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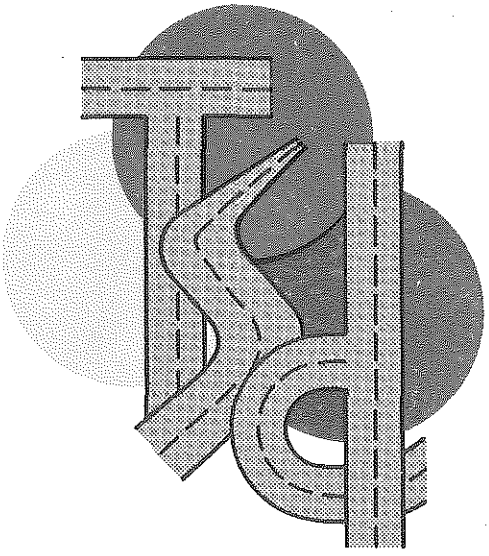
An Evaluation of 8-Phase Signal Control

TSD 486-81



TRAFFIC and SAFETY DIVISION

MICHIGAN DEPARTMENT OF STATE HIGHWAYS
AND TRANSPORTATION

MICHIGAN DEPARTMENT
OF
TRANSPORTATION

An Evaluation of 8-Phase Signal Control

TSD 486-81

by

Peter M. Briglia, Jr.
Safety Programs Unit

November 1981

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ABSTRACT

A before-and-after study was undertaken by the Michigan Department of Transportation to assess accident experience and changes in travel time, stopped delay, fuel consumption, and vehicle emissions after changing from two-phase, fixed-time control to 8-phase, fully-actuated control at nine Michigan intersections.

The intersections selected for 8-phase control were unique in that they were generally located at or near large regional shopping centers in a suburban setting. Variable and high left-turning volumes were present resulting in significant delays and a pattern of head-on, left-turn accidents for left-turning motorists.

Total, property damage, and injury accidents and injuries decreased. Property damage accidents were reduced at six intersections, combined injury/fatal accidents were reduced at seven, and combined injuries/fatalities were reduced at eight. Left-turn, angle, and head-on accidents were decreased and rear-end accidents were increased. Property damage accident rates decreased at five intersections and combined injury/fatal accident rates decreased at eight. Tests of statistical significance are discussed in the text.

NETSIM modelling of three intersections at a non-peak hour showed increases in travel time, stopped delay, fuel consumption, and vehicle emissions.

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SUMMARY

A before-and-after study was undertaken by the Michigan Department of Transportation to assess accident experience and changes in travel time, stopped delay, fuel consumption, and vehicle emissions after changing from two-phase, fixed-time control to 8-phase, fully-actuated control at nine Michigan intersections.

The intersections selected for 8-phase control were unique in that they were located at or near large regional shopping centers generally in a suburban setting. Variable and high left-turning volumes were present resulting in significant delays and a pattern of head-on, left-turn accidents for left-turning motorists.

Volume changes at all intersections ranged from a 7 percent decrease to a 24 percent increase. Left-turn volumes at the three intersections selected for NETSIM modelling increased by 50 percent.

The total number of accidents at the nine intersections decreased by 10 percent. Property damage accidents decreased by 6 percent, injury accidents decreased by 20 percent, and injuries by 28 percent. The small number of fatal accidents and fatalities make it impossible to draw legitimate conclusions concerning them.

Six of the nine intersections experienced fewer property damage accidents than had been anticipated. Seven of nine showed fewer combined injury and fatal accidents and eight of nine showed fewer combined injuries and fatalities. The overall reductions in accidents for the three categories were statistically significant at the 99 percent confidence level.

Left-turn, angle, and head-on accidents decreased by 91 percent, 67 percent, and 33 percent, respectively. Rear-end accidents increased by 66 percent.

Property damage accident rates decreased at five intersections and increased at four intersections. The combined injury and fatal accident rates decreased at eight intersections and increased at one intersection. The difference in property damage accident rates was not statistically significant. The difference in combined injury and fatal accident rates was significant at the 99 percent confidence level.

NETSIM modelling of three intersections at non-peak hour (11 a.m. to noon) volumes showed average increases of 65 percent in travel time, 656 percent in stopped delay, 51 percent in fuel consumption, 37 percent in hydrocarbon emissions, 55 percent in carbon monoxide emissions, and 7 percent in emissions of oxides of nitrogen.

Introduction

Michigan's first 8-phase traffic-actuated signal was installed in May, 1970, at the junction of Jackson (BL-94) and Maple Roads in Ann Arbor. Eleven additional 8-phase signals were installed between 1970 and 1977. These signals were generally located at or near large regional shopping centers in suburban settings. Variable and high left-turn volumes were present resulting in significant delays and a pattern of head-on, left-turn accidents for left-turning motorists. The signals were installed to reduce left-turn delay by freeing left-turning movements of opposite-direction, through-traffic conflicts.

Nine intersections controlled by 8-phase traffic-actuated signals were evaluated to determine the effects of this control compared to the two-phase signal controls they replaced. Three intersections were deleted from consideration due to extensive changes in the roadway between the before and after periods. The factors evaluated were accident experience, travel time, stopped delay, fuel consumption, and vehicle emissions. These factors were evaluated using a NETSIM analysis of several of these intersections.

The nine intersections, their locations (see Location Map, page 2), dates of 8-phase signal installation, and speed limits are:

1. Jackson (BL-94) at Maple, Ann Arbor, 5-4-70
   Posted Speed: 35 mph (both roads)

2. Saginaw (M-43) at Waverly, Lansing, 2-22-70 to 10-21-71
   Posted Speed: Saginaw (40 mph), Waverly (45 mph)

   (This signal operated under 4-phase, fixed-time control for brief periods during the installation period due to malfunctions of the 8-phase, fully actuated signal).

3. Logan (M-99) at Holmes, Lansing, 1-10-72
   Posted Speed: Logan (40 mph), Holmes (WB-30 mph, EB-35 mph)

4. Cedar (BL-96) at Jolly, Lansing, 12-23-74
   Posted Speed: Cedar (NB-35 mph, SB-45 mph), Jolly (35 mph)

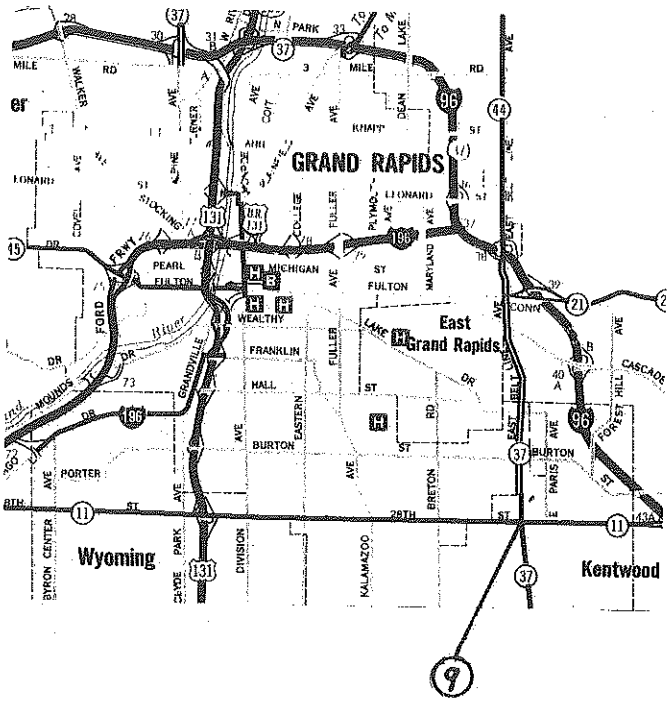
5. Grand River (M-43) at Hagadorn, East Lansing, 7-28-76
   Posted Speed: Grand River (WB-35 mph, EB-40 mph), Hagadorn (35 mph)

6. Washtenaw (M-17) at Carpenter, Ann Arbor, 10-28-76
   Posted Speed: Washtenaw (45 mph), Carpenter (35 mph)

7. Logan (M-99) at Jolly, Lansing, 5-25-77
   Posted Speed: Logan (40 mph), Jolly (35 mph)

8. Fair (M-139) at Napier, Benton Harbor, 8-12-77
   Posted Speed: Fair (45 mph), Napier (35 mph)

9. 28th Street (M-11) at East Beltline (M-37), Grand Rapids, 10-27-77
   Posted Speed: 28th Street (WB-45 mph, EB-50 mph), East Beltline (50 mph)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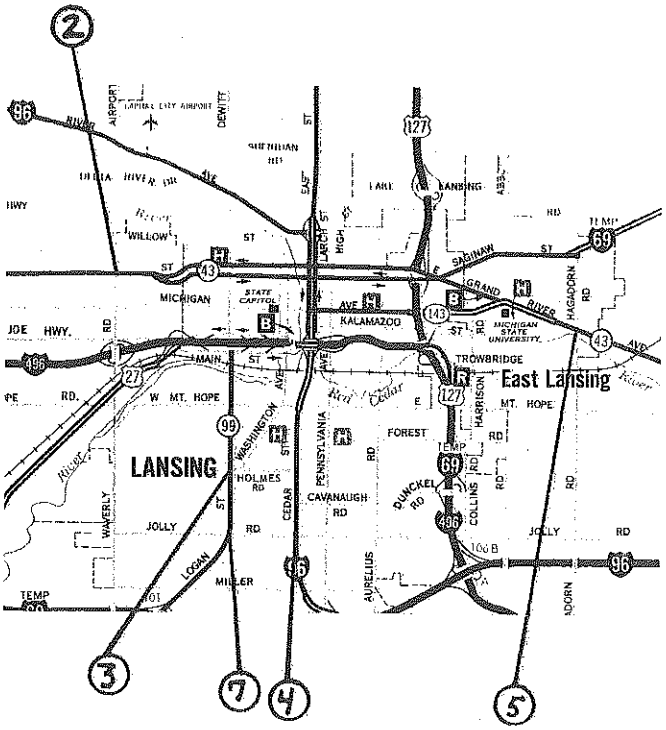
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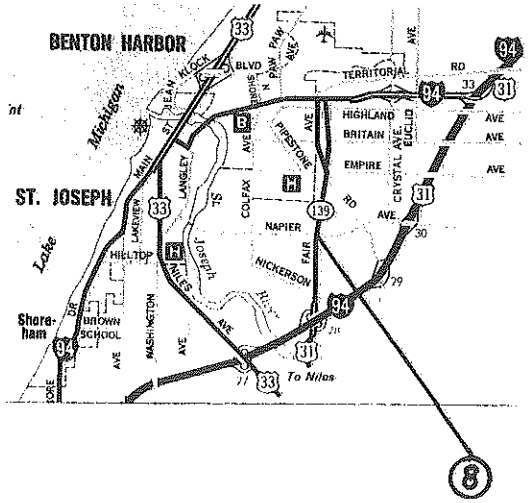
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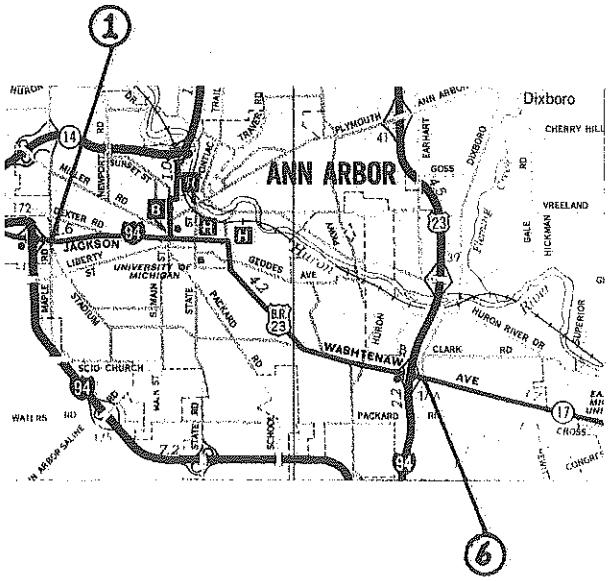
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Conclusions

The purpose of installation of 8-phase, fully-actuated traffic control was to effectively accommodate large, variable, left-turning movements.

These signals reduced injuries and injury accidents by 20 and 28 percent, respectively. Seven of the nine intersections showed fewer combined injury and fatal accidents than expected and eight of the nine showed fewer combined injuries and fatalities than expected. The combined injury and fatal accident rates decreased at eight intersections and increased at one. The overall decrease was statistically significant. Although total accidents decreased by 10 percent and property damage accidents decreased by 6 percent, these decreases were not uniform. Five of the nine intersections showed decreased property damage rates, but the overall change in rates was not statistically significant.

The 8-phase signals produced the expected changes in accident types - i.e. decreasing left-turn, angle, and head-on accidents and increasing rear-end accidents. The overall effect of the installation of the 8-phase signals on accident types was to reduce accident types that occurred at the actual intersection (i.e. between crosswalks) and increase accident types that occurred on the approaches (i.e. parking, rear-end, and "other" accidents). This shift in accident types was presumably due to the longer back-ups created at these signals and the increased conflicts at driveways in the vicinity of these intersections as a result of these back-ups.

It was not possible to classify injuries by severity in this study. An additional study, using a smaller sample size and actual accident reports indicating injury severity, would aid in evaluating changes in average severity.

The results of NETSIM modelling indicated increased travel time, stopped delay, fuel consumption, and vehicle emissions. These changes ranged from a 7 percent increase in oxides of nitrogen emissions to a 656 percent increase in stopped delay during a non-peak hour. Part of these increases may be attributed to the volume increases at two of the three intersections and the increase in left-turning volumes of 50 percent, and part to the increased delay due to the installation of 8-phase control. Back-up delay studies conducted for two of the intersections indicated peak hour delays may be up to twice the non-peak hour delays. Field observations and the results of the NETSIM modelling indicate that adequate storage must be provided to accommodate these large back-ups without impacting an excessive number of intersections and driveways in the vicinity.

A study utilizing the NETSIM program currently being developed to better simulate fully-actuated signals would be useful to confirm the results of this study and simulate the peak hour.

Clearly, the installation of an 8-phase, fully-actuated signal is a drastic measure, to be used when significant left-turn volumes cause the left-turn delay and head-on, left-turn accidents to become excessive. Fixed-time signals with left-turn phases may provide similar operational characteristics and cost less to install and maintain. A comparative study would prove beneficial to traffic engineers seeking to more effectively accommodate left-turning vehicles.

Volumes

Daily approach volumes were obtained from machine counts performed before and after installation of the 8-phase signals. For three intersections only one count was available (i.e. either the before or after count was not taken), and the same volumes were used for the before and after periods. These volumes are shown in Table 1.

Table 1
Daily Approach Volumes

Location	Before	After	Percentage Change
1. Jackson (BL-94) at Maple		39018	---*
2. Saginaw (M-43) at Waverly	59537	56618	- 5
3. Logan (M-99) at Holmes	40798	46699	+14
4. Cedar (BL-96) at Jolly	42017	47469	+13
5. Grand River (M-43) at Hagadorn	50888	51982	+ 2
6. Washtenaw (M-17) at Carpenter	43354	53841	+24
7. Logan (M-99) at Jolly	35147		---*
8. Fair (M-139) at Napier	33666		---*
9. 28th Street (M-11) at East Beltline (M-37)	57291	53056	- 7

*Same count used for "before" and "after" daily approach volume.

Table 2 shows the total hourly approach volumes and hourly left-turn volumes of all approaches at the non-peak hour (11 a.m. to noon) for the three intersections selected for NETSIM modelling. Table 3 shows the same information for the peak hour.

Table 2
Non-Peak Hour Volumes (11 a.m. to Noon)

	Left-Turn Volume All Approaches			Total Approach Volume		
Location	Before	After	Percentage Change	Before	After	Percentage Change
Saginaw (M-43) at Waverly	436	681	+56	3,706	3,379	- 9
Cedar (BL-96) at Jolly	346	519	+50	2,087	2,628	+26
Grand River (M-43) at Hagadorn	325	499	+54	1,843	2,818	+53

Table 3
Peak-Hour Volumes

	Left-Turn Volume All Approaches			Total Approach Volume		
Location	Before	After	Percentage Change	Before	After	Percentage Change
Saginaw (M-43) at Waverly	451	808	+79	4,800	4,521	- 6
Cedar (BL-96) at Jolly	405	715	+77	3,058	3,879	+27
Grand River (M-43) at Hagadorn	449	752	+67	3,424	4,323	+26

Accident Frequency

Three years of "before" accident data were evaluated for all intersections. Three years of "after" accident data were evaluated for all intersections except Logan (M-99) at Jolly, Fair (M-139) at Napier, and 28th Street (M-11) at East Beltline (M-37). Only two years and seven months of data were available for these because of their more recent installation of 8-phase signals. The data for these intersections were extrapolated by straight-line method to reflect 3-year periods. The complete accident data for all nine intersections are shown in Appendix A. Accidents were obtained for distances of 500 feet on either side of the intersections to include any increase in driveway accidents due to traffic backed-up at the signals. All intersections were controlled by two-phase, fixed-time signals in the "before" period and 8-phase, fully-actuated signals in the "after" period.

The numbers of accidents for all nine intersections for three years are shown below:

	Before	After	Percentage Change
Total Accidents	1,556	1,402	- 10
Property Damage Accidents	1,113	1,049	- 6
Injury Accidents	442	350	- 21
Injuries	706	511	- 28
Fatal Accidents	1	3	+200
Fatalities	1	4	+300

Despite volume changes ranging from a 7 percent decrease to a 24 percent increase, the total number of accidents at these intersections decreased by 10 percent. Property damage accidents decreased by 6 percent, injury accidents decreased by 21 percent, and injuries decreased by 28 percent. The small number of fatal accidents and fatalities make it impossible to draw legitimate conclusions.

The numbers of property damage accidents, injury and fatal accidents, and injuries and fatalities expected to occur in the "after" period were projected using the corresponding numbers in the "before" period and the rate of change of these factors for the entire state (Table 4). Injury accidents and fatal accidents, and injuries and fatalities were combined due to the low number of fatal accidents and fatalities. Chi-square tests were used to determine the statistical significance of the reductions (Appendix B). The overall reductions in property damage accidents, injury and fatal accidents, and injuries and fatalities for all nine intersections were statistically significant at the 99 percent confidence level. However, two intersections (Grand River at Hagadorn and Fair at Napier) were the major contributors to the property damage accident Chi-square value. Two intersections (Grand River at Hagadorn and 28th Street at East Beltline) were the major contributors to the injury and fatal accident Chi-square value. Three intersections (Grand River at Hagadorn, Fair at Napier, and 28th Street at East Beltline) were the major contributors to the injuries and fatalities Chi-square value.

Six of the nine intersections showed fewer "after observed" than "after expected" property damage accidents. Seven showed fewer injury and fatal accidents and eight showed fewer injuries and fatalities.

Table 4
Expected and Observed Accidents (3-Year Total)

Location	Property Damage Accidents			Injury and Fatal Accidents			Injuries and Fatalities		
	Before	After Expected	After Observed	Before	After Expected	After Observed	Before	After Expected	After Observed
Jackson (BL-94) at Maple	21	25	35	18	16	12	25	28	16
Saginaw (M-43) at Waverly	159	187	160	57	51	55	101	107	79
Logan (M-99) at Holmes	128	139	137	57	53	51	77	67	74
Cedar (BL-96) at Jolly	127	134	141	39	37	39(1)	74	67	51(2)
Grand River (M-43) at Hagadorn	140	169	112	72	85	58(2)	105	126	99(2)
Washtenaw (M-17) at Carpenter	157	190	152	56	66	33	94	113	51
Logan (M-99) at Jolly	60	66	70*	26	29	23*	34	38	34*
Fair (M-139) at Napier	188	206	105*	50	55	38*	83	92	52*
28th Street (M-11) at East Beltline (M-37)	133	146	137*	68(1)	75	44*	114(1)	126	59*

*Two years, seven months of data extrapolated to three years.
( ) denotes number of fatal accidents and fatalities.

There were three "after" period fatal accidents. In 1979, a motorist passing through the intersection of Grand River and Hagadorn on the amber signal struck a pedestrian resulting in a fatality. The other fatal accident at Grand River and Hagadorn occurred in 1977 and involved a rear-end collision. The remaining fatal accident occurred in 1975, at the intersection of Cedar and Jolly and was a fixed object collision that resulted in two fatalities.

Table 5 shows the total number of accidents, by type, for all nine intersections. As expected, angle, left-turn, and right-turn accidents decreased and rear-end accidents increased. Chi-square tests were used to evaluate the significance of the changes (Appendix B). The accident types were divided into two categories,

those that increased and those that decreased, and separate Chi-square tests were performed on each. Both categories experienced statistically significant changes at the 99 percent confidence level. The major contributors to the Chi-square value for those intersections which had increases were parking and "other" accidents. Rear-end accidents contributed a minor amount to the overall Chi-square value. The major contributors for those intersections which had decreases were head-on, angle, and left-turn accidents. The large increase in "other" accidents was attributed to an increase in driveway and entrance-exit accidents near these intersections caused by longer traffic queues.

The overall effect on accident types of the installation of the 8-phase signals was to reduce the types of accidents which occur at the actual intersection (i.e. between crosswalks - angle, left-turn accidents) and increase the types that occur on the approaches (i.e. rear-ends, parking, and "other" accidents).

Table 5
Number of Accidents By Type (3-Year Totals)

	Before	After	Percentage Change
Head-On	15	10	- 33
SS	61	64	+ 5
Angle	313	103	- 67
Left-Turn	407	38	- 91
Right-Turn	34	14	- 59
Rear-End	469	779	+ 66
Backing	16	22	+ 38
Parking	149	173	+ 16
Other	38	145	+282
Other - Misc.*	54	54	0
Total	1,556	1,402	- 10

*Involving other than two motor vehicles.

The signals at four of these intersections (Saginaw at Waverly, Cedar at Jolly, Grand River at Hagadorn, and 28th at East Beltline) were interconnected with other signals in the before period, while operating under two-phase control. However, the distance between the interconnected signals was so great that traffic progression generally was not very good. Therefore, no attempt was made to assess the effects of the installation of the 8-phase signals on traffic progression.

Accident Rates

Table 6 shows the yearly accident rates per million vehicles for all nine intersections. The volumes used to calculate these rates are those shown in Table 1. Property damage accident rates decreased at five intersections and increased at four intersections. Injury and fatal accident rates decreased at eight intersections and increased at one intersection.

Table 6
Accident Rates (Accidents/MV)

Location	Property Damage Accidents			Injury and Fatal Accidents		
	Before	After	Percentage Change	Before	After	Percentage Change
Jackson (BL-94) at Maple	0.49	0.82	+67	0.42	0.28	-33
Saginaw (M-43) at Waverly	2.44	2.58	+ 6	0.87	0.89	+ 2
Logan (M-99) at Holmes	2.87	2.68	- 7	1.28	1.00	-22
Cedar (BL-96) at Jolly	2.76	2.71	- 2	0.85	0.75	-12
Grand River (M-43) at Hagadorn	2.51	1.97	-22	1.29	1.02	-21
Washtenaw (M-17) at Carpenter	3.31	2.58	-22	1.18	0.56	-53
Logan (M-99) at Jolly	1.56	1.82	+17	0.68	0.60	-12
Fair (M-139) at Napier	5.10	2.85	-44	1.36	1.03	-24
28th Street (M-11) at East Beltline (M-37)	2.12	2.36	+11	1.08	0.76	-30

The significance of the changes in accident rates was evaluated using paired T-tests (Appendix B). There was no significant difference in the before and after property damage accident rates. The difference in before and after injury and fatal accident rates was statistically significant at the 99 percent confidence level.

NETSIM Traffic Model

Three intersections were modelled using the NETSIM computer program. These were the intersections of Saginaw at Waverly, Cedar at Jolly, and Grand River at Hagadorn. Those intersections were simulated as operating under two-phase, fixed-time control in the "before" period and 8-phase, fully-actuated control in the "after" period. The geometrics of the intersections were simulated as they existed in the before and after periods (Appendix C). The volumes used for these simulations were machine counts taken in the years shown. Turning movement counts, taken in conjunction with the machine counts, were also used. The actual before and after volumes were used, rather than identical volumes, to best simulate the actual operating conditions. Only a non-peak hour (11 a.m. to noon) was simulated. A summary of the simulation is shown in Table 7 and the complete output statistics are shown in Appendix C.

An attempt was made to simulate the peak hour for the three intersections, however, the results seemed unrealistic. Apparently, the volumes experienced by these intersections during the peak hour are beyond the ability of the traffic-actuated portion of the NETSIM model to handle adequately.

Table 7
Results of NETSIM Modelling
(Non-Peak Hour - 11 a.m. - 12 Noon)

	Saginaw @ Waverly			Cedar @ Jolly			Grand River @ Hagadorn			Average
	Before	After	% Change	Before	After	% Change	Before	After	% Change	% Change
Year of Count	1969	1980		1972	1979		1969	1978		
Hourly Volume	3,706	3,379	-9	2,087	2,628	+26	1,843	2,818	+53	+ 23
Stopped Delay/Vehicle (Min.)	0.15	1.70	+1033	0.14	1.16	+729	0.14	0.43	+207	+656
Travel Time/Veh. - Mile (Min./V-Mile)[1/]	2.04	4.21	+106	2.13	3.58	+68	2.16	2.63	+22	+ 65
Fuel Consumption (Gallons/Year)	701,100	888,900	+27	372,500	599,400	+61	325,500	541,600	+66	+ 51
MPG	12.78	9.08	-29	13.46	10.40	-23	13.74	12.45	-9	- 20
Vehicle Emissions										
Hydrocarbons (grams/mile)	2.60	4.01	+54	2.39	3.38	+41	2.33	2.71	+16	+ 37
Carbon Monoxide (grams/mile)	38.79	69.34	+79	34.40	55.67	+62	32.85	40.50	+23	+ 55
Oxides of Nitrogen (grams/mile0	6.39	6.97	+9	5.60	6.08	+9	5.38	5.60	+4	+ 7

1/Travel time is computed over a distance beginning 2,000 feet upstream and ending 2,000 feet downstream of the intersection.

Averaging the results for the non-peak hour simulation for the three intersections gave a 65 percent increase in travel time, a 656 percent increase in stopped delay, a 51 percent increase in fuel consumption, and increases in vehicle emissions of 37 percent for hydrocarbons, 55 percent for carbon monoxide, and 7 percent for oxides of nitrogen.

Back-up delay studies conducted at Grand River at Hagadorn and Saginaw at Waverly in the after period indicated delays of 0.8 minutes and 1.2 minutes, respectively. These agree fairly well with the NETSIM figures for stopped delay of 0.4 and 1.7 minutes for the two intersections. These back-up delay studies also indicated delays of 1.8 minutes and 1.1 minutes for these intersections during the peak hour. This increase in delay is partly due to the installation of the 8-phase signals, but part must also be attributed to the increase in left-turning volumes and the increase in total approach volumes at two of the three intersections, as shown in Tables 2 and 3.

APPENDIX A

Accident Tabulation

	Grand River (M-43) at Hagadorn								Jackson (BL-94) at Maple								Saginaw (M-43) at Waverly Road							
	Before				After				Before				After				Before				After			
	1973	1974	1975	TOTAL	1977	1978	1979	TOTAL	1967	1968	1969	TOTAL	1971	1972	1973	TOTAL	1967	1968	1969	TOTAL	1972	1973	1974	TOTAL
P.D. Accidents	44	42	54	140	31	39	42	112	3	7	11	21	8	15	12	35	48	45	66	159	53	63	44	160
Inj. Accidents	24	25	23	72	17	18	21	56	2	6	10	18	6	4	2	12	20	16	21	57	19	16	20	55
Injuries	(34)	(39)	(32)	(105)	(30)	(36)	(31)	(97)	(2)	(11)	(12)	(25)	(7)	(6)	(3)	(16)	(35)	(28)	(38)	(101)	(29)	(22)	(28)	(79)
Fatal Accidents	0	0	0	0	1	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fatalities	(0)	(0)	(0)	(0)	(1)	(0)	(1)	(2)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Total Accidents	68	67	77	212	49	57	64	170	5	13	21	39	14	19	14	47	68	61	87	216	72	79	64	215
Head-On	0	1	0	1	2	0	0	2	0	0	0	0	0	0	0	0	0	2	0	2	0	0	1	1
SS-SM & SS-OP	1	1	2	4	2	4	1	7	0	0	1	1	0	2	2	4	7	1	6	14	2	3	3	8
Angle	5	9	14	28	4	6	5	15	4	3	6	13	1	1	1	3	23	25	20	68	1	1	2	4
L-Turn	14	17	19	50	3	1	3	7	0	5	8	13	1	0	1	2	15	13	23	51	0	1	4	5
R-Turn	0	1	0	1	0	1	1	2	0	0	2	2	0	0	0	0	0	3	5	8	0	1	1	2
Rear-End	35	30	27	92	24	30	41	95	1	5	3	9	7	8	8	23	20	11	26	57	38	48	40	126
Backing	2	0	0	2	0	2	1	3	0	0	0	0	1	0	0	1	1	0	1	2	0	2	0	2
Parking	4	3	5	12	9	0	0	9	0	0	0	0	2	7	2	11	0	0	0	0	29	22	11	62
Other	3	2	0	5	0	12	5	17	0	0	0	0	1	0	0	1	1	4	6	11	2	1	2	5
Other-Misc.**	4	3	10	17	5	1	7	13	0	0	1	1	1	1	0	2	1	2	0	3	0	0	0	0
Total	68	67	77	212	49	57	64	170	5	13	21	39	14	19	14	47	68	61	87	216	72	79	64	215

**Accidents involving other than two motor vehicles.

Location	Logan (M-99) at Jolly								Fair (M-139) at Napier								28th Street (M-11) at Beltline (M-37)							
	Before				After				Before				After				Before				After			
	1974	1975	1976	TOTAL	1978	1979	1980*	TOTAL	1974	1975	1976	TOTAL	1978	1979	1980*	TOTAL	1974	1975	1976	TOTAL	1978	1979	1980*	TOTAL
P.D. Accidents	15	28	17	60	28	23	9	60	67	62	59	188	38	35	17	90	40	40	53	133	52	50	16	118
Inj. Accidents	10	8	8	26	8	8	4	20	19	17	14	50	19	11	3	33	15	21	31	67	13	14	11	38
Injuries	(14)	(9)	(11)	(34)	(12)	(13)	(4)	(29)	(36)	(27)	(20)	(83)	(25)	(17)	(3)	(45)	(25)	(30)	(58)	(113)	(16)	(17)	(18)	(51)
Fatal Accidents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Fatalities	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(1)	(1)	(0)	(0)	(0)	(0)
Total Accidents	25	36	25	86	36	31	13	80	86	79	73	238	57	46	20	123	55	61	85	201	65	64	27	156
Head-On	0	1	0	1	0	0	0	0	1	1	1	3	1	0	1	2	0	2	0	2	0	0	1	1
SS-SM & SS-OP	1	2	1	4	1	0	0	1	1	4	3	8	3	4	0	7	6	1	4	11	3	5	1	9
Angle	5	5	0	10	5	5	1	11	13	22	12	47	3	3	1	7	7	8	9	24	3	4	8	15
L-Turn	7	8	12	27	0	0	0	0	20	16	5	41	2	2	1	5	23	25	40	88	3	2	1	6
R-Turn	0	1	1	2	0	0	0	0	2	4	0	6	0	1	0	1	0	0	2	2	1	0	0	1
Rear-End	10	9	6	25	20	14	10	44	16	10	27	53	24	21	11	56	9	17	23	49	34	40	15	89
Backing	1	1	0	2	2	1	0	3	1	2	1	4	0	0	0	0	0	0	0	0	0	2	1	3
Parking	0	5	5	10	0	0	0	0	28	18	19	65	1	1	0	2	8	6	5	19	0	0	0	0
Other	0	1	0	1	5	8	2	15	1	1	0	2	21	14	6	41	2	2	1	5	14	11	0	25
Other-Misc.**	1	3	0	4	3	3	0	6	3	1	5	9	2	0	0	2	0	0	1	1	7	0	0	7
Total	25	36	25	86	36	31	13	80	86	79	73	238	57	46	20	123	55	61	85	201	65	64	27	156

*January through July
**Accidents involving other than two motor vehicles.

Location	Logan (M-99) at Holmes								Cedar (BL-96) at Jolly								Washtenaw (M-17) at Carpenter							
	Before				After				Before				After				Before				After			
	1969	1970	1971	TOTAL	1973	1974	1975	TOTAL	1971	1972	1973	TOTAL	1975	1976	1977	TOTAL	1973	1974	1975	TOTAL	1977	1978	1979	TOTAL
P.D. Accidents	48	47	33	128	50	42	45	137	39	47	41	127	46	52	43	141	56	56	45	157	49	52	51	152
Inj. Accidents	20	23	14	57	19	16	16	51	9	15	15	39	13	10	15	38	20	15	21	56	14	9	10	33
Injuries	(29)	(29)	(19)	(77)	(28)	(19)	(27)	(74)	(19)	(31)	(24)	(74)	(17)	(15)	(17)	(49)	(36)	(22)	(36)	(94)	(23)	(16)	(12)	(51)
Fatal Accidents	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Fatalities	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(2)	(0)	(0)	(2)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Total Accidents	68	70	47	185	69	58	61	188	48	62	56	166	60	62	58	180	76	71	66	213	63	61	61	185
Head-On	1	1	0	2	1	0	1	2	1	0	0	1	0	0	0	0	1	1	1	3	0	2	0	2
SS-SM & SS-OP	1	1	1	3	3	6	4	13	0	5	1	6	2	4	2	8	4	4	2	10	4	1	0	5
Angle	31	15	5	51	3	3	4	10	10	5	8	23	2	2	1	5	20	12	17	49	8	10	10	28
L-Turn	12	12	8	32	1	1	0	2	9	17	16	42	1	2	2	5	20	23	20	63	0	0	4	4
R-Turn	2	4	2	8	0	2	1	3	1	1	0	2	2	0	1	3	1	1	1	3	1	0	1	2
Rear-End	15	31	14	60	32	23	25	80	19	24	21	64	42	39	41	122	22	21	17	60	42	39	33	114
Backing	1	0	2	3	0	1	2	3	0	1	1	2	3	1	1	5	0	1	0	1	1	0	1	2
Parking	0	0	8	8	23	17	22	62	4	5	6	15	3	13	6	22	7	6	7	20	5	0	0	5
Other	4	2	4	10	1	1	1	3	3	1	0	4	2	0	0	2	0	0	0	0	1	9	9	19
Other-Misc.**	1	4	3	8	5	4	1	10	1	3	3	7	3	1	4	8	1	2	1	4	1	0	3	4
Total	68	70	47	185	69	58	61	188	48	62	56	166	60	62	58	180	76	71	66	213	63	61	61	185

**Accidents involving more than two motor vehicles.

APPENDIX B

Statistical Analysis

Location	Middle Year Before/After	Percentage Changes* Property Damage Accidents	Injury and Fatal Accidents	Injuries And Fatalities	Property Damage Accidents Before	Property Damage Accidents After Expected	Injury and Fatal Accidents Before	Injury and Fatal Accidents After Expected	Injuries and Fatalities Before	Injuries and Fatalities After Expected
1 Jackson (BL-94) at Maple	1968 1972	+.201	-.131	+.113	21	25	18	16	25	28
2 Saginaw (M-43) at Waverly	1968 1973	+.174	-.098	+.055	159	187	57	51	101	107
3 Logan (M-99) at Holmes	1970 1974	+.085	-.065	-.127	128	139	57	53	77	67
4 Cedar (BL-96) at Jolly	1972 1976	+.052	-.059	-.090	127	134	39	37	74	67
5 Grand River (M-43) at Hagadorn	1974 1978	+.208	+.176	+.198	140	169	72	85	105	126
6 Washtenaw (M-17) at Carpenter	1974 1978	+.208	+.176	+.198	157	190	56	66	94	113
7 Logan (M-99) at Jolly	1975 1979	+.096	+.104	+.103	60	66	26	29	34	38
8 Fair (M-139) at Napier	1975 1979	+.096	+.104	+.103	188	206	50	55	83	92
9 28th Street (M-11) at Beltline (M-37)	1975 1979	+.096	+.104	+.103	133	146	68	75	114	126

*Calculated using data from Michigan Traffic Accident Facts prepared by Michigan Department of State Police.

Property Damage Accidents (3 Years)

Location	Before	After Expected	After Observed	$A_{EXP}-A_{OBS}$	$(A_{EXP}-A_{OBS})^2$	$\frac{(A_{EXP}-A_{OBS})^2}{A_{EXP}}$
1	21	25	35	10	100	4.0
2	159	187	160	27	729	3.9
3	128	139	137	2	4	0.0
4	127	134	141	7	49	0.4
5	140	169	112	57	3249	19.2
6	157	190	152	38	1444	7.6
7	60	66	70*	4	16	0.2
8	188	206	105*	101	10201	49.5
9	133	146	137*	9	81	0.6

$X^2 = 85.4$

*2 years, 7 months of data adjusted to 3 years

$df = (9-1)(2-1) = 8$

$P < 0.001$

∴There is a significant difference between the after expected and after observed

Injury & Fatal Accidents (3 Years)

Location	Before	After Expected	After Observed	$A_{EXP}-A_{OBS}$	$(A_{EXP}-A_{OBS})^2$	$\frac{(A_{EXP}-A_{OBS})^2}{A_{EXP}}$
1	18	16	12	4	16	1.0
2	57	51	55	4	16	0.3
3	57	53	51	2	4	0.1
4	39	37	39	2	4	0.1
5	72	85	58	27	729	8.6
6	56	66	33	33	1089	16.5
7	26	29	23*	6	36	1.2
8	50	55	38*	17	289	5.3
9	68	75	44*	31	961	12.8

$X^2 = 45.9$

$df = (9-1)(2-1) = 8$

$P < 0.001$

*2 years, 7 months of data adjusted to 3 years

∴There is a significant difference between the after expected and after observed.

Injuries & Fatalities (3 Years)

Location	Before	After Expected	After Observed	$A_{EXP}-A_{OBS}$	$(A_{EXP}-A_{OBS})^2$	$\frac{(A_{EXP}-A_{OBS})^2}{A_{EXP}}$
1	25	28	16	12	144	5.1
2	101	107	79	28	784	7.3
3	77	67	74	7	49	0.7
4	74	67	51	16	256	3.8
5	105	126	99	27	729	5.8
6	94	113	51	62	3844	34.0
7	34	38	34*	4	16	0.4
8	83	92	52*	40	1600	17.4
9	114	126	59*	67	4489	35.6

$X^2=110.1$

$df = (9-1)(2-1) = 8$

$P < 0.001$

*2 years, 7 months of data adjusted to 3 years

:.There is a significant difference between after expected and after observed.

Chi-Square Test of Accidents by Type
Expected Values

	Before	After
Head-On	$\frac{25}{2958}$ X 1556 = 13	$\frac{25}{2958}$ X 1402 = 12
SS-SM & SS-OP	$\frac{125}{2958}$ X 1556 = 66	$\frac{125}{2958}$ X 1402 = 59
Angle	$\frac{416}{2958}$ X 1556 = 219	$\frac{416}{2958}$ X 1402 = 197
L-Turn	$\frac{445}{2958}$ X 1556 = 234	$\frac{445}{2958}$ X 1402 = 211
R-Turn	$\frac{48}{2958}$ X 1556 = 25	$\frac{48}{2958}$ X 1402 = 23
R-End	$\frac{1248}{2958}$ X 1556 = 656	$\frac{1248}{2958}$ X 1402 = 592
Backing	$\frac{38}{2958}$ X 1556 = 20	$\frac{38}{2958}$ X 1402 = 18
Parking	$\frac{322}{2958}$ X 1556 = 169	$\frac{322}{2958}$ X 1402 = 153
Other	$\frac{183}{2958}$ X 1556 = 96	$\frac{183}{2958}$ X 1402 = 87
Other-Misc.	$\frac{108}{2958}$ X 1556 = 57	$\frac{108}{2958}$ X 1402 = 51

OBS	EXP	OBS-EXP	$(OBS-EXP)^2$	$\frac{(O-E)^2}{EXP}$
15	13	2	4	0.31
10	12	2	4	0.33
61	66	5	25	0.38
64	59	5	25	0.42
313	219	94	8836	40.35
103	197	94	8836	44.85
407	234	173	29929	127.90
38	211	173	29929	141.84
34	25	9	81	3.24
14	23	9	81	3.52
469	656	187	34969	53.31
779	592	187	34969	59.07
16	20	4	16	0.80
22	18	4	16	0.89
149	169	20	400	2.37
173	153	20	400	2.61
38	96	58	3364	35.04
145	87	58	3364	38.67
54	57	3	9	0.16
54	51	3	9	0.18
2958	2958			

$X^2 = 556.24$

df = (10-1)(2-1) = 9

$P < 0.001$ critical value = 27.877

∴ Significant difference in before and after

Chi-Square Test of Accidents by Type
Accident Types That Increased

	Before	After	Total
SS-SM & SS-OP	61	64	125
R-End	469	779	1248
Backing	16	22	38
Parking	149	173	322
Other	38	145	183
Total	733	1183	1916

SS-SM & SS-OP	$\frac{125}{1916} \times 733 = 48$	$\frac{125}{1916} \times 1183 = 77$
R-End	$\frac{1248}{1916} \times 733 = 477$	$\frac{1248}{1916} \times 1183 = 771$
Backing	$\frac{38}{1916} \times 733 = 15$	$\frac{38}{1916} \times 1183 = 23$
Parking	$\frac{322}{1916} \times 733 = 123$	$\frac{322}{1916} \times 1183 = 199$
Other	$\frac{183}{1916} \times 733 = 70$	$\frac{183}{1916} \times 1183 = 113$

OBS	EXP	OBS-EXP	$(OBS-EX)^2$	$\frac{(O-E)^2}{EXP}$
61	48	13	169	3.52
64	77	13	169	2.19
469	477	8	64	0.13
779	771	8	64	0.08
16	15	1	1	0.07
22	23	1	1	0.04
149	123	26	676	5.50
173	199	26	676	3.40
38	70	32	1024	14.63
145	113	32	1024	9.06
1916	1916			$X^2 = 38.62$

$df = (5-1)(2-1) = 4$

$P < 0.001$ critical value = 18.467

∴ Significant difference in before and after

Chi-Square Test of Accidents By Type
Accident Types That Decreased

	Before	After	Total
Head-On	15	10	25
Angle	313	103	416
L-Turn	407	38	445
R-Turn	34	14	48
Total	769	165	934

Head-On	$\frac{25}{934} \times 769 = 21$	$\frac{25}{934} \times 165 = 4$
Angle	$\frac{416}{934} \times 769 = 343$	$\frac{416}{934} \times 165 = 73$
L-Turn	$\frac{445}{934} \times 769 = 366$	$\frac{445}{934} \times 165 = 79$
R-Turn	$\frac{48}{934} \times 769 = 40$	$\frac{48}{934} \times 165 = 8$

OBS	EXP	OBS-EXP	$(OBS-EXP)^2$	$\frac{(O-E)^2}{EXP}$
15	21	6	36	1.71
10	4	6	36	9.00
313	343	30	900	2.62
103	73	30	900	12.33
407	366	41	1681	4.59
38	79	41	1681	21.28
34	40	6	36	0.90
14	8	6	36	4.50
934	934			$X^2 = 56.93$

$df = (4-1)(2-1) = 3$

$P < 0.001$
Critical Value = 16.266
∴ Significant difference in before and after

Paired T Test - Property Damage Accident Rates

Location	Before (X_B)	After (X_A)	$d=X_A-X_B$	d^2
1	0.49	0.82	+0.33	0.1089
2	2.44	2.58	+0.14	0.0196
3	2.87	2.68	-0.19	0.0361
4	2.76	2.71	-0.05	0.0025
5	2.51	1.97	-0.54	0.2916
6	3.31	2.58	-0.73	0.5329
7	1.56	1.82	+0.26	0.0676
8	5.10	2.85	-2.25	5.0625
9	2.12	2.36	+0.24	0.0576
			$\Sigma = -2.79$	$\Sigma = 6.1793$

$H_o : U_A = U_B$ $\quad d = X_A - X_B = 0$

$N = 9$ $\quad \sum d = -2.79$ $\quad \sum d^2 = 6.1793$

$\bar{d} = \sum d/N = -2.79/9 = -0.31$

$$S = \sqrt{\frac{\sum d^2 - (\sum d)^2/N}{N-1}} = \sqrt{\frac{6.1793 - (-2.79)^2/9}{9-1}} = 0.82$$

$$t = \frac{\bar{d} - 0}{S/\sqrt{N}} \quad \frac{-0.31 - 0}{0.82/\sqrt{9}} = -1.13 \quad /t/ = 1.13$$

$df = 8$ $\quad 0.50 > p > 0.20$

∴ There is no significant difference in before and after

Paired t Test - Injury and Fatal Accident Rates

Location	Before X_B	After X_A	$d=X_A-X_B$	d^2
1	0.42	0.28	-0.14	0.0196
2	0.87	0.89	+0.02	0.0004
3	1.28	1.00	-0.28	0.0784
4	0.85	0.75	-0.10	0.01
5	1.29	1.02	-0.27	0.0729
6	1.18	0.56	-0.62	0.3844
7	0.68	0.60	-0.08	0.0064
8	1.36	1.03	-0.33	0.1089
9	1.08	0.76	-0.32	0.1024
			$\sum = -2.12$	$\sum = 0.7834$

$H_o = U_A = U_B$ $\quad d = X_A - X_B = 0$

$N = 9$ $\quad \sum d = -2.12$ $\quad \sum d^2 = 0.7834$

$\bar{d} = \sum d/N = -2.12/9 = -0.24$

$$S = \sqrt{\frac{\sum d^2 - (\sum d)^2/N}{N-1}} = \sqrt{\frac{0.7834 - (-2.12)^2/9}{8}} = 0.19$$

$$t = \frac{\bar{d} - 0}{S/\sqrt{N}} = \frac{-0.24 - 0}{0.19/\sqrt{9}} = -3.79 \qquad /t/ = 3.79$$

$df = 8$ $\quad p < 0.005$

:. There is a significant change in before and after

APPENDIX C

NETSIM SIMULATION SUMMARY

SIMULATION OF TRAFFIC

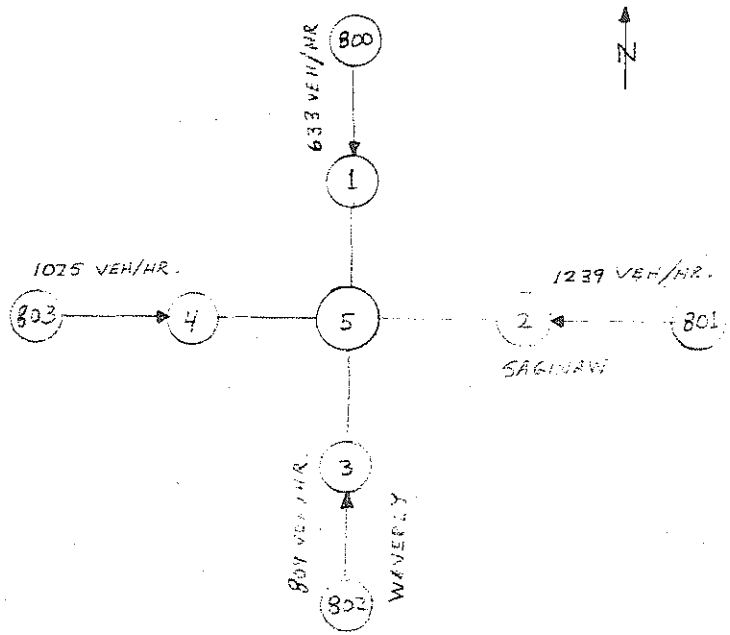
THE UTCS-1 MODEL

BRIGLIASIGSTUDY/SAG/WAV (BEFORE - 1969)

BRIGLIAFXTIME/4PHASE, LANSING , MI 0 02/23/81

SEED FOR RANDOM NUMBER GENERATOR IS 7581

LINK	LANE	SPAN	POCK L	POCK R	MEAN U-F	H	TURNING MOVEMENTS LEFT	THRU	RT	DIAG	DESTINATION NODES LEFT	THRU	RT	DIAG	LOST	PED DEN	LANE CHAN 1	2	3	4	5	TYPE	G	L	IDENTIFICATION
(800, 1)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	1	
(1, 5)	2	2000	12	0	45	21	6	66	28	0	2	3	4	0	37	0	0	0	0	0	0	1	2	2	
(802, 3)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	3	
(3, 5)	2	2000	10	0	45	21	23	62	15	0	4	1	2	0	37	0	0	0	0	0	0	1	2	4	
(803, 4)	4	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		3	0	0	3	0	1	2	5	
(4, 5)	4	2000	0	0	40	21	11	73	16	0	1	2	3	0	37	0	4	0	0	1	0	1	2	6	
(801, 2)	4	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		3	0	0	3	0	1	2	7	
(2, 5)	4	2000	0	0	40	21	8	89	3	0	3	4	1	0	37	0	0	0	0	1	0	1	2	8	
(5, 1)	2	2000	0	0	45	21	0	100	0	0	0	800	0	0	37	0	0	0	0	0	0	1	2	9	
(5, 2)	2	2000	0	0	40	21	0	100	0	0	0	801	0	0	37	0	0	0	0	0	0	1	2	10	
(5, 3)	2	2000	0	0	45	21	0	100	0	0	0	802	0	0	37	0	0	0	0	0	0	1	2	11	
(5, 4)	3	2000	0	0	40	21	0	100	0	0	0	803	0	0	37	0	0	0	0	0	0	1	2	12	



SIMULATION OF TRAFFIC

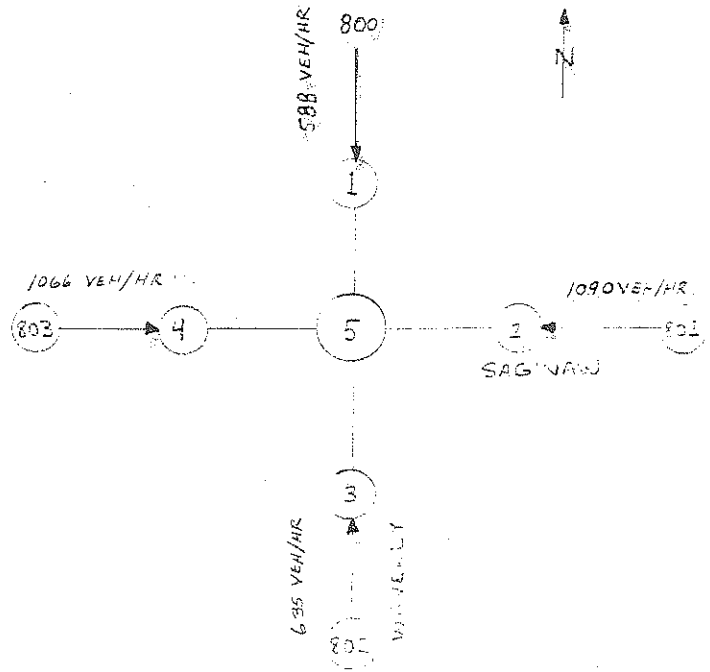
THE UTCS-1 MODEL

BRIGLIASIGSTUDY/SAG@WAV (AFTER - 1980)

BRIGLIA/8PHASE , LANSING , MI 0 05/01/81

SEED FOR RANDOM NUMBER GENERATOR IS 7581

LINK	LANE	SPAN	POCK L	POCK R	MEAN U-F	H	TURNING MOVEMENTS LEFT	THRU	RT	DIAG	DESTINATION NODES LEFT	THRU	RT	DIAG	LOST	PED DEN	LANE CHAN 1	2	3	4	5	TYPE	G	L	IDENTIFICATION
(800, 1)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	1	
(1, 5)	2	1999	40	0	45	21	13	52	35	0	2	3	4	0	37	0	0	0	0	0	0	1	2	2	
(801, 2)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	3	
(2, 5)	3	1999	40	0	40	21	11	86	3	0	3	4	1	0	37	0	0	0	0	0	0	1	2	4	
(802, 3)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	5	
(3, 5)	2	1999	40	0	45	21	42	45	13	0	4	1	2	0	37	0	0	0	0	0	0	1	2	6	
(803, 4)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	7	
(4, 5)	2	1999	40	9	40	21	21	64	15	0	1	2	3	0	37	0	0	0	0	0	0	1	2	8	
(5, 1)	2	1999	0	0	45	21	0	100	0	0	0	800	0	0	37	0	0	0	0	0	0	1	2	9	
(5, 2)	2	1999	0	0	40	21	0	100	0	0	0	801	0	0	37	0	0	0	0	0	0	1	2	10	
(5, 3)	2	1999	0	0	45	21	0	100	0	0	0	802	0	0	37	0	0	0	0	0	0	1	2	11	
(5, 4)	2	1999	0	0	40	21	0	100	0	0	0	803	0	0	37	0	0	0	0	0	0	1	2	12	



SIMULATION OF TRAFFIC

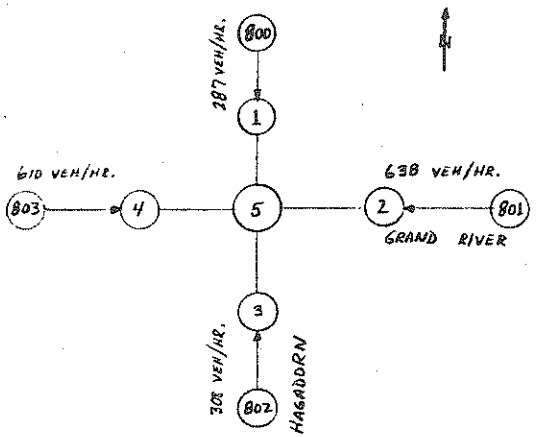
THE UTCS-1 MODEL

BRIGLIASIGSTUDY/GRNDRIV/HAG (BEFORE - 1969)

BRIGLIAFXTIME/4PHASE, LANSING , MI 0 03/02/81

SEED FOR RANDOM NUMBER GENERATOR IS 7581

LINK	LANE	SPAN	POCK L	POCK R	MEAN U-F	II	TURNING MOVEMENTS LEFT	THRU	RT	DIAG	DESTINATION NODES LEFT	THRU	RT	DIAG	LOST	PED DEN	LANE CHAN 1	2	3	4	5	TYPE	G	L	IDENTIFICATION
(800, 1)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	1	
(1, 5)	2	2000	14	0	35	21	35	41	24	0	2	3	4	0	37	0	0	0	0	0	0	1	2	2	
(802, 3)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	3	
(3, 5)	2	2000	6	0	35	21	32	38	30	0	4	1	2	0	37	0	0	0	0	0	0	1	2	4	
(801, 2)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	5	
(2, 5)	3	2000	0	0	40	21	9	82	9	0	3	4	1	0	37	0	0	0	1	0	0	1	2	6	
(803, 4)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	7	
(4, 5)	3	2000	0	0	35	21	12	77	11	0	1	2	3	0	37	0	0	0	1	0	0	1	2	8	
(5, 1)	2	2000	0	0	35	21	0	100	0	0	0	800	0	0	37	0	0	0	0	0	0	1	2	9	
(5, 2)	2	2000	0	0	40	21	0	100	0	0	0	801	0	0	37	0	0	0	0	0	0	1	2	10	
(5, 3)	2	2000	0	0	35	21	0	100	0	0	0	802	0	0	37	0	0	0	0	0	0	1	2	11	
(5, 4)	2	2000	0	0	35	21	0	100	0	0	0	803	0	0	37	0	0	0	0	0	0	1	2	12	



SIMULATION OF TRAFFIC

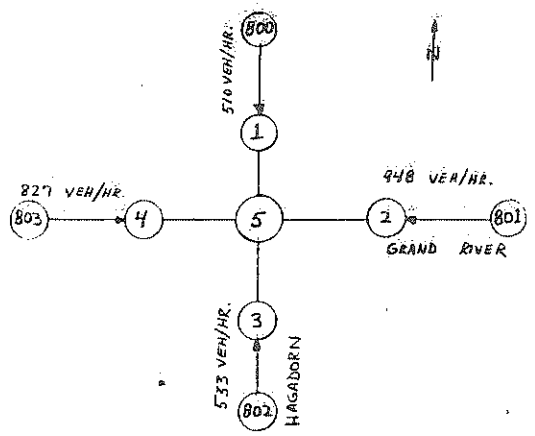
THE UTCS-1 MODEL

BRIGLIASIGSTUDY/GRNDRV@HAG (AFTER - 1978)

BRIGLIA/8PHASE , LANSING , MI 0 05/01/81

SEED FOR RANDOM NUMBER GENERATOR IS 7581

LINK	LANE	SPAN	POCK L	POCK R	MEAN U-F	H	TURNING MOVEMENTS LEFT	THRU	RT	DIAG	DESTINATION NODES LEFT	THRU	RT	DIAG	LOST	PED DEN	LANE CHAN 1	2	3	4	5	TYPE	G	L	IDENTIFICATION
(800, 1)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	1	
(1, 5)	2	1999	40	0	35	21	37	42	21	0	2	3	4	0	37	0	0	0	0	0	0	1	2	2	
(801, 2)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	3	
(2, 5)	2	1999	40	9	40	21	11	79	10	0	3	4	1	0	37	0	0	0	0	0	0	1	2	4	
(802, 3)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	5	
(3, 5)	2	1999	40	9	35	21	27	37	36	0	4	1	2	0	37	0	0	0	0	0	0	1	2	6	
(803, 4)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	7	
(4, 5)	2	1999	40	9	35	21	7	83	10	0	1	2	3	0	37	0	0	0	0	0	0	1	2	8	
(5, 1)	2	1999	0	0	35	21	0	100	0	0	0	800	0	0	37	0	0	0	0	0	0	1	2	9	
(5, 2)	2	1999	0	0	40	21	0	100	0	0	0	801	0	0	37	0	0	0	0	0	0	1	2	10	
(5, 3)	2	1999	0	0	35	21	0	100	0	0	0	802	0	0	37	0	0	0	0	0	0	1	2	11	
(5, 4)	2	1999	0	0	35	21	0	100	0	0	0	803	0	0	37	0	0	0	0	0	0	1	2	12	



SIMULATION OF TRAFFIC

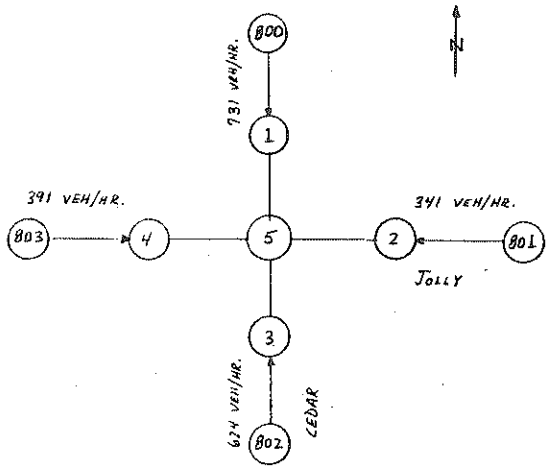
THE UTCS-1 MODEL

BRIGLIASIGSTUDY/CEDAR/JOLLY (BEFORE - 1972)

BRIGLIAFXTIME/4PHASE, LANSING , MI 0 03/02/81

SEED FOR RANDOM NUMBER GENERATOR IS 7581

LINK	LANE	SPAN	POCK L	POCK R	MEAN U.F	H	TURNING MOVEMENTS LEFT	THRU	RT	DIAG	DESTINATION NODES LEFT	THRU	RT	DIAG	LOST	PED DEN	LANE CHAN 1	2	3	4	5	TYPE	G	L	IDENTIFICATION
(800, 1)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	1	
(1, 5)	2	2000	18	0	35	21	11	72	17	0	2	3	4	0	37	0	0	0	0	0	0	1	2	2	
(802, 3)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	3	
(3, 5)	2	2000	25	0	45	21	19	73	8	0	4	1	2	0	37	0	0	0	0	0	0	1	2	4	
(801, 2)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	5	
(2, 5)	2	2000	0	0	35	21	15	59	26	0	3	4	1	0	37	0	0	0	0	0	0	1	2	6	
(803, 4)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	7	
(4, 5)	2	2000	0	0	35	21	25	47	28	0	1	2	3	0	37	0	0	0	0	0	0	1	2	8	
(5, 1)	2	2000	0	0	35	21	0	100	0	0	0	800	0	0	37	0	0	0	0	0	0	1	2	9	
(5, 2)	2	2000	0	0	35	21	0	100	0	0	0	801	0	0	37	0	0	0	0	0	0	1	2	10	
(5, 3)	2	2000	0	0	45	21	0	100	0	0	0	802	0	0	37	0	0	0	0	0	0	1	2	11	
(5, 4)	2	2000	0	0	35	21	0	100	0	0	0	803	0	0	37	0	0	0	0	0	0	1	2	12	



SIMULATION OF TRAFFIC

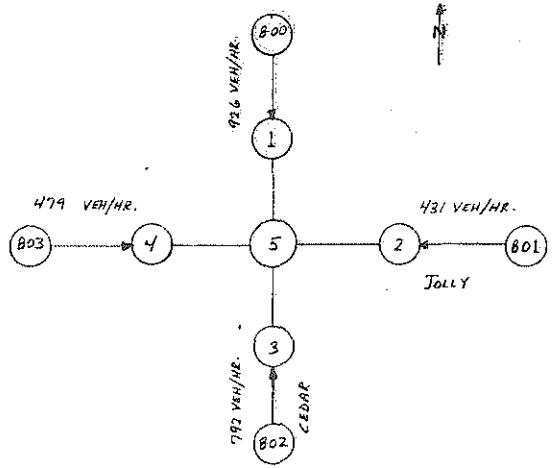
THE UTCS-1 MODEL

BRIGLIASIGSTUDY/CEDAR-JOLLY (AFTER - 1979)

BRIGLIA/8PHASE , LANSING , MI 0 05/01/81

SEED FOR RANDOM NUMBER GENERATOR IS 7581

LINK	LANE	SPAN	POCK L	POCK R	MEAN U-F	H	TURNING MOVEMENTS LEFT	THRU	RT	DIAG	DESTINATION NODES LEFT	THRU	RT	DIAG	LOST	PED DEN	LANE CHAN 1	2	3	4	5	TYPE	G	L	IDENTIFICATION
(800, 1)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	1	
(1, 5)	2	1999	40	0	35	21	14	77	9	0	2	3	4	0	37	0	0	0	0	0	0	1	2	2	
(801, 2)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	3	
(2, 5)	2	1999	10	0	35	21	25	56	19	0	3	4	1	0	37	0	0	0	0	0	0	1	2	4	
(802, 3)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	5	
(3, 5)	2	1999	40	0	45	21	19	73	8	0	4	1	2	0	37	0	0	0	0	0	0	1	2	6	
(803, 4)	2	1000	0	0	ENTRY	21	0	100	0	0	0	5	0	0	37		0	0	0	0	0	1	2	7	
(4, 5)	2	1999	11	0	35	21	27	47	26	0	1	2	3	0	37	0	0	0	0	0	0	1	2	8	
(5, 1)	2	1999	0	0	35	21	0	100	0	0	0	800	0	0	37	0	0	0	0	0	0	1	2	9	
(5, 2)	2	1999	0	0	35	21	0	100	0	0	0	801	0	0	37	0	0	0	0	0	0	1	2	10	
(5, 3)	2	1999	0	0	45	21	0	100	0	0	0	802	0	0	37	0	0	0	0	0	0	1	2	11	
(5, 4)	2	1999	0	0	35	21	0	100	0	0	0	803	0	0	37	0	0	0	0	0	0	1	2	12	



OFF-PEAK HOUR

	SAGINAW AT WAVERLY		% CHANGE	CEDAR AT JOLLY		% CHANGE	GRAND RIVER AT HAGADORN		% CHANGE
	Before	After		Before	After		Before	After	
Vehicle-Miles	2818.92	2477.20	-12	1577.83	1929.23	+22	1401.33	2114.19	+51
Vehicle-Minutes	5759.9	10427.2	+81	3361.5	6900.6	+105	3024.5	5550.6	+84
Vehicle-Trips	3724	3322	-11	2087	2593	+24	1848	2796	+51
Stops/Vehicle	0.66	1.02	+55	0.63	0.98	+56	0.61	0.88	+44
Moving/Total Trip Time	0.716	0.350	-51	0.769	0.456	-41	0.777	0.635	-18
Ave. Speed (MPH)	29.36	14.25	-51	28.16	16.77	-40	27.80	22.85	-18
Mean Occupancy (Veh.)	95.6	173.4	+81	55.8	114.7	+106	50.2	92.2	+84
Ave. Delay/Vehicle (Sec.)	26.33	122.37	+365	22.32	86.80	+289	21.94	43.48	+98
Total Delay (Min.)	1634.4	6775.1	+315	776.4	3751.3	+383	675.7	2025.9	+200
Delay/Veh.-Mile (Min/V-Mile)	0.58	2.74	+372	0.49	1.94	+296	0.48	0.96	+100
Travel Time/Veh.-Mile (Min/V-Mile)	2.04	4.21	+106	2.13	3.58	+68	2.16	2.63	+22
Stopped Delay as a Percentage of Total Delay	34.8	83.5	+140	37.1	80.5	+117	39.6	58.8	+48
Fuel Consumption (Gallons)	192.08	243.54	+27	102.06	164.22	+61	89.17	148.38	+66
M.P.G.	12.78	9.08	-29	13.46	10.46	-23	13.74	12.45	-9
HC (Grams/Mile)	2.60	4.01	+54	2.39	3.38	+41	2.33	2.71	+16
CO (Grams/Mile)	38.79	69.34	+79	34.40	55.67	+62	32.85	40.50	+23
NO_x (Grams/Mile)	6.39	6.97	+9	5.60	6.08	+9	5.38	5.60	+4

11-13-81
PHB(63B-604)-7
Safety Programs Unit