	270	540	19	2.9	0.708	382
Off peak	16	210	3,360	15	14.0	0.692	2,325
Total Harrison					79.9		9,551
Total intersection					190.3		29,907

APPENDIX 5
CALCULATION OF DELAYS AND STOPS - 1975

Approach	Duration (Hours)	Volume (Veh./Hr.)	Volume (Veh./Day)	Delay (Sec./Veh.)	Total Delay (Hours/Day)	Proportion Stopped	Vehicles Stopped
EB Michigan:							
Peak period	2	900	1,800	12	6.0	0.574	1,033
Off peak	16	400	6,400	14	24.9	0.658	4,211
EB Michigan R.T.:							
Peak	2	350	700	7	1.4	0.404	283
Off peak	16	170	2,720	9	6.8	0.496	1,352
WB Michigan:							
Peak	2	1,300	2,600	13	9.4	0.688	1,789
Off peak	16	700	11,200	15	46.7	0.729	8,165
WB Michigan U-turn:							
Peak	2	250	500	26	3.6	0.821	411
Off peak	16	130	2,080	19	11.0	0.714	1,485
Total Michigan					109.8		18,729
NB Harrison:							
Peak	2	920	1,840	22	11.2	0.841	1,547
Off peak	16	400	6,400	11	19.6	0.576	4,686
SB Harrison:							
Peak	2	270	540	90	13.5	0.990	535
Off peak	16	180	2,880	23	18.4	0.833	2,399
Total Harrison					62.7		8,162
Total intersection					172.5		26,891

APPENDIX 6
COST AND BENEFIT ANALYSIS

Project Cost

Preliminary engineering	25,000
Construction	495,200
Construction engineering and contingencies	45,000
Temporary street lighting	5,800
Signal installation	14,800
Landscaping	20,000
Total cost	$605,800

Yearly Benefits

Accident cost reduction:		
Injury ($4,000 per accid.) = 9 x 4,000 =	36,000	
P.D. ($530 per accid.) = 14 x 530 =	7,420	
Total accident cost reduction		$43,420
Delay reduction ($3.38 per veh./hr.):		
Stopped delay:		
(190.3 - 172.5) 260 x 3.38 =	15,643	
Acceleration-Deceleration:		
Michigan Avenue (40 MPH):		
(4.42 hrs. per 1,000 stops):		
$\frac{20,356 - 18,729}{1,000}$ x 260 x 4.42 x 3.38 =	6,320	
Harrison Road (25 MPH):		
(2.98 hrs. per 1,000 stops):		
$\frac{9,551 - 8,162}{1,000}$ x 260 x 2.98 x 3.38 =	3,638	
Total delay reduction =		$25,601
Operating cost reduction:		
Engine idling ($0.18 per veh./hr):		
(190.3 - 172.5) 365 x 0.18 =	1,169	
Stopping and starting:		
Michigan Ave. (40 MPH):		
($13.84 per 1,000 veh.):		
$\frac{20,356 - 18,729}{1,000}$ x 365 x 13.84 =	8,219	
Harrison Rd. (25 MPH):		
($7.53 per 1,000 veh.):		
$\frac{9,551 - 8,162}{1,000}$ x 365 x 7.53 =	3,818	
Total operating cost reduction =		$13,206
Total yearly benefits		$82,227

Annual Return on Investment

$$\frac{82,227}{605,800} \times 100 = 13.57\%$$