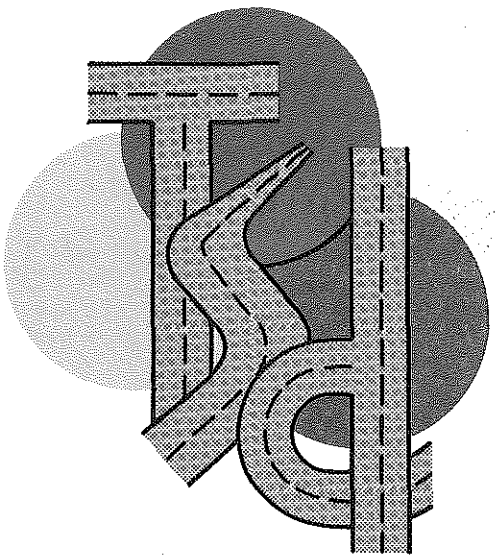
FINAL SUMMARY REPORT

STUDY OF THE OPERATIONAL ASPECTS
OF ONE-WAY AND TWO-WAY STREETS

Report TSD-RD-220-72



TRAFFIC and SAFETY DIVISION

DEPARTMENT OF STATE HIGHWAYS
STATE OF MICHIGAN

65-9417

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Report TSD-RD-220-72

By

Nejad Enustun

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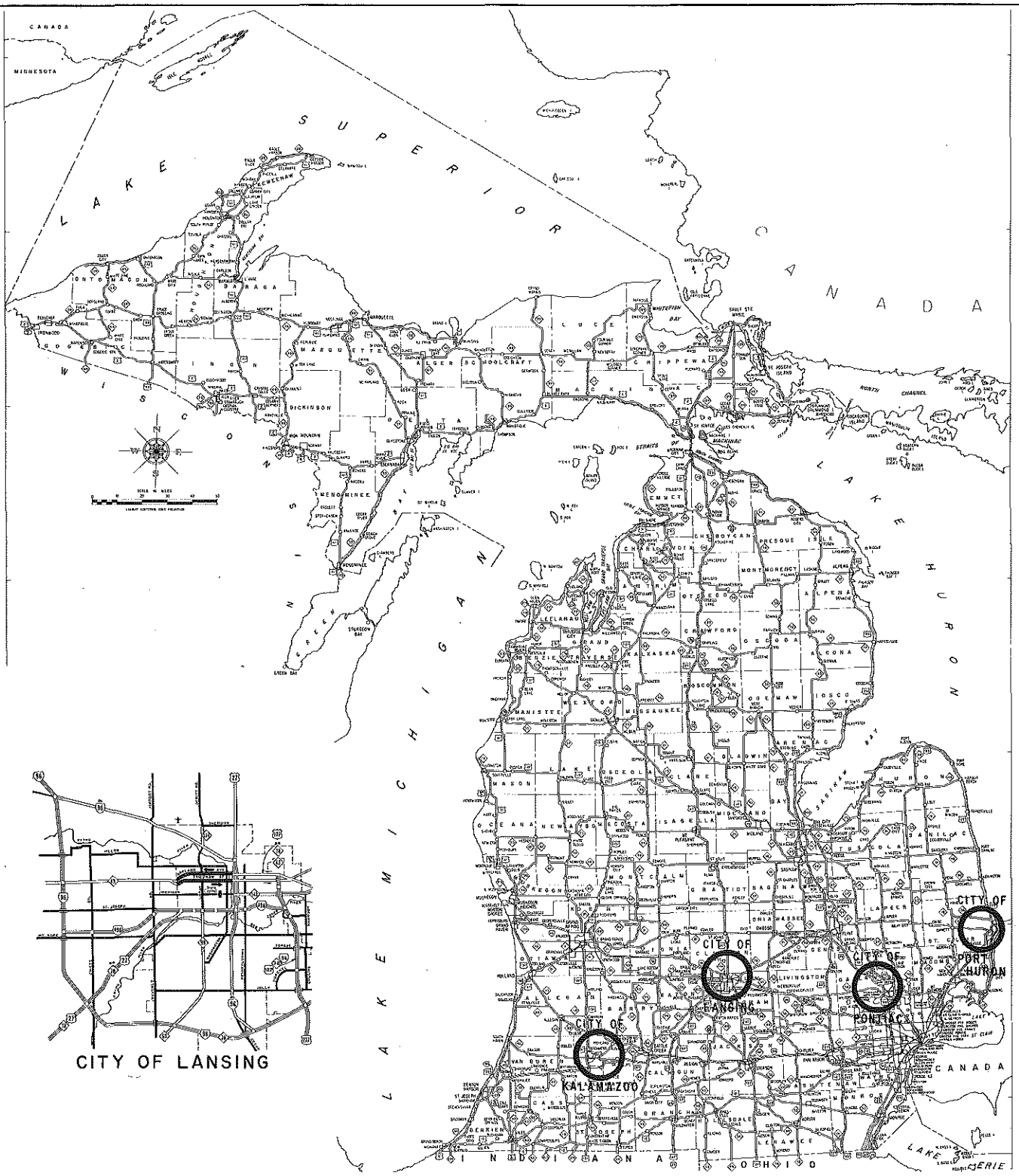


LOCATION OF STUDY CITIES AND ONE-WAY STREETS

FOREWORD

This report is a summary of the Final Report TSD-RD-219-72 for the research project entitled Study of the Operational Aspects of One-Way and Two-Way Streets. The detailed report is 182 pages long, contains 41 figures, 62 tables, 27 appendices and 16 photographs, and provides a complete documentation of the project which was partly financed by Federal Highway Planning and Research funds. The purpose of the present summary report is to provide an opportunity for those individuals who cannot afford the time and attention required by the comprehensive report to get familiar with the project and its results.

The purpose of the study was to obtain quantitative data on the quality of traffic operation when state trunk lines through urban areas are converted to one-way operation because of need for extra capacity. Four Michigan cities, Lansing, Kalamazoo, Pontiac and Port Huron were selected for a before-and-after type of evaluation of a definite segment of their one-way system as each was prepared for and converted to one-way traffic.

LIST OF TABLES

ACKNOWLEDGMENT

This study was accomplished as a result of efforts provided by several people and organizations. All Traffic Surveys were conducted by the Transportation Survey and Analysis Section of the Transportation Planning Division, Michigan Department of State Highways. Traffic volume data were processed by the Computer Services Division of the Department. Accident reports were made available by the City Traffic Engineer's office in Lansing and by the City Police Departments in Kalamazoo, Pontiac and Port Huron. Department of State Highways' District Traffic Engineers at the Jackson, Kalamazoo and Pontiac offices were extremely helpful in compiling the accident data for the cities involved. The Office Services Division is credited for the reproduction of the reports.

The author, on behalf of the Michigan Department of State Highways, extends his deepest appreciation to each individual whose work helped to conduct the study and prepare this report.

DESCRIPTION OF THE STUDIES

THE KALAMAZOO STUDY

The state trunk line sections through the City of Kalamazoo that were studied are I-94 BL and M-43 which cross the central business district in a general east-west direction. Before conversion to one-way operation, the two numbered routes shared Michigan Avenue for the major part of the section, and separated near the west end of the study area where M-43 followed Main Street to the west, and I-94 BL continued along Michigan Avenue which ran diagonally southwest. For the one-way operation, Kalamazoo Avenue, which is another east-west street three blocks north of the larger section of Michigan Avenue, was widened to carry the westbound trunk line traffic while Michigan carried the eastbound. This conversion was done on October 10, 1965.

Two sets of traffic surveys and accident data collection were done, one before and the other after the start of one-way operation. Volume counts were taken by 15-minute periods for at least 48 hours at 105 stations dispersed in an area about 1.5 miles long and 0.7 mile wide. Time gaps in the traffic stream on Kalamazoo and on Michigan Avenues were measured at their intersections with Church Street during rush hours. The total numbers and sizes of these gaps were recorded. Turning movements were counted at two major intersections. Stoppage of left lanes caused by traffic waiting to make left turns at one of these intersections was also recorded. Speed-and-delay study runs were made by the floating car method along six routes, each approximately 1.5 miles long, on the trunk lines for determining total travel time and points and durations of all delays. Total travel time only was clocked on six cross streets which are situated in a general north-south direction and which intersect the one-way pair. Accidents were studied in the general area traversed by the one-way arteries, covering about one square mile.

THE LANSING STUDY

The Lansing study area is within the northern fringe of the central business district and includes the street network along an east-west corridor 1.9 miles long and about 0.4 mile wide. Within this corridor, Saginaw Street and Oakland Avenue carry M-43 traffic. The study examines the two-way operation and two successive phases of the one-way operation along this state trunk line corridor. During the two-way phase Saginaw Street was the two-way artery. On January 31, 1965, after completion of widening and reconstruction of Jefferson Street and part of Oakland Avenue as far west as Logan Street, the initial phase of the one-way operation began. The new route, two blocks north of Saginaw in the eastern part of the study area and only one block north of Saginaw near the west, carried the westbound traffic, leaving only eastbound traffic on Saginaw east of Logan Street. During this phase Logan Street was the west terminal of the one-way system, and carried the westbound trunk line traffic south to Saginaw, and from there to the west the trunk line operated two-way.

The final phase of the operation started on May 13, 1969 after the construction of the rest of Oakland Avenue west of Logan, and a railroad bridge carrying Belt Line Railroad over reconstructed M-43 highway at west city limits. Near the bridge location, the one-way street system transitioned to a two-way, four-lane highway.

Traffic volume counts in Lansing were done similar to Kalamazoo, and 15-minute counts were taken at 87 stations. Gap surveys were taken on Saginaw Street at its intersections with Seymour, Chestnut, Clayton-Carey, Westmoreland, Cawood and Durant. Turning movement counts were made at the intersections of Oakland and Logan, Saginaw and Verlinden. Delays caused by traffic waiting to turn left were also recorded at these intersections. Speed-and-delay test runs during peak traffic on Saginaw and Oakland were made between Belt Line Railroad on the west and Cedar Street on the east. Cross-street travel time runs were made on Washington, Capitol, Walnut, Pine, Logan, Jenison and Verlinden. Accident reports were studied on all streets in the study area. All surveys and studies were repeated for the three phases of the Lansing study.

THE PONTIAC STUDY

The Pontiac study area is a 1.2-mile corridor along US-10 BR northwest of the central business district. The effect of the change in operation was examined along the corridor for a width of about 0.3 mile. During the before phase, Oakland Avenue was a two-way state trunk line between its intersection with Cass Avenue-Montcalm Street and Wide Track Drive. During the after phase, Cass Avenue, two blocks to the southwest, was developed into a southeast-bound one-way state trunk line, and Oakland Avenue became one-way northwest-bound. The change to one-way was implemented on May 18, 1967. However, interconnection of traffic signals by electrical cables was delayed until April 5, 1968, and the "after" study was conducted subsequent to this date.

Survey procedures in Pontiac were similar to Kalamazoo and Lansing, except that instead of the cross-street travel-time runs, perpendicular to the study trunk lines, a closed loop run 1.2 miles long was made on the side streets and crossing the one-way pair. This was done as part of the speed-and-delay procedure along the state route. The speed-and-delay runs on Oakland had for terminals Northview Street on the northwest, and Saginaw Street on the southeast. Runs on Cass Avenue also had Northview Street as one of the terminals, but Wide Track Drive was the southeast terminal. Each of these runs was 1.3 miles long.

Traffic volumes in the study area were taken at 59 stations. Gap surveys were conducted on Oakland Avenue at its intersection with Blaine, Cadillac and Florence Streets, and on Cass Avenue at Florence intersection. Turning-movements and stoppage of left lanes due to left turns were recorded at the intersections of Oakland Avenue with Cass-Montcalm, Johnson, and Allison-Baldwin Streets; and at the intersection of Cass Avenue and Johnson Street.

Accidents were also studied within the above-described area. In addition, accidents along the unchanged two-way section of Oakland Avenue between West Boulevard and Montcalm-Cass were studied for control purposes.

THE PORT HURON STUDY

The change over to one-way traffic operation in Port Huron was basically different from the three other cities. In those cities an existing two-way state trunk line was converted to one-way, and a parallel street was used for the opposite direction. In Port Huron the old state trunk line was abandoned to the city, and a new corridor approximately 3/4 mile to the south was selected for the one-way pair.

During the two-way phase, M-21 followed Lapeer and Water Streets between 32nd Street to the west and Military Street to the east. This is a stretch of 1.8 miles, and is to the west of the central business district. The new one-way trunk line corridor is the Griswold-Oak pair, Griswold Street running westbound and Oak Street eastbound. The area is mainly residential. These two streets were widened and reconstructed. Oak Street was connected with Mitchell Street to the east, providing continuity on a straight alignment up to Military Street. The new one-way pair transitioned to the limited-access highway near the west city limits. The Griswold-Oak pair was opened to traffic on October 19, 1966.

Traffic volumes in Port Huron were recorded at 78 stations within three separate traffic corridors. The third corridor was the Union and Court Streets pair which already operated as a one-way city system even before the re-routing of the state trunk line. Gap surveys during peak periods were conducted only on Griswold Street at its intersections with 7th, 16th, 20th and 22nd Street. Turning-movement counts were taken at the intersections of Griswold Street with Military and 24th. The speed-and-delay runs were made on Lapeer, and on the Griswold-Oak pair, in both directions, between 32nd Street and Military Street. The Lapeer route was 1.8 miles, and the

one-way route was 2.0. Cross-street travel time data were taken only across the Griswold-Oak corridor on five north-south streets.

Accident study in Port Huron involved three traffic corridors. The Union-Court pair was included for comparison, and accidents were recorded only on these two streets but did not include accidents on streets crossing this pair. Accident studies for the Lapeer and Griswold-Oak corridors, however, included accidents on the cross-streets one block north and one block south from the trunk lines.

ANALYSIS OF RESULTS

Quality of traffic service in general can be measured by the parameters of time, convenience, safety, distance and cost. The present study mainly deals with the first three. In an overall evaluation of a street system such as the ones examined in this project, the results are bound to reflect the effects of a whole set of conditions and circumstances in addition to the uni- or bi-directional character of the trunk line traffic. Optimum adjustment of traffic signals and other traffic control measures, temporal changes in the intensity and type of land use and in the age and social-group brackets of drivers using the facilities are but a few of these circumstances. This should be kept in mind in reviewing the results of the study.

SPEED AND DELAY STUDY RESULTS

Table I contains results of speed and delay studies on principal routes in Kalamazoo. The westbound trips via Kalamazoo Avenue and Douglas Street gained 8.9 miles per hour in average over-all speed during the morning peak with one-way operation. There were, on the average, 2.4 less stops during the same peak, and this shortened stopped-delay by 24 seconds per mile of travel. There were lesser but significant gains in the westbound direction also. The greatest savings in time, however, occurred on the westbound trip when compared to the former westbound traffic on the state trunk line through Michigan Avenue and Main Street. An average speed gain of 10.6 miles per hour was measured.

Table II is the corresponding evaluation for Lansing. Up to 4.8 miles per hour was gained in speed. There were modest but consistent reductions in stops and seconds of delay. Although speed increase was less than what was accomplished in Kalamazoo, the optimum progression speed of 30 m.p.h. was reached in Lansing.

Table III is for Pontiac. In this city although 3.0 to 3.7 miles per hour of speed increase has been realized on the southeastbound trips, a slight decrease was found during the morning peak in the northwestbound direction, with stopped delay increasing by 16 seconds per mile. This adverse result is believed to arise because of inadequate capacity at the northwest transition point to two-way operation.

Table IV compares eastbound and westbound trip parameters on Lapeer Street with those on the new Griswold-Oak one-way pair in Port Huron. The average over-all speeds on the one-way streets range from 26.1 to 30.7 m.p.h. as compared to 19.0 to 22.6 on the two-way street.

Table V shows average change percentages in speeds, number of stops and delays in all of the four cities. It gives a quick picture of the comparative degree of accomplishment by the one-way projects in these cities.

There are some other consequences of the one-way operations which the present study cannot quantify. Among these are reductions in air pollution and traffic noise. These reductions result from a smoother flow of the traffic stream thereby minimizing engine exhaust pollutants and noise.

CROSS-STREET SPEED STUDY RESULTS

To detect the possibility of having created any excessive delays on the cross-streets due to the one-way trunk line operations, cross-street travel time studies were made. Table VI lists average results obtained from these studies. In Kalamazoo, where no signals were added to those already in operation at certain intersections, there was an actual reduction in the over-all average. Slight increases in Lansing and Port Huron, due to the addition of signals to some intersections, is a sacrifice that can be afforded as a trade-off for even small gains in travel time on the trunk lines, since these gains benefit larger traffic volumes. Nevertheless, introduction of the new one-way trunk line pair has not resulted in delays of any objectionable duration on the cross-streets.

RESULTS OF GAP STUDIES

Table VII indicates total numbers of gaps of

TABLE I
CITY OF KALAMAZOO
SPEED AND DELAY STUDY RESULTS
FOR PRINCIPAL ROUTES

Direction	Peak Period	DURING TWO-WAY OPERATION				DURING ONE-WAY OPERATION				CHANGE IN:		
		ROUTE	Average Over-All Speed (m.p.h.)	Average Number of Stops	Delay (Sec./mi.)	ROUTE	Average Over-All Speed (m.p.h.)	Average Number of Stops	Delay (Sec./mi.)	* Average Over-All Speed (m.p.h.)	* Average Number of Stops	Delay (Sec./mi.)
Westbound	Morn.	Via Kalamazoo-Douglas	20.6	2.7	27	Via Kalamazoo-Douglas	29.5	0.3	3	+ 8.9 (S)	- 2.4 (S)	- 24
	Noon	" " "	20.2	2.9	28	" " "	26.2	1.0	11	+ 6.0 (S)	- 1.9 (S)	- 17
	Aft.	" " "	19.1	2.9	34	" " "	21.3	2.0	28	+ 2.2	- 0.9	- 6
Eastbound	Morn.	Via Main-Michigan	19.7	2.0	29	Via Main-Michigan	22.4	1.6	23	+ 2.7	- 0.4	- 6
	Noon	" " "	18.7	3.0	36	" " "	20.8	1.6	25	+ 2.1	- 1.4 (S)	- 11
	Aft.	" " "	16.6	3.8	45	" " "	20.4	1.8	30	+ 3.8 (S)	- 2.0 (S)	- 15
Westbound	Morn.	Via Michigan-Main	18.9	4.0	28	Via Kalamazoo-Douglas	29.5	0.3	3	+10.6 (S)	- 3.7 (S)	- 25
	Noon	" " "	17.4	4.0	34	" " "	26.2	1.0	11	+ 8.8 (S)	- 3.0 (S)	- 23
	Aft.	" " "	14.7	5.7	70	" " "	21.3	2.0	28	+ 6.6 (S)	- 3.7 (S)	- 42

* - These changes have been tested for statistical significance.
(S) - The change is statistically significant.

TABLE II
CITY OF LANSING
SPEED AND DELAY STUDY RESULTS

Direction	Peak Period	DURING TWO-WAY OPERATION				DURING ONE-WAY OPERATION				CHANGE IN:		
		ROUTE	Average Over-All Speed (m.p.h.)	Average Number of Stops	Delay (Sec./mi.)	ROUTE	Average Over-All Speed (m.p.h.)	Average Number of Stops	Delay (Sec./mi.)	* Average Over-All Speed (m.p.h.)	* Average Number of Stops	Delay (Sec./mi.)
Eastbound	Morn.	Via Saginaw St.	26.0	1.9	15	Via Saginaw St.	30.0	1.0	9	+ 4.0 (S)	−0.9 (S)	− 6
	Noon	" " "	25.2	2.3	18	" " "	28.3	1.3	12	+ 3.1 (S)	− 1.0	− 6
	Aft.	" " "	23.2	3.4	22	" " "	25.4	2.0	17	+ 2.2	− 1.4	− 5
Westbound	Morn.	Via Sheridan-Center-Saginaw	26.3	1.8	10	Via Oakland-Logan-Saginaw	28.4	1.1	8	+ 2.1 (S)	−0.7 (S)	− 2
	Noon	" " " "	25.9	1.8	9	" " " "	30.7	0.2	1	+ 4.8 (S)	− 1.6 (S)	− 8
	Aft.	" " " "	25.0	2.0	12	" " " "	26.0	1.5	11	+ 1.0	−0.5	− 1

*-These changes have been tested for statistical significance.
(S)-The change is statistically significant.

TABLE III

CITY OF PONTIAC

SPEED AND DELAY STUDY RESULTS FOR PRINCIPAL ROUTES

Direction	Peak Period	DURING TWO-WAY OPERATION				DURING ONE-WAY OPERATION				CHANGE IN:		
		ROUTE	Average Over-All Speed (m.p.h.)	Average Number of Stops	Delay (Sec./mi.)	ROUTE	Average Over-All Speed (m.p.h.)	Average Number of Stops	Delay (Sec./mi.)	*Average Over-All Speed (m.p.h.)	*Average Number of Stops	Delay (Sec./mi.)
Southeast-bound	Morn.	Via Oakland	22.0	1.9	18	Via Cass	25.0	1.8	14	+ 3.0 (S)	- 0.1	- 4
	Noon	" "	22.3	2.2	23	" "	25.3	1.8	19	+ 3.0	- 0.4	- 4
	Aft.	" "	21.1	2.3	22	" "	24.8	1.9	16	+ 3.7 (S)	- 0.4	- 6
Northwest-bound	Morn.	Via Oakland	22.9	1.6	15	Via Oakland	22.3	1.6	31	- 0.6	0.0	+ 16
	Noon	" "	21.0	2.5	22	" "	22.9	1.7	29	+ 1.9 (S)	- 0.8 (S)	+ 7
	Aft.	" "	21.1	2.3	25	" "	21.2	2.0	32	+ 0.1	- 0.3	+ 7

*- These changes have been tested for statistical significance.
(S)- The change is statistically significant.

TABLE IX
CITY OF PORT HURON
SPEED AND DELAY STUDY RESULTS
FOR PRINCIPAL ROUTES

Direction	Peak Period	DURING TWO-WAY OPERATION				DURING ONE-WAY OPERATION				CHANGE IN:		
		ROUTE	Average Over-All Speed (m.p.h.)	Average Number of Stops	Delay (Sec./mi.)	ROUTE	Average Over-All Speed (m.p.h.)	Average Number of Stops	Delay (Sec./mi.)	* Average Over-All Speed (m.p.h.)	* Average Number of Stops	Delay (Sec./mi.)
Eastbound	Morn.	Via Lapeer	21.3	3.2	22	Via Oak	27.4	1.6	20	+ 6.1	- 1.6	- 2
	Noon	" "	19.0	3.9	34	" "	30.7	1.2	10	+11.7	- 2.7	-24
	Aft.	" "	20.6	3.0	24	" "	27.8	2.0	21	+ 7.2	- 1.0	- 3
Westbound	Morn.	Via Lapeer	22.6	2.7	17	Via Griswold	27.0	1.0	8	+ 4.4	- 1.7	- 9
	Noon	" "	21.3	3.1	22	" "	27.4	1.1	12	+ 6.1	- 2.0	-10
	Aft.	" "	20.8	3.1	23	" "	26.1	1.3	14	+ 5.3	- 1.8	- 9

* - These changes have been tested and found to have statistical significance.

TABLE V

SPEED AND DELAY

AVERAGE CHANGE PERCENTAGES
TWO-WAY AND ONE-WAY OPERATION

City	Average Change Percentage In:		
	Over-all Speed	Stops Per Mile	Stopped Delay Per Mile
Kalamazoo	+28%	-70%	-56%
Lansing*	+11%	-45%	-29%
Pontiac	+ 2%	+ 8%	+28%
Port Huron	+19%	-46%	-18%

*Comparison of Initial One-Way with Two-Way Operation.

TABLE VI

CROSS-STREET TRAVEL TIME OVER-ALL AVERAGES
(Peak Periods Only)

	Two-Way	One-Way	Change
Kalamazoo	106.5 sec.	103.6 sec.	- 2.9 sec.
Lansing	69.0	79.6*	+10.6
Port Huron	58.1	76.3	+18.2

* Initial Phase

TABLE VII

TOTAL NUMBERS OF TRAFFIC GAPS OF VARIOUS SIZES DURING FIVE PEAK HOURS

LOCATION	GAP SIZES IN SECONDS								TOTAL GAPS	
	6 to 10 seconds		10 to 15 seconds		15 to 20 seconds		Over 20 seconds			
	Two-way	One-way	Two-way	One-way	Two-way	One-way	Two-way	One-way	TWO-WAY	ONE-WAY
KALAMAZOO:										
On Michigan at Church	161	359	45	148	16	82	8	74	230	663
On Kalamazoo at Church	346	182	142	194	58	95	38	131	584	602
LANSING: *										
On Saginaw at Seymour	248	203	111	147	42	89	17	100	418	539
On Saginaw at Chestnut	220	185	146	160	49	85	16	145	431	575
On Saginaw at Sycamore	277	232	113	187	52	76	34	151	476	646
PONTIAC:										
On Oakland at Blaine	205	415	114	199	67	72	172	92	558	778
On Oakland at Cadillac	277	269	157	190	101	73	99	108	634	640
On Oakland at Florence	261	190	136	123	70	67	36	226	503	606
On Cass at Florence	43	167	43	108	44	95	252	232	382	602
PORT HURON:										
On Griswold at 7th St.	314	143	193	114	115	110	203	241	825	608
On Griswold at 16th St.	327	347	206	183	119	140	205	211	857	881
On Griswold at 20th St.	306	373	218	220	125	121	188	215	837	929
On Griswold at 22nd St.	389	316	228	176	143	117	176	169	936	778

* = One-way Operation Refers to Initial Phase.

various sizes in the traffic stream on the study streets with two-way and one-way operation. The general trend, with very few exceptions, is that there were more total gaps with one-way traffic. More significantly, the increase in the number of gaps was more pronounced in the larger size gaps. The result is that better conditions have been created for the side street traffic by shortening the time that drivers had to wait at stop-controlled intersections.

RESULTS OF TRAFFIC VOLUME STUDIES

Traffic volume data in this study were used to evaluate the capacity of a system of streets in an area, rather than of individual streets or intersections. A Burroughs B 5500 computer was used to process the volume data.

By designating those stations which counted traffic near the periphery of the study area, on an inbound or outbound basis, the computer selected the maximum occurring 15-minute volumes at these stations, and added them together yielding comparative tabulations of entering or leaving traffic totals by 15-minute periods for the two-way and one-way operation phases.

Information on travel distances controlled by each volume-count station was also introduced into the computer. The computer calculated the maximum values of the 15-minute vehicle-miles of travel for each station and then added these up for all stations to yield an area-wide comparative table of vehicle-miles by 15-minute periods.

Similar to the 15-minute peak values of flow and travel, 24-hour values were also calculated. The changes in the 15-minute peak figures after conversion to one-way operation were compared with the changes in the 24-hour figures. Table VIII shows this information for Lansing and Pontiac. The same analysis was made for Kalamazoo, but the results were irrelevant because the "after" surveys were taken during a different season from the "before" surveys, and traffic characteristics proved to be different. This analysis was not applied to the Port Huron study because the one-way traffic corridor was not the same as the two-way traffic corridor.

Referring to Table VIII, in Lansing a 16 percent increase with one-way operation is seen in the morning peak traffic entering the area, in comparison to only 8 percent in the 24-hour traffic entering the area. Similar changes in leaving traffic are +74 percent during the p.m. peak, in comparison to +17 percent in the 24-hour period. Theoretically, traffic entering in 24 hours should equal traffic leaving in the same period. The main reason for the discrepancy in this presentation (8 percent change in entering traffic, and 17 percent in leaving) is that count stations were not complete enough to form a tight cordon. This does not, however, detract from the validity of the comparison since the same stations were used each time. Another reason for the discrepancies is the fact that counts were not simultaneous but were taken during a span of two to four weeks.

The one-way system in Pontiac, in the lower half of Table VIII, also displays these higher growth ratios in entering and leaving traffic during peak 15-minutes as compared with the 24-hour growth ratios.

The higher increases in peak flows in relation to daily flows are indications of the freedom of movement in the area, and an indirect measure of the improvement in traffic capacity.

RESULTS OF TURNING-MOVEMENT STUDIES

The numbers of vehicles making turns did not in themselves provide information of any significance other than some auxiliary data which on occasion provided supplement to the volume counts. Surveys of left-lane stoppages which were taken during the turning-movement counts, however, provided insight into vehicle delays. Table IX indicates the cumulative number of minutes when left lanes were blocked by vehicles waiting to make left turns. The extent of time gained in such waiting during one-way operation is evident.

TABLE VIII

PERCENTAGES OF CHANGE
IN PEAK-PERIOD AND 24-HOUR TRAFFIC

TWO-WAY AND ONE-WAY OPERATION

	Traffic Entering Area	Traffic Leaving Area	Vehicle-Miles In Area
Lansing:*			
Morning 15-Min. Peak	+16%	+52%	+20%
Noon 15-Min. Peak	+ 3%	+85%	+ 2%
Afternoon 15-Min. Peak	- 2%	+74%	+13%
24-Hour Total	+ 8%	+17%	+23%
Pontiac:			
Morning 15-Min. Peak	+ 6%	+20%	0
Noon 15-Min. Peak	+ 5%	+10%	- 6%
Afternoon 15-Min. Peak	+ 5%	+ 1%	+ 7%
24-Hour Total	+ 2%	+ 4%	+ 4%

* Comparison of Initial One-Way with Two-Way Operation.

TABLE IX

CUMULATIVE DURATION OF LANE STOPPAGES
DUE TO LEFT TURNS AT SURVEY STATIONS

(Extent of Delay on All Approaches,
in Minutes Within 6-Hour Survey)

	Two-Way Operation	One-Way Operation
Kalamazoo:		
Intersection of Kalamazoo & Rose	87	0
Lansing:*		
Intersection of Saginaw & Verlinden	50	2
Intersection of Saginaw & Jenison	23	14
Pontiac:		
Intersection of Oakland, Cass & Montcalm	52	49
Intersection of Oakland & Johnson	31	0
Intersection of Oakland & Baldwin	2	0
Intersection of Cass & Johnson	17	0
Port Huron:		
Intersection of Griswold & 24th	56	0
Intersection of Griswold & Military	32	0

* One-Way Operation Refers to Final Phase.

RESULTS OF ACCIDENT STUDIES

Accident data compiled in this study failed to indicate, in all cases, similar trends in all cities resulting from change to one-way traffic.

Table X is a summary indicating the percentages of change in accident experience in the individual cities and in all cities lumped together. The four sections of this table facilitate comparison of the different components of the network of streets in the study area in each city with each other, as well as with the whole city.

The figures for Lansing refer to the comparison of the initial one-way phase with the two-way phase. A follow up of accident experience during the final one-way phase indicated some improvement over the initial phase.

Some results common to all cities were that on the two-way state trunk lines which were converted to one-way operation the total accidents, injury accidents, rear-end collisions and accidents at signalized intersections decreased; and sideswipes and collisions at non-signalized intersections increased. Considering the three cities of Lansing, Kalamazoo and Pontiac, an appraisal of the two streets forming the one-way pairs before and after conversion fails to indicate a trend toward either a gain or a loss in safety of operation, based on rates per million vehicle miles.

TABLE X

PERCENTAGES OF CHANGE IN ACCIDENT EXPERIENCE
TWO-WAY AND ONE-WAY OPERATION

	Lansing	Kalamazoo	Pontiac	Port Huron	All Cities
1. STREET WHICH CHANGED FROM TWO-WAY TRUNK LINE TO ONE-WAY TRUNK LINE:					
Total Number of Accidents	-23%	-25%	-18%	(1)	-22%
Total Accident Rate per MVM	+ 8%	- 9%	+28%	(1)	+ 4%
Number of Injury Accidents	-28%	-49%	-24%	(1)	-35%
Injury Accident Rate per MVM	0	-38%	+11%	(1)	-11%
Rear-End Collisions	-59%	-39%	-32%	(1)	-43%
Sideswipes	+173%	+ 2%	+87%	(1)	+60%
Right-Angle Collision	-46%	+14%	-35%	(1)	-23%
Accidents at Signalized Intersections	-33%	-15%	-25%	(1)	-22%
Accidents At Non-Signalized Intersections	+ 6%	+11%	+21%	(1)	+12%
Midblock Accidents	-51%	-38%	0	(1)	-39%
2. THE TWO STREETS FORMING THE ONE-WAY PAIR:					
Total Number of Accidents	+36%	-19%	+20%	(1)	+ 1%
Total Accident Rate per MVM	+ 1%	-17%	+19%	(1)	- 5%
Number of Injury Accidents	+32%	-39%	+14%	(1)	- 6%
Injury Accident Rate per MVM	- 2%	-38%	+14%	(1)	-11%
Intersection Accidents	+56%	- 5%	+12%	(1)	+12%
Midblock Accidents	-15%	-38%	+77%	(1)	-25%
3. ALL STREETS IN STUDY AREA: (2)					
Total Number of Accidents	+20%	- 6%	+18%	+30%	+ 7%
Number of Injury Accidents	+17%	- 6%	+10%	+26%	+ 8%
Pedestrian Accidents	+500%	- 4%	-43%	-25%	+10%
4. WHOLE CITY:					
Total Number of Accidents	+14%	- 1%	+ 5%	+38%	+ 9%
Number of Injury Accidents	+24%	- 6%	+ 4%	+24%	+10%
Pedestrian Accidents	- 5%	+21%	- 6%	+61%	+ 4%

(1) Port Huron data are not included in this section because the situation is not similar to the other three cities.

(2) In Port Huron: Two corridors along Lapeer, and Oak and Griswold Streets.

CONCLUSIONS AND RECOMMENDATIONS

The primary advantage of the one-way systems was their contribution to good signal progression. This resulted in shorter travel time and less and shorter stops with consequent vehicle operating economy and, which is more important in cities, less air pollution because a gas engine's exhaust gases are more objectionable when it accelerates or decelerates than when it runs at constant speed. Reduction in traffic noise is another result of eliminating stop-and-go driving.

Increases of up to 10.6 miles per hour in average over-all speeds during peak periods have been observed. In a typical morning rush-hour trip in Kalamazoo, average number of stops has decreased from 6.3 to 1.0. Average delay (stopped time) during such trips has been reduced in one case from 71 to 11 seconds per mile.

One-way operation has resulted in more numerous gaps in the traffic stream. Also, the sizes of these gaps have grown larger, making it easier for stop-controlled side-street traffic to enter the trunk line.

Higher peak-traffic demands have been accommodated. Up to 74 percent of rise in the 15-minute afternoon-peak totals for traffic leaving the study area have been found, compared with only 17 percent of rise in the 24-hour total for leaving traffic.

In a transportation system, the roadway is only one of several factors playing a role in traffic safety. The results of this study indicate that in some cases of one-way operation, adverse changes in the other factors have offset the safety advantage of the unidirectional flow. However, the data reveal that accidents directly related to the stability of the flow, such as rear-end collisions and accidents at signalized intersections, have been alleviated on the trunk lines. On the other hand, in cases where a residential street was converted to a thoroughfare, larger exposure to accidents has created a more hazardous environment. Also, indications are that the safety record of the new one-way systems improves with time.

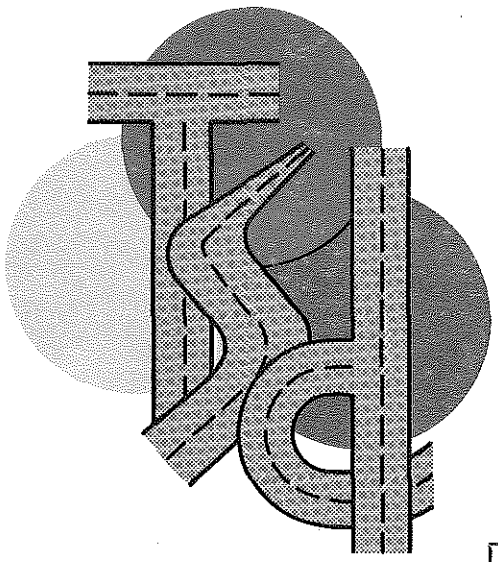
Careful system design is important if full advantage of a one-way system is expected. Bottlenecks created at the transition points of the system sometimes have materially diminished the advantages of the rest of the system. Elimination of as many signals as possible, especially at the transition points to two-way operation, should be a goal.

If opportunities occur in the future for further evaluation of one-way conversions, measurement of spot speeds and a more detailed survey to determine the total time loss to drivers should be considered.

FINAL DETAILED REPORT

STUDY OF THE OPERATIONAL ASPECTS
OF ONE-WAY AND TWO-WAY STREETS

Report TSD-RD-219-72



TRAFFIC and SAFETY DIVISION

DEPARTMENT OF STATE HIGHWAYS
STATE OF MICHIGAN

MICHIGAN STATE HIGHWAY COMMISSION

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FINAL DETAILED REPORT

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Report TSD-RD-219-72

By

Nejad Enustun

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STUDY CONDUCTED BY THE

Traffic Research & Development Section
Traffic & Safety Division
Michigan Department of State Highways

in cooperation with

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FOREWORD

State highway departments traditionally have been involved in the construction and operation of rural roads. The purpose of the state trunk lines in the past has been to provide transportation between cities. To provide continuity of the network through urban areas, existing city streets have later been designated as urban extensions of the state highway systems. The phenomenal increase in highway traffic during the last fifty years, both within and between urban areas, has necessitated seeking ways and means to provide ample traffic capacity along such urban extensions.

Traffic capacity can be augmented either by building new arteries or by utilizing two streets along a certain corridor to carry the trunk line traffic, usually one street for each direction of travel. Michigan has often established one-way street pairs to carry the state trunk line traffic through urban areas. This can only be accomplished in cooperation and agreement with the local governments concerned. It is essential that the State Highway Commission and the local jurisdictions be aware of the benefits and drawbacks, if any, obtained as a result of converting two-way streets into one-way trunk lines.

Although there seems to exist general knowledge about the benefit of one-way streets, specific cases where these benefits are described in a quantitative way are very scarce. It was believed that much could be learned from a documentation of the quantitative results obtained when actual two-way state trunk lines are converted to a one-way street and a parallel local street is added; or in a few instances when the existing two-way state trunk line is abandoned for a new pair of one-way streets. This led to the present study of the Operational Aspects of One-Way and Two-Way Streets.

Four projects involving conversion of operations in four cities, Kalamazoo, Lansing, Pontiac and Port Huron, were selected for the study (See Figure 1). An interim report (1)* was earlier published presenting the results of the studies in Kalamazoo and the first phase of the operation in Lansing. Studies of the remaining two projects, in Pontiac and Port Huron, and the final phase in Lansing have now been concluded. This report contains full information for all of the four projects.

The field data obtained were reduced and condensed to make them easier to interpret. Even with such condensation considerable space is devoted to documentation of the study methods by including several maps and charts. Although some of the data may not render themselves to immediate and direct interpretation and clear-cut conclusions, they are included for future reference and because of local and historic interest. The details provided in the report should make it possible for those who are directly concerned with traffic operation in each city to closely study the traffic conditions. On the other hand, it is hoped that these four projects provide a useful set of case studies for others who need not be familiar with these cities.

* *The numbers refer to publications listed in the BIBLIOGRAPHY at the end of the report.*

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ACKNOWLEDGMENT

This study was accomplished as a result of efforts provided by several people and organizations. All Traffic Surveys were conducted by the Transportation Survey and Analysis Section of the Transportation Planning Division, Michigan Department of State Highways. Traffic volume data were processed by the Computer Services Division of the Department. Accident reports were made available by the City Traffic Engineer's office in Lansing and by the City Police Departments in Kalamazoo, Pontiac and Port Huron. Department of State Highways' District Traffic Engineers at the Jackson, Kalamazoo and Pontiac offices were extremely helpful in compiling the accident data at the cities involved. The Office Services Division is credited for the reproduction of the reports.

The author, on behalf of the Michigan Department of State Highways, extends his deepest appriciation to each individual whose work helped to conduct the study and prepare this report.

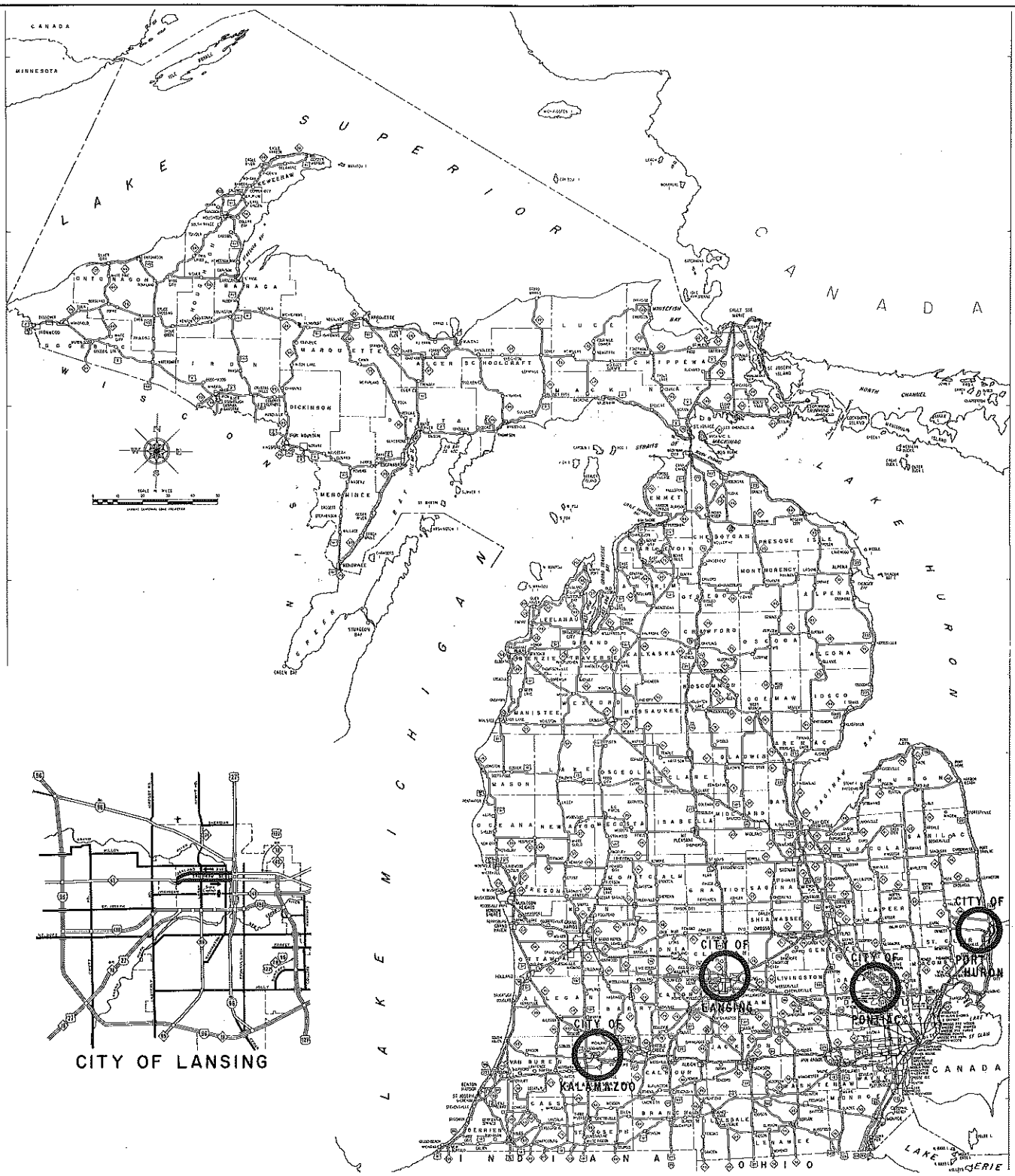

FIGURE I - LOCATION OF STUDY CITIES AND ONE-WAY STREETS

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

As the implementation of plans for one-way traffic on some state trunk lines penetrating four selected cities was realized according to schedule, before-and-after surveys were conducted in each city for the purpose of obtaining quantitative information to study the traffic operation on the streets before and after conversion to one-way. These surveys included volume and turning-movement counts, speed-and-delay runs, traffic gap studies and accident analyses. The study evaluated not only the conditions on the one-way trunk lines themselves but also on the rest of the network of city streets in the immediate area which might be affected by the traffic on the trunk lines. The four cities were Kalamazoo, Lansing, Pontiac and Port Huron.

In Lansing a second "after" phase of the operation was also studied. During the first "after", or initial one-way, phase the state trunk line was operating as a one-way pair of streets only to a certain point, on a temporary basis. During the second "after" or final phase, the construction project was completed as far as the west city limits where the one-way system transitioned into a four-lane two-way highway of higher operating speed.

Study results in all cities did not show the same trends in the change in quality of traffic as evaluated by the parameters of time, convenience and safety. Some of the cities indicated greater degrees of improvement than others. In some cases the elapse of considerable time between the before and after phases of the study detracted somewhat from the value of the comparative data.

The most undisputable advantage of the one-way systems was their contribution to good signal progression. This resulted in shorter travel time and less and shorter stops with consequent vehicle-operating economy and, which is more important in cities, less air pollution, because a gas engine's exhaust gasses are more objectionable when it slows down or speeds up than when it runs at constant speed. Reduction in traffic noise is another result of alleviating stop-and-go driving.

In Kalamazoo, the average over-all speed on some of the one-way routes during peak periods increased by up to 10.6 miles per hour, which was 56 percent above the two-way traffic speed of 18.9 miles per hour. On another one-way trunk line route in Kalamazoo, stopped delay was reduced by 60 seconds per mile of travel, or by 75 percent. In Lansing, up to 4.8 miles per hour or 18 percent gain in speed and 8 sec/mile or 12 percent reduction in delays were found. In Port Huron, speed increase of up to 11.7 miles per hour or 62 percent, and delay decrease of 24 sec/mile or 71 percent were observed. Pontiac showed the least gain from one-way operation. In the southeastbound direction, up to 3.7 miles per hour in speed was gained on the Cass Avenue route over Oakland Avenue, but practically no increase was measured on the northwestbound one-way Oakland Avenue except during the noon peak.

Travel time on some major streets crossing the one-way state trunk lines was also examined on a before-and-after basis in the study cities. In most cases, establishment of another street as one of the one-way pair necessitated installation of traffic signals. These signals caused a slight increase in the travel time on the cross-streets. However, these delays were within tolerable limits. In Lansing the largest increase in the average travel time on a cross-street was 37 seconds during the initial one-way phase. During the final one-way phase, which was five years after the "before" phase, and when the traffic had increased by about 50 percent, the largest increase in travel time on any cross-street was one minute and four seconds. In Port Huron the greatest increase was 40 seconds. In Kalamazoo, where no signals were added because of the one-way operation, travel time on some cross-streets showed a decrease, the maximum decrease being one minute and two seconds. Some showed an increase, the maximum being 41 seconds.

Availability of gaps in the trunk line traffic stream at some stop-controlled intersections

along the one-way pair was also studied. In general, these studies indicated an increase in the total number of gaps usable by the traffic approaching from the side streets. Also, duration of gaps in seconds showed an increase. Cities of Pontiac and Port Huron, however, did not show this trend at all of the intersections studied. Existence of extra gaps have added to the traffic capacity of the areas by enabling more vehicles to cross or enter the one-way streets.

Traffic volume studies revealed several interesting results of the one-way trunk line operation. First of all, the capacity of the street network in each study area to move traffic during peak periods, as measured by 15-minute counts of entering, leaving and circulating traffic, improved. State trunk lines assumed more of the peak-period traffic load by attracting traffic from the city streets, thereby giving relief to city streets. Comparing the total daily travel in the area with the total daily traffic entering and leaving the area, it was possible to calculate the extent of adverse travel caused by one-way routing. The largest increase in such travel was found to be 15 percent for the final phase in Lansing. Pontiac showed only 2 percent, and there was no change in Kalamazoo. The reason for such small indications for adverse travel is believed to be an already existing adverse travel during two-way operation because of left-turn prohibitions and other circuitous routes preferred by drivers to avoid some bottlenecks.

Another advantage of the one-way streets was the elimination of delays due to blocking of left lanes by vehicles waiting to turn left.

Contrary to expectations, these projects have failed to show conclusive evidence supporting the safety aspects of one-way trunk line operation. On the street which earlier served as a two-way state trunk line, there was a reduction in total accidents as a consequence of reduced traffic flow obtained by eliminating one of the flow directions. However, considering the totals of the accidents on both streets forming the one-way pair, the rise in accidents on the new trunk line offset, in most cases, the reduction on the old state trunk line. Especially in the cases of Lansing and Port Huron, where one of the pair was earlier a very minor residential street with no through-traffic, such additions to the state trunk line system increased the area of exposure to accidents.

Some characteristic results of the accident analysis on the one-way streets in all cities are reduction in: (1) Total and injury accidents, (2) Rear-end collisions, and (3) Accidents at signalized intersections. On the other hand, increase is observed in: (1) Sideswipes and (2) Collisions at non-signalized intersections.

A second "after" study in Lansing indicated that the safety record of the one-way system improved with time, confirming some earlier studies conducted elsewhere.

Careful system design is very important if full advantage of a one-way pair is expected. The Pontiac project is an example of some room for improvement in this respect. The lack of full traffic capacity for northwestbound traffic at the transition point at the Cass-Montcalm intersection has greatly reduced the effectiveness of extra capacity provided by one-way Oakland Avenue further upstream. The addition of another lane is recommended at that location.

Another consideration, especially in the design of the transition points from one-way to two-way roadways, is to try to eliminate signals. In most situations one-way streets permit merge type of intersection operation, as was accomplished in Kalamazoo, which has proved safer than signal control.

The present study has been designed as a general overview of several one-way projects. Speeds and delays have been determined by test vehicles, and measurements of delays caused by left-turning vehicles have been on a cumulative basis. If further studies of one-way operation are conducted in the future, it is recommended to study spot speeds and their variation along the arteries in more detail. The contribution of speed characteristics to traffic safety is well known, and such studies may provide some insight into the wide variation found in the accident experiences of the

cities in this study. It may also be feasible to study actual delays incurred by individual vehicles in the traffic stream. This would provide useful data to determine the economy in vehicle operation.

In most instances one-way operation is an inescapable measure in cities. Therefore, the aim of future studies should be not a proof of their superiority over two-way streets, but rather the determination of design details which can be incorporated into the system to get the most benefit out of it.

Some design recommendations derived from the present study will be found at the end of the report (page 141a).

STUDY PROCEDURES

KALAMAZOO STUDY AREA

The study area in the City of Kalamazoo is made up of a network of all of the streets included in Figure 2. The area includes a substantial portion of the central business district. During the two-way phase of the study (upper half of Figure 2), Michigan Route 43 crossed this area following Main Street from the west, then Michigan Avenue for the rest of the way. Two other numbered routes also followed Michigan Avenue, one of them only the western section. Business loop for Interstate Highway 94 and business route for U.S. Highway 131 followed Michigan Avenue from the southwest, then joined M-43 at the Main Street intersection. US-131 BR was then distributed into a north-south one-way pair formed by Westnedge Avenue and Park Street. I-94 BL continued along Michigan all the way to King Highway.

To improve traffic circulation in Kalamazoo, the state trunk line plan was changed to incorporate Kalamazoo Avenue to handle one-way westbound traffic through the city. Main Street from Douglas to Michigan, and Michigan Avenue from Main to Kalamazoo intersection were made into an eastbound one-way thoroughfare. Douglas Avenue, also functioning as a short one-way southbound street, connected the west end of Kalamazoo Avenue with Main Street. To carry a heavy outbound movement, a new diagonal one-way road, Michikal Street, was built carrying southwestbound traffic from the intersection of Kalamazoo and Westnedge to the intersection of Michigan and Main. A connector was also built across Michikal to handle left-turns from northeastbound Michigan to Elm Street. (Shown in Figure 4.) Kalamazoo Avenue west of Westnedge was improved and resurfaced. Other modifications in the street system, made in preparation for the one-way operation, were the construction of channelizing islands at the intersections of Michigan and Main, Kalamazoo and Douglas, Main and Douglas, Michigan and Portage, and Michigan and Kalamazoo. Necessary revisions were also made in the various traffic control devices. Parking was removed from Kalamazoo Avenue west of Westnedge Avenue, and other minor parking regulation changes were made.

The state trunk line scheme according to the one-way plan is seen in the lower half of Figure 2. The new scheme started operating on October 10, 1965. Figure 3 shows the laneage of the

KALAMAZOO: One-way traffic on Michigan Avenue east of Main Street

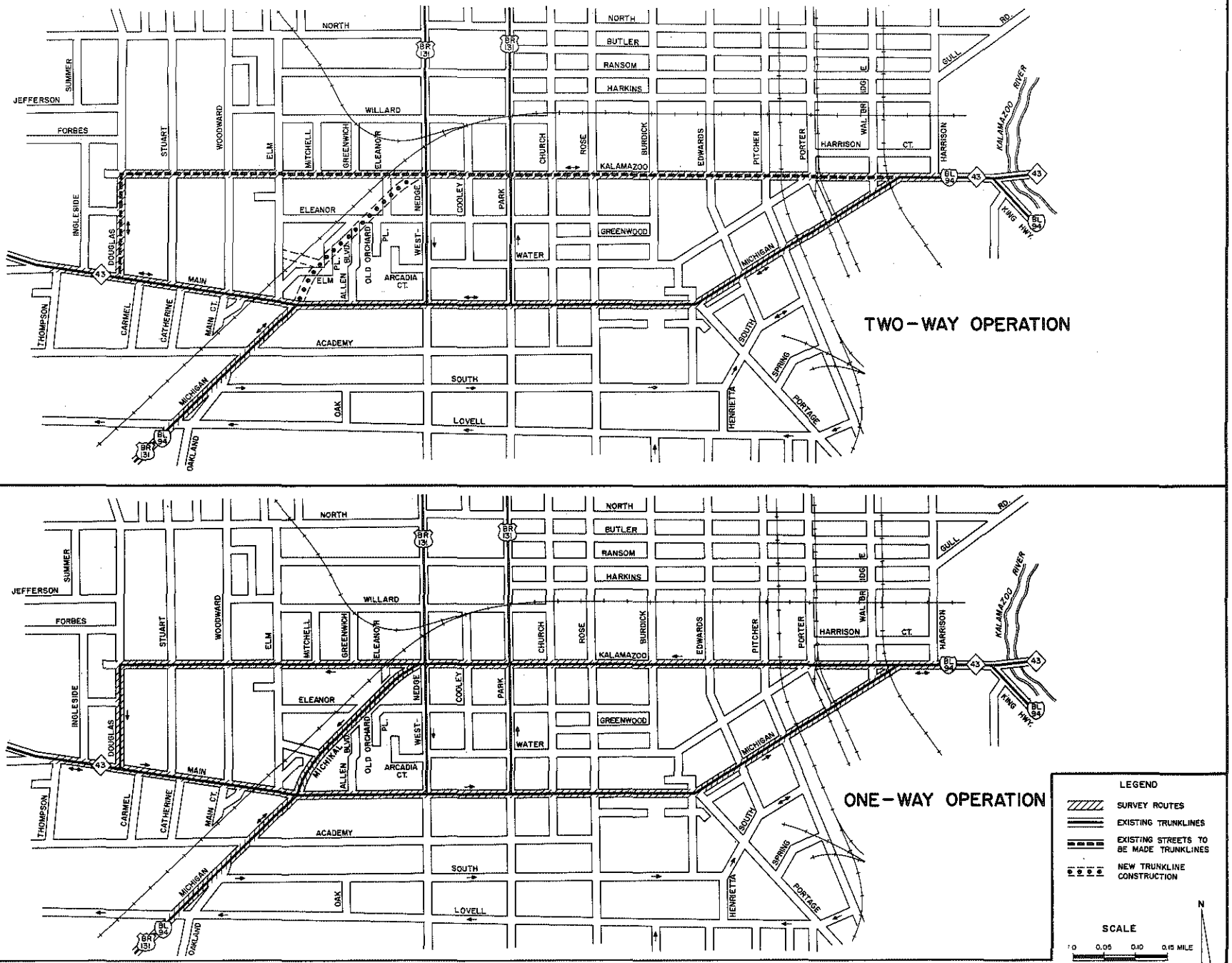

FIGURE 2 - CITY OF KALAMAZOO: STUDY AREA & SURVEY ROUTES

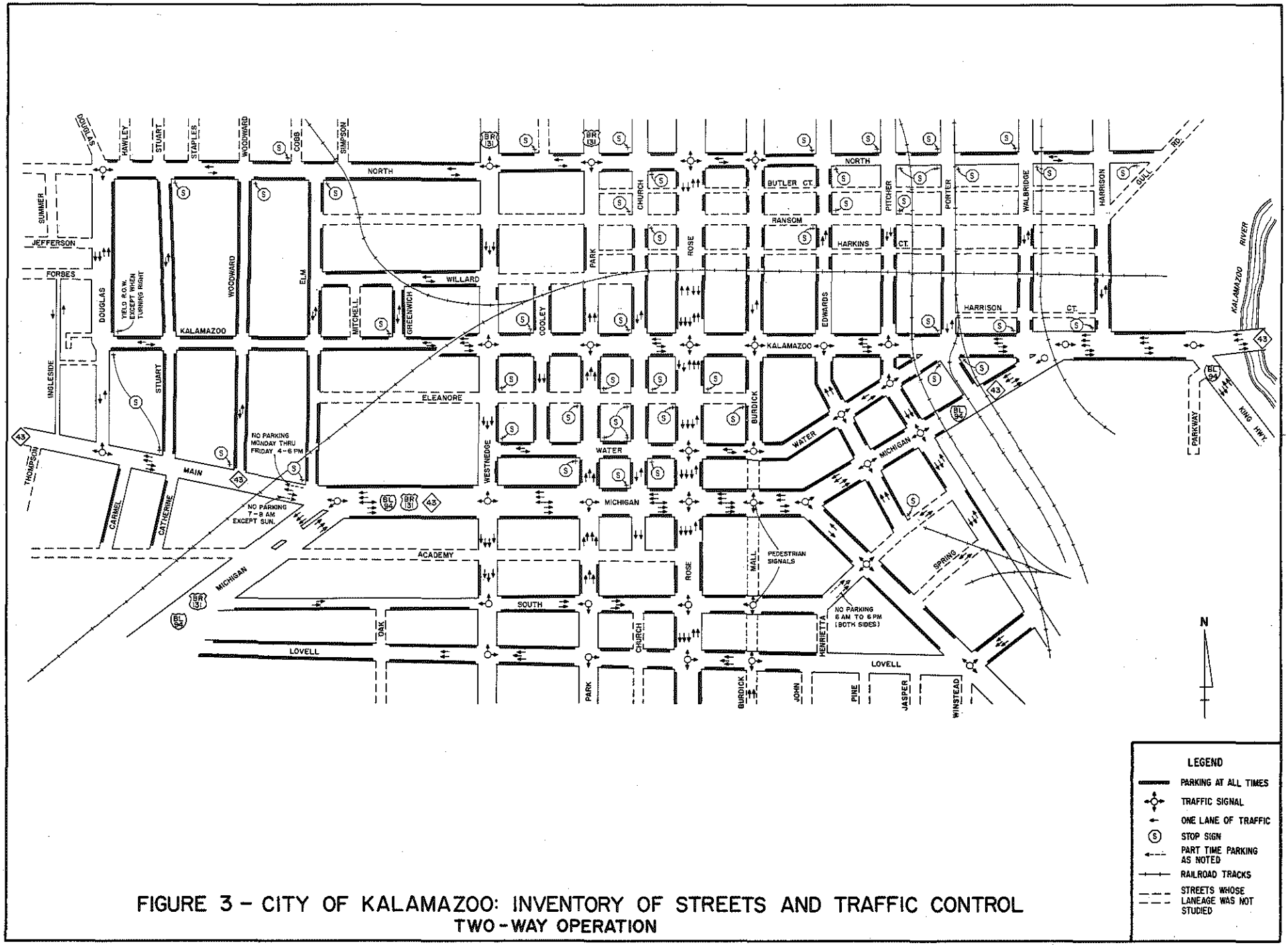

FIGURE 3 - CITY OF KALAMAZOO: INVENTORY OF STREETS AND TRAFFIC CONTROL
TWO-WAY OPERATION

KALAMAZOO: One-way Michigan Avenue at Portage Street

KALAMAZOO: Westbound one-way traffic on Kalamazoo Avenue at Park Street

principal streets, and parking and other traffic controls during two-way operation in the study area. Figure 4 is the corresponding map for the one-way operation.

TRAFFIC SURVEYS IN KALAMAZOO

To obtain data representing the quality of traffic operation during the "before" phase of the study, surveys were made between October 19 and October 30, 1964. The "after" phase surveys were made between May 2 and 4, 1966. The sample sizes for the various surveys were based on established methods normally used for similar work by Michigan Department of State Highways.

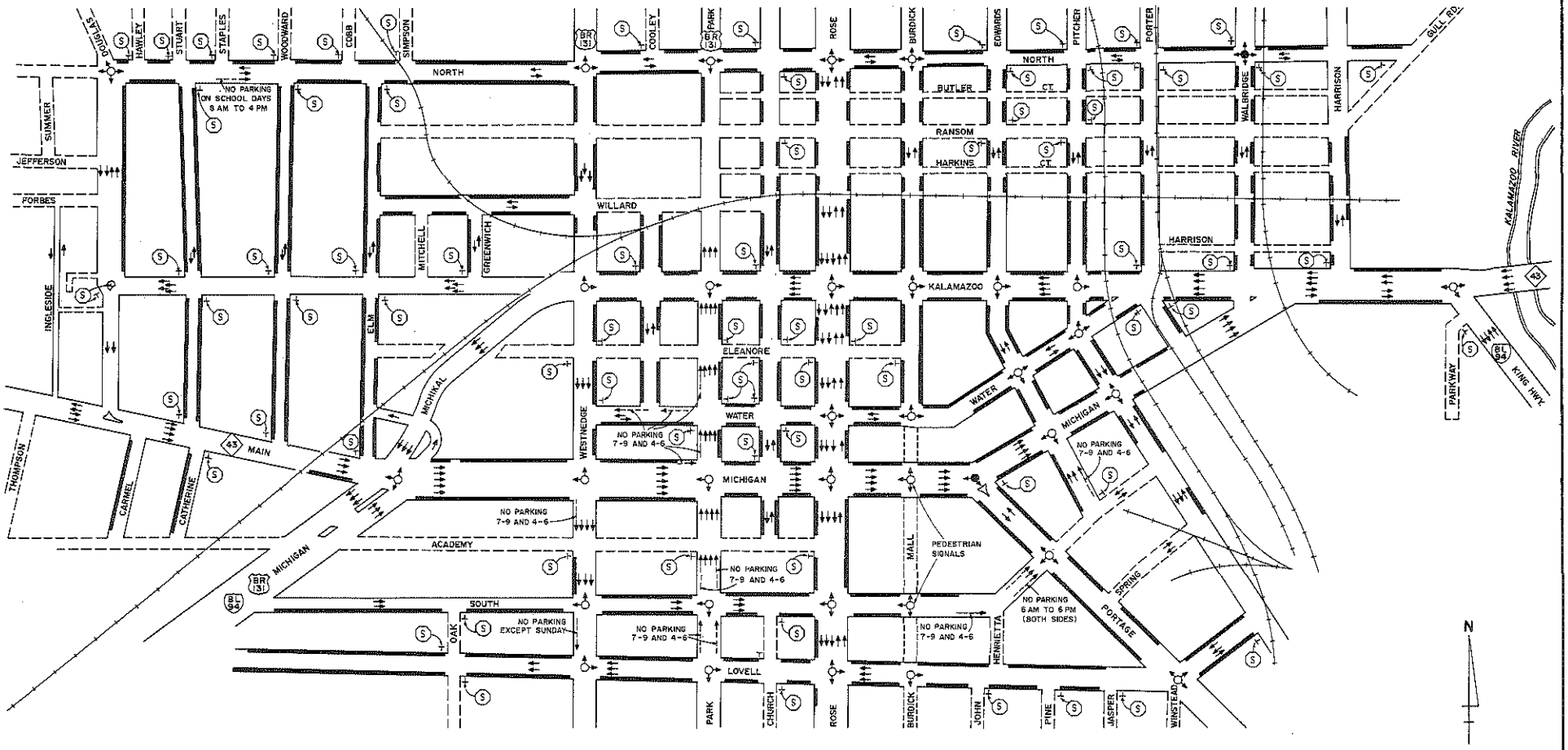

FIGURE 4 – CITY OF KALAMAZOO: INVENTORY OF STREETS AND TRAFFIC CONTROL
ONE-WAY OPERATION

Volume counts were taken by pneumatic counters recording by 15-minute periods.

Time gaps in the traffic stream were measured on Kalamazoo and Michigan Avenues at their intersections with Church Street. Nothing shorter than six seconds was recorded, and the gaps were divided into four size-groups of 6 to 10 seconds, 10 to 15 seconds, 15 to 20 seconds, and over 20 seconds.

Turning-movements were counted for six hours at the intersections of Kalamazoo and Rose, and Michigan and Lovell. Stoppage of left lanes caused by traffic waiting to make left turns at the Kalamazoo and Rose intersection was recorded in seconds.

Figure 5 shows the locations of the survey stations. A full description of all surveys will be found in Appendix 1.

The speed-and-delay study runs were made by the so-called floating car method. Total travel time and points and durations of all stopped delays were recorded in these runs using automatic recording equipment (See Figures 6 and 7).

Total travel time only was clocked by a survey car on six cross-streets which are situated in a general north-south direction and which intersect the one-way pair.

ACCIDENT DATA FOR KALAMAZOO

Accident reports compiled by the City of Kalamazoo Police Department were studied for a one-year-before and one-year-after evaluation. A period of three months after the change of the traffic operation was skipped before starting the "after" period of the accident study. This was done to give ample time for the drivers to get used to the new situation, and for the Department to readjust any traffic devices as might be necessary. A large majority of the streets in the area already described was covered in the canvassing of accident reports. A full list of the streets will be found in Appendix 15.

The details of accident information extracted from the individual police reports can be seen in the recording form in Appendix 10. The classification of the accident types is given in Appendix 11.

LANSING STUDY AREA

The Lansing study area includes the street network shown in Figure 8. The area contains part of the northern fringe of the central business district. During the two-way operation of the state

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KALAMAZOO: One-way Kalamazoo Avenue west of Park Avenue

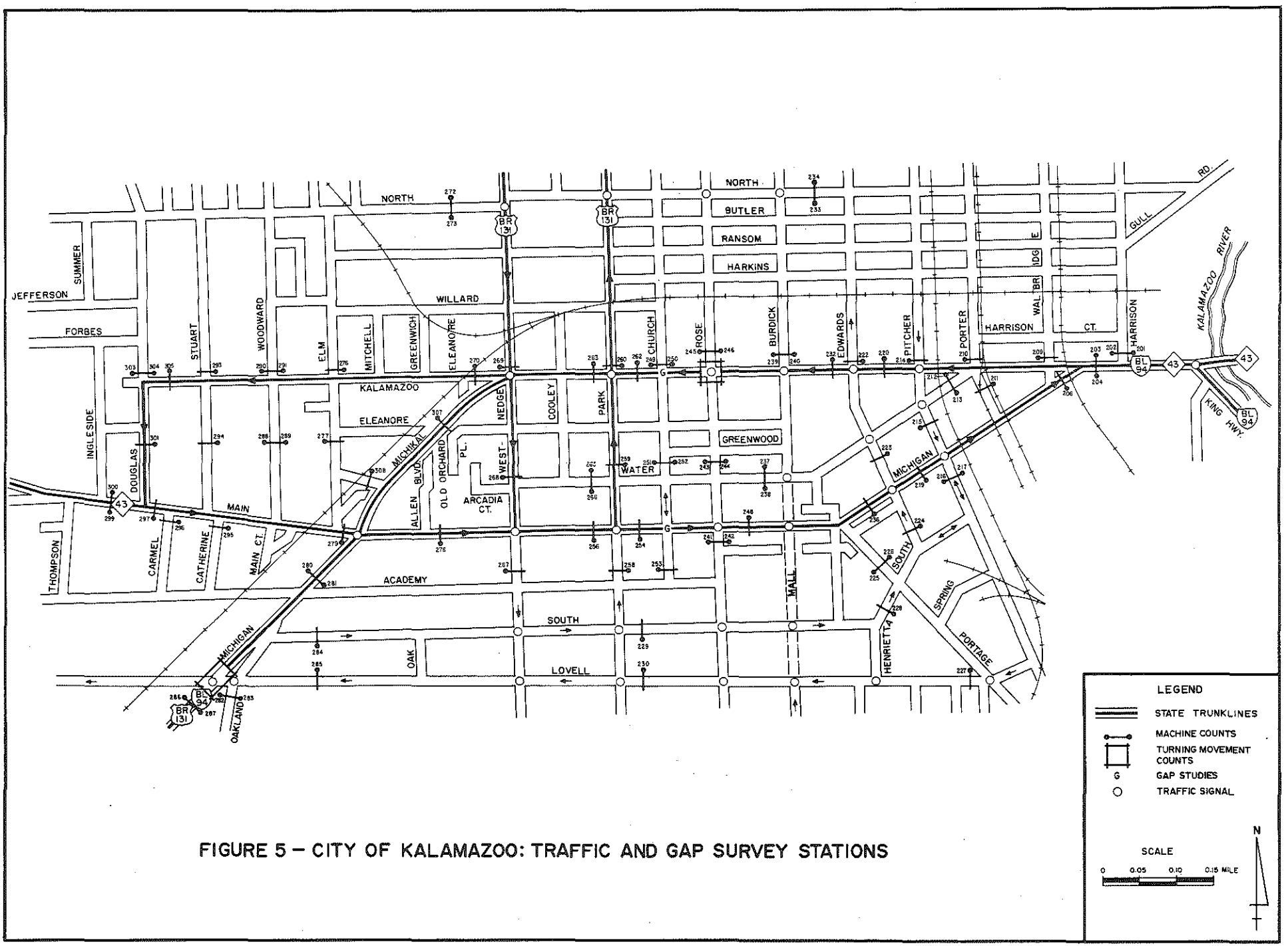


FIGURE 5 – CITY OF KALAMAZOO: TRAFFIC AND GAP SURVEY STATIONS

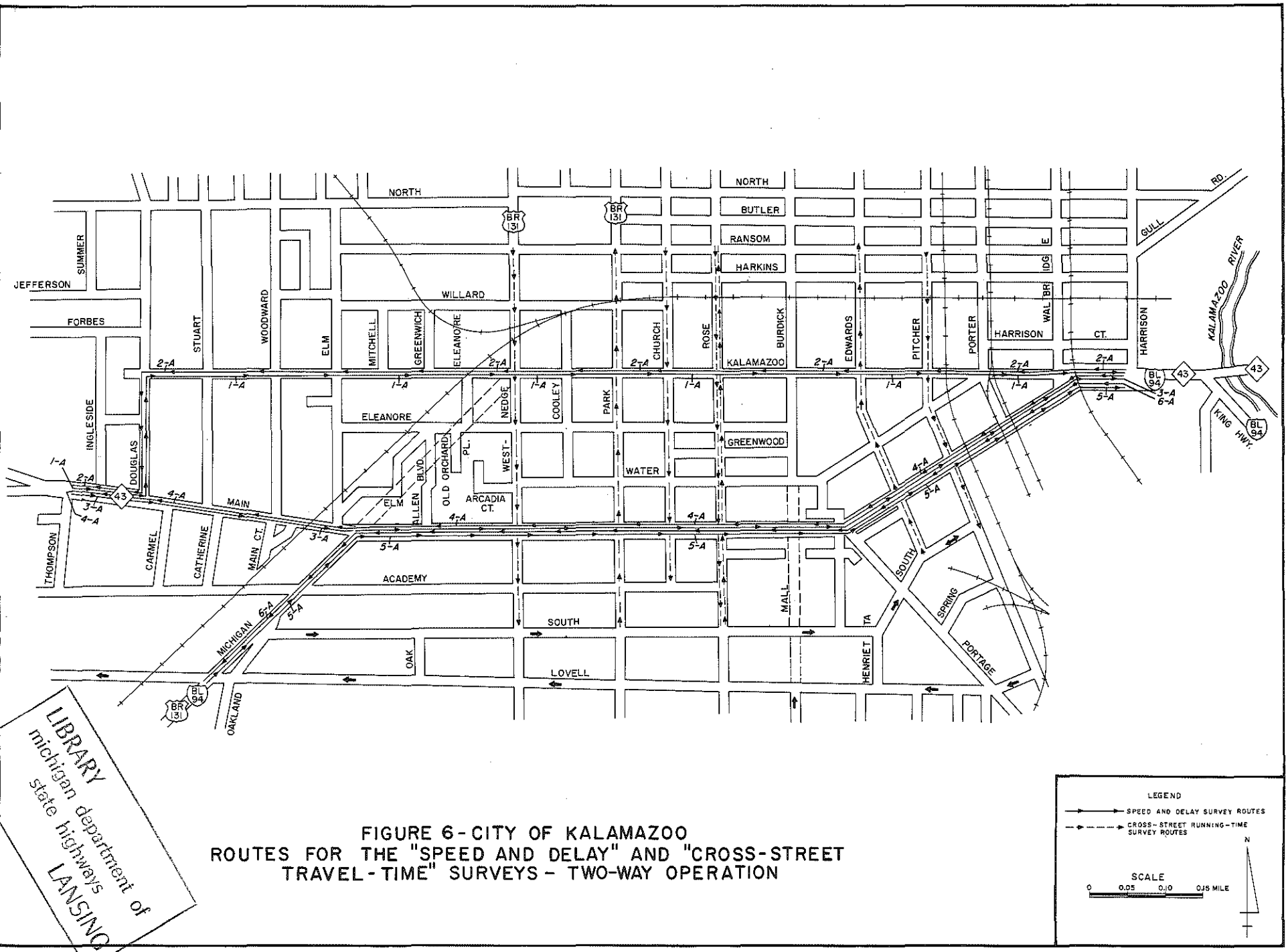


FIGURE 6 - CITY OF KALAMAZOO
ROUTES FOR THE "SPEED AND DELAY" AND "CROSS-STREET TRAVEL-TIME" SURVEYS - TWO-WAY OPERATION

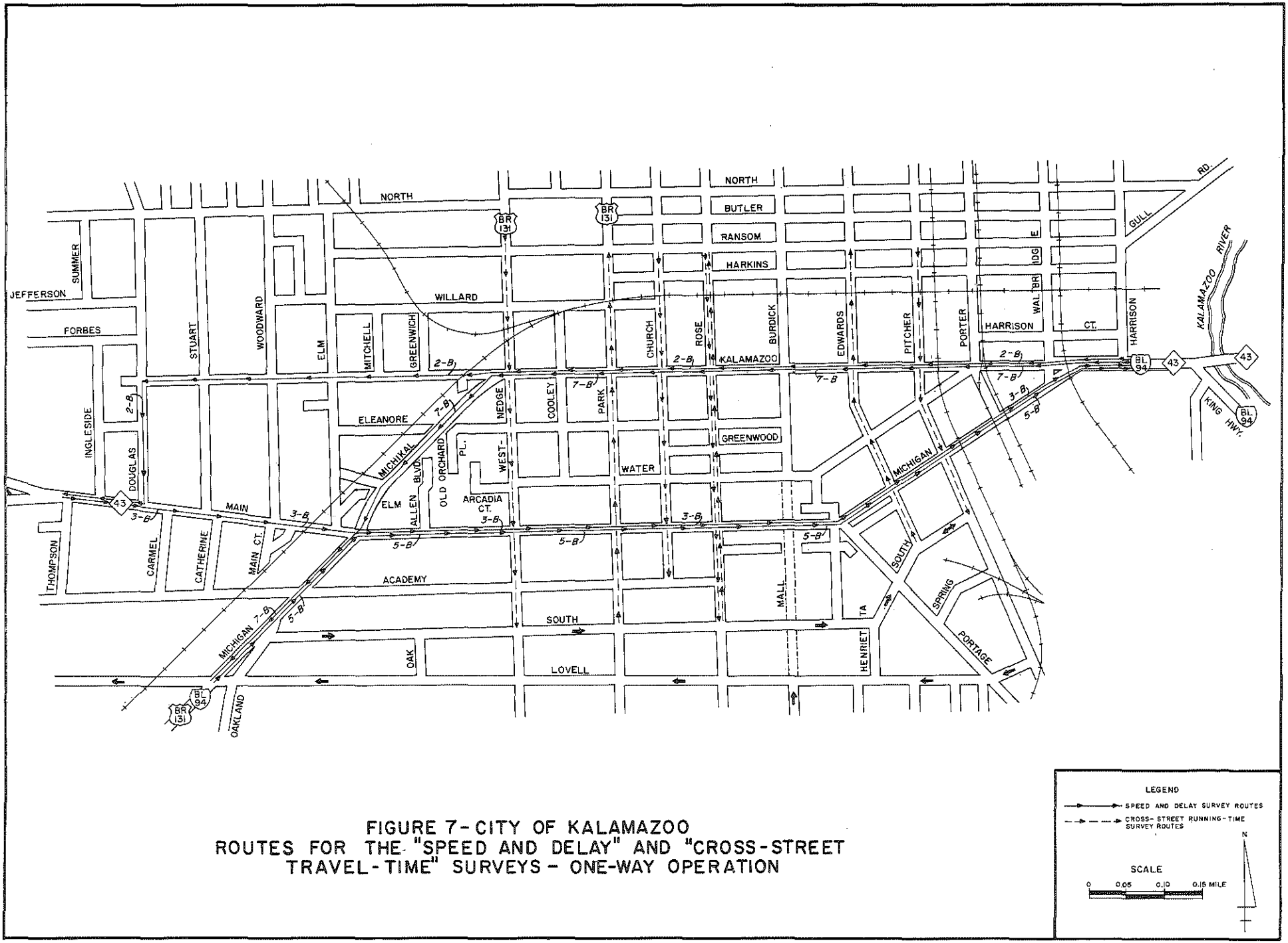
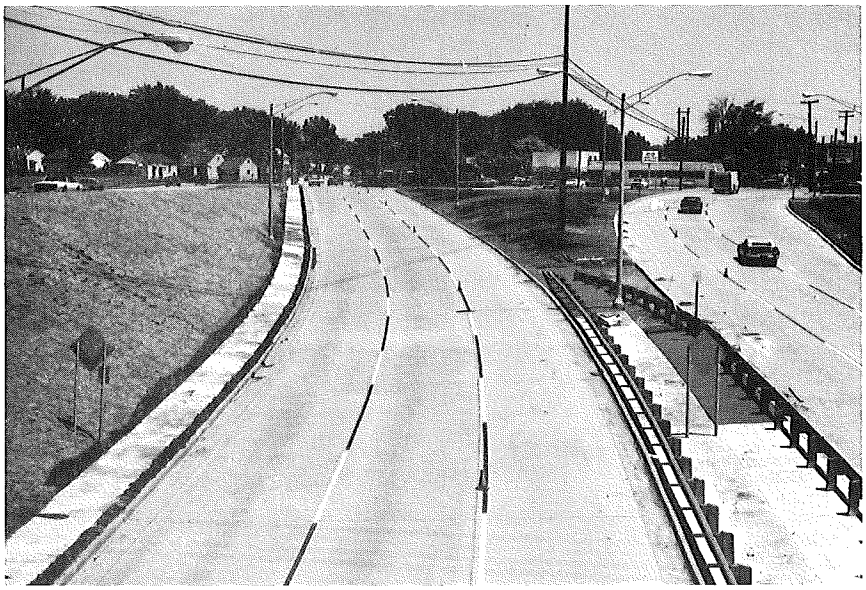


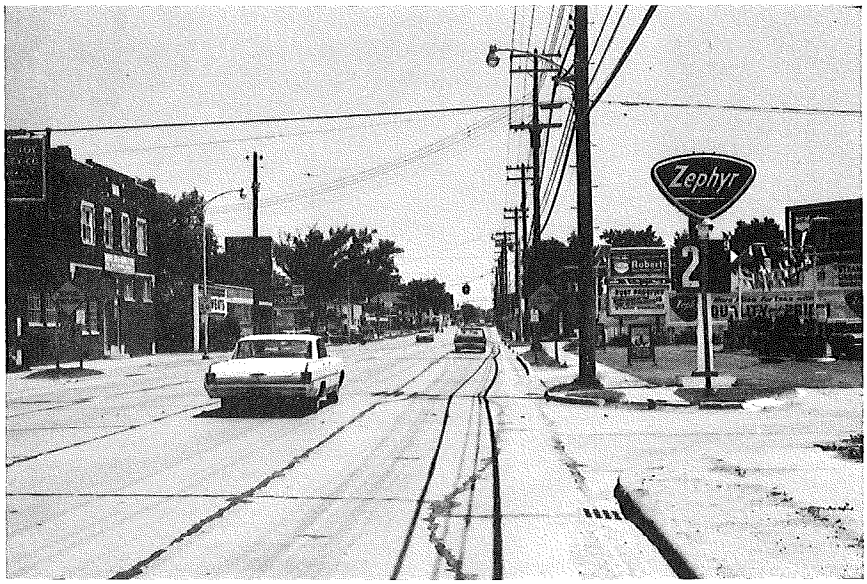
FIGURE 7 - CITY OF KALAMAZOO
ROUTES FOR THE "SPEED AND DELAY" AND "CROSS-STREET TRAVEL-TIME" SURVEYS - ONE-WAY OPERATION

trunk line through this area (upper half of Figure 8) Michigan Highway 43 followed Saginaw Street from the west city limits near the Belt Line Railroad east to Center Street. From there east, M-43 was already operating on the Saginaw-Sheridan one-way pair. There were existing one-way streets intersecting the trunk line. These were Pine Street and Capitol Avenue, at that time running northbound, and Walnut Street and Grand Avenue running southbound.

As an intermediate step in the implementation of the one-way operation of M-43 (lower part of Figure 8), a new bridge was built over the Grand River, and Jefferson and Oakland Streets were widened, reconstructed and joined to form a con-

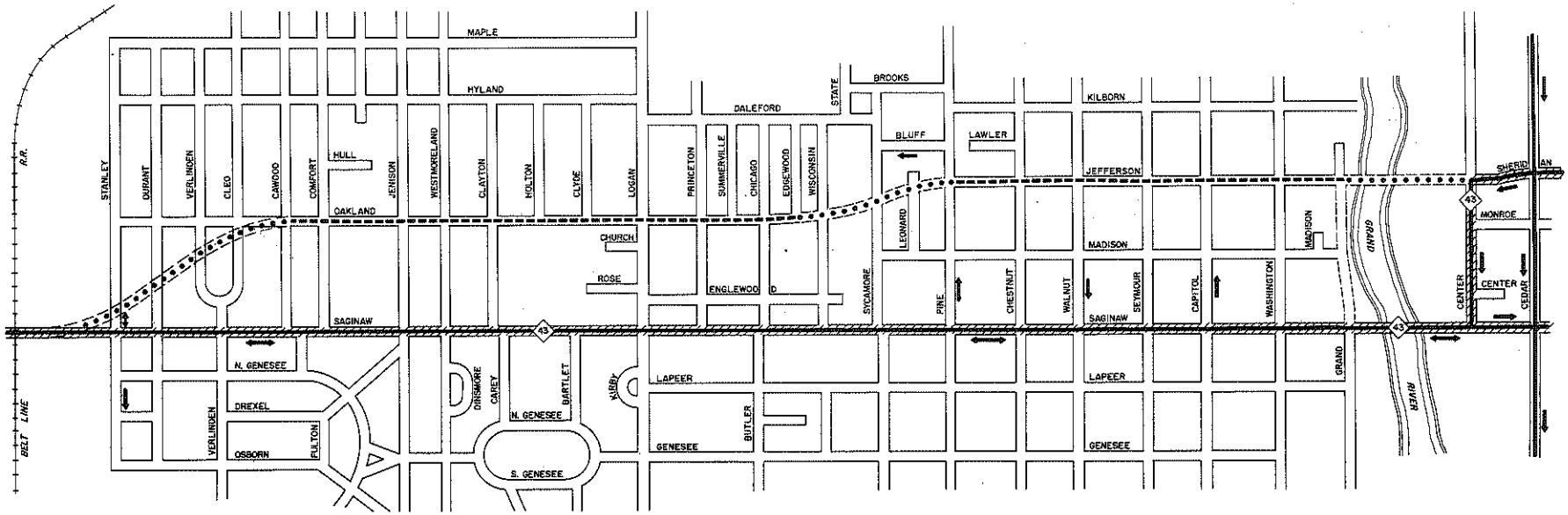


LANSING: Oakland-Saginaw one-way pair as seen from the Belt Line Railroad structure looking east



LANSING: One-way Saginaw Street west of Verlinden intersection

TWO-WAY OPERATION



ONE-WAY OPERATION

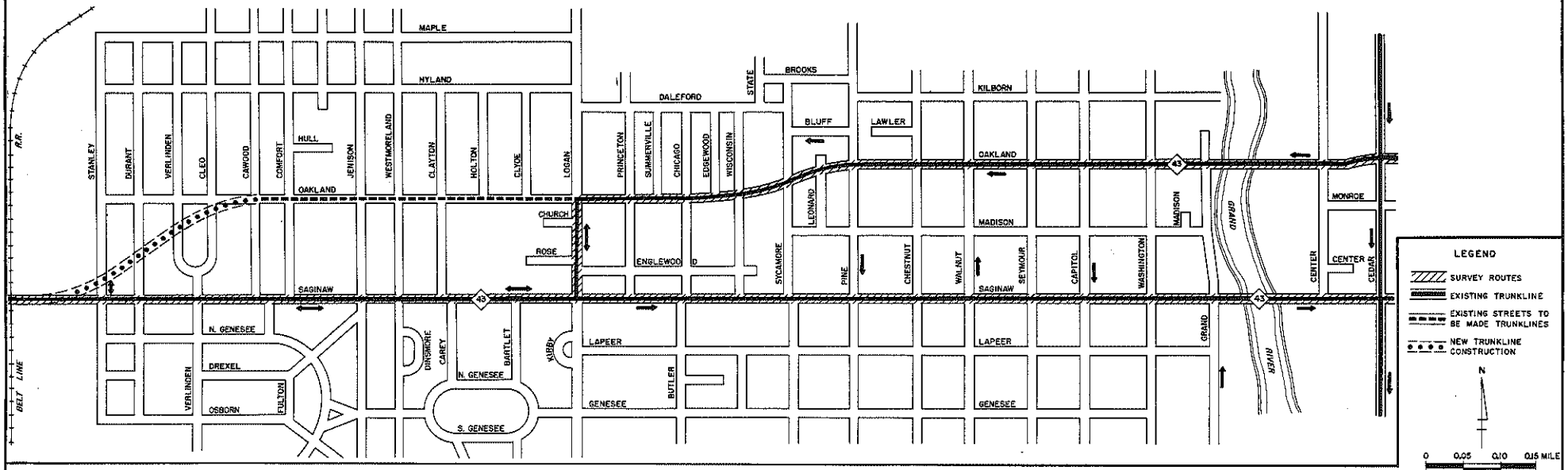
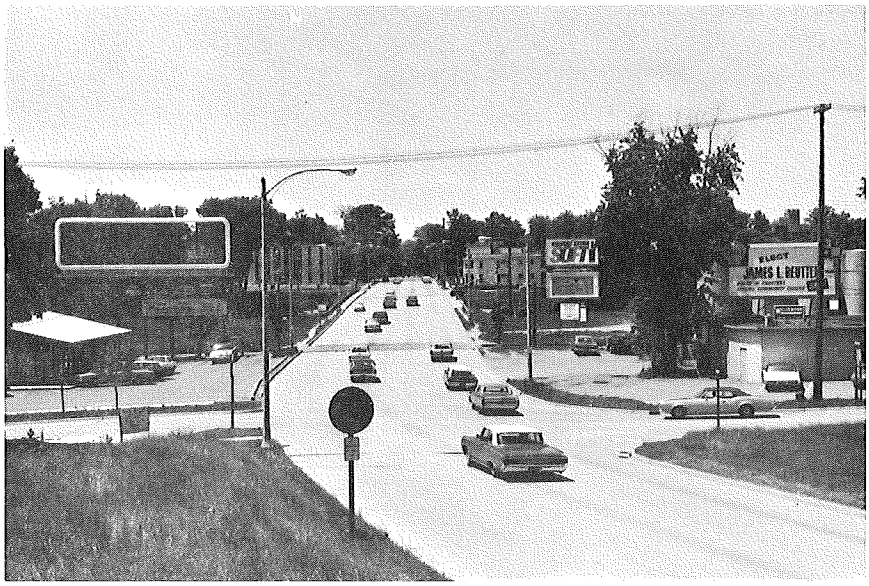


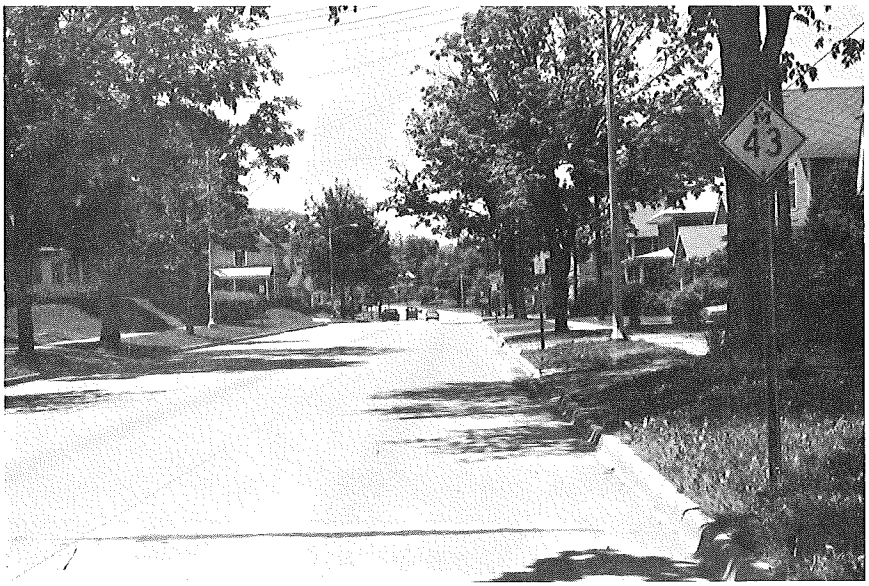
FIGURE 8 – CITY OF LANSING: STUDY AREA & SURVEY ROUTES
DURING TWO-WAY AND INITIAL PHASE OF ONE-WAY OPERATION

tinuous westbound trunk line as far as Logan Street. The entire westbound route was then named Oakland Avenue. Median islands on Saginaw Street between Washington Avenue and Center Street were removed and the area converted into a traffic lane. Part-time parking was removed from Saginaw Street, and all other necessary revisions were made in the traffic control devices and parking regulations. In this report, this period is referred to as the initial phase of the one-way operation, and it began on January 31, 1965. Logan Street operated as a two-way street between Oakland and Saginaw. Saginaw Street west of Logan also operated two-way as before. At the same time, the direction of flow on the north-and-south one-way city streets mentioned earlier was reversed in order to better fit the ultimate city traffic plan to be implemented after

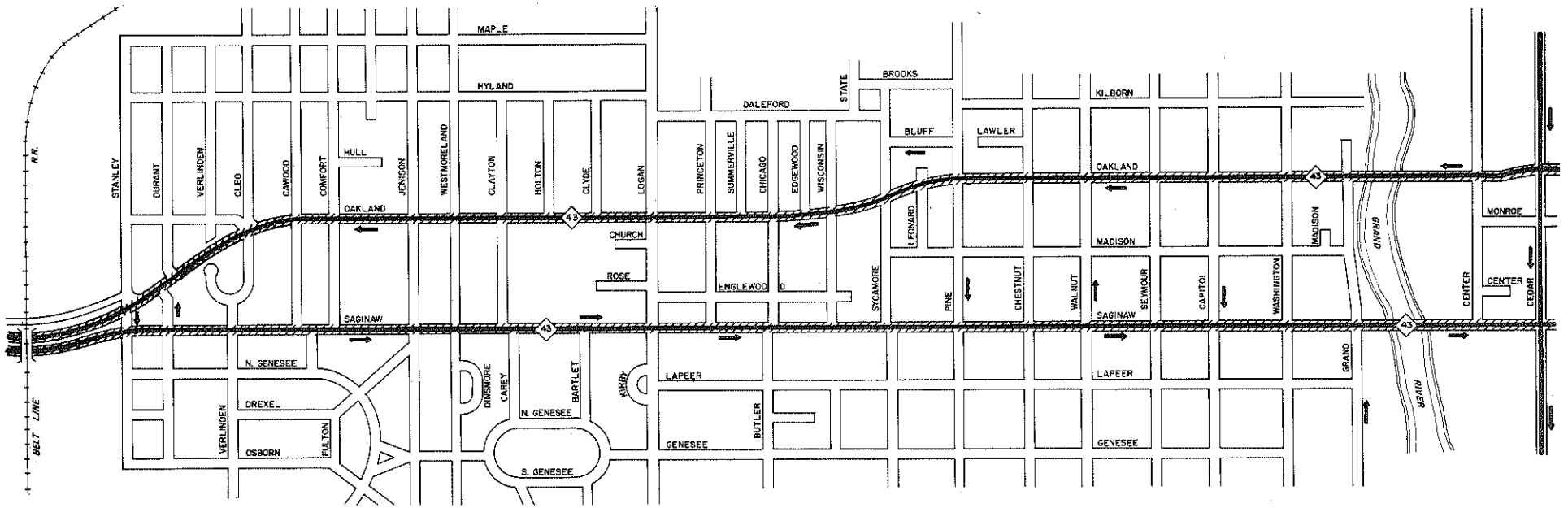
(Text continued on p. 34)



LANSING: One-way Oakland Avenue at Center Street



LANSING: One-way Oakland Avenue near Pine Street intersection



LEGEND

SURVEY ROUTES

EXISTING TRUNKLINES

N

0 0.05 0.10 0.15MILE

SCALE

FIGURE 9 – CITY OF LANSING: SURVEY ROUTES

DURING FINAL PHASE OF ONE-WAY OPERATION

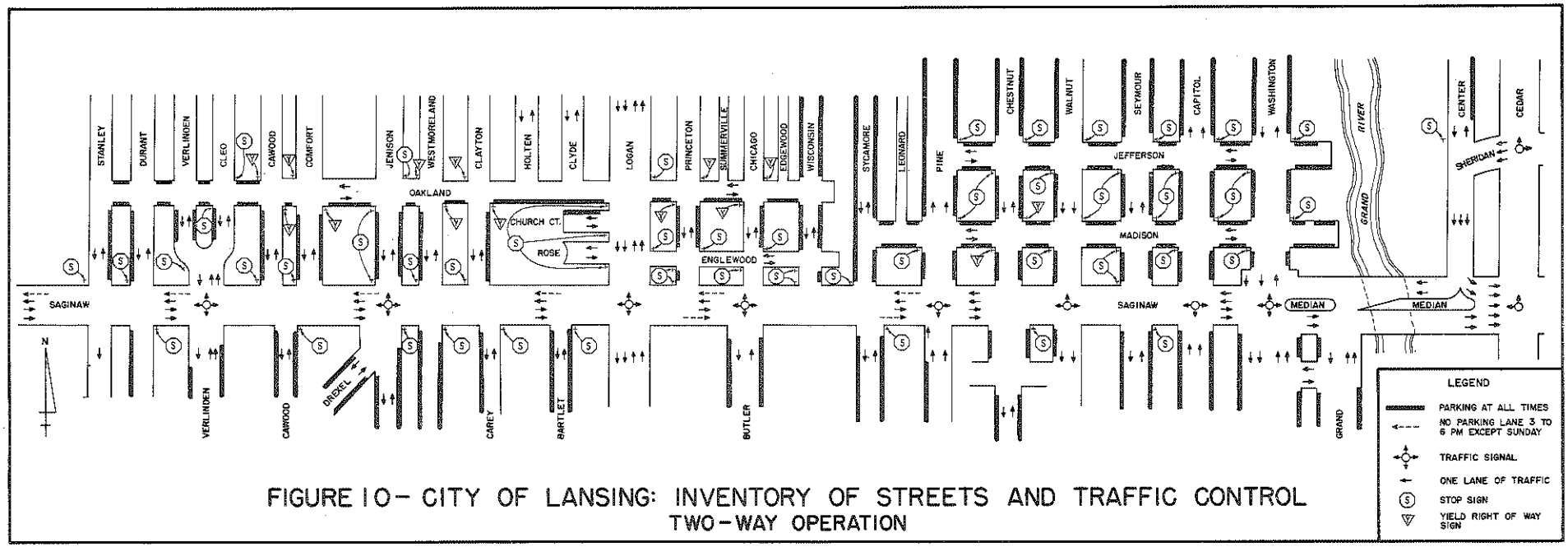


FIGURE 10 – CITY OF LANSING: INVENTORY OF STREETS AND TRAFFIC CONTROL
TWO-WAY OPERATION

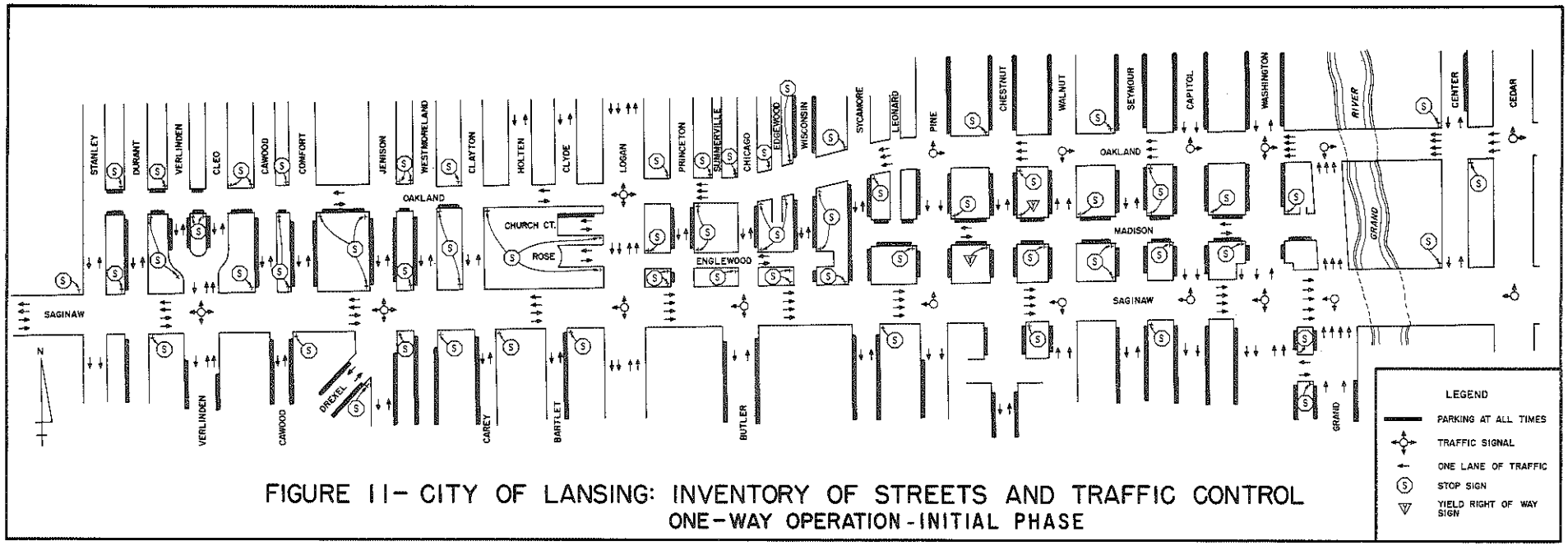
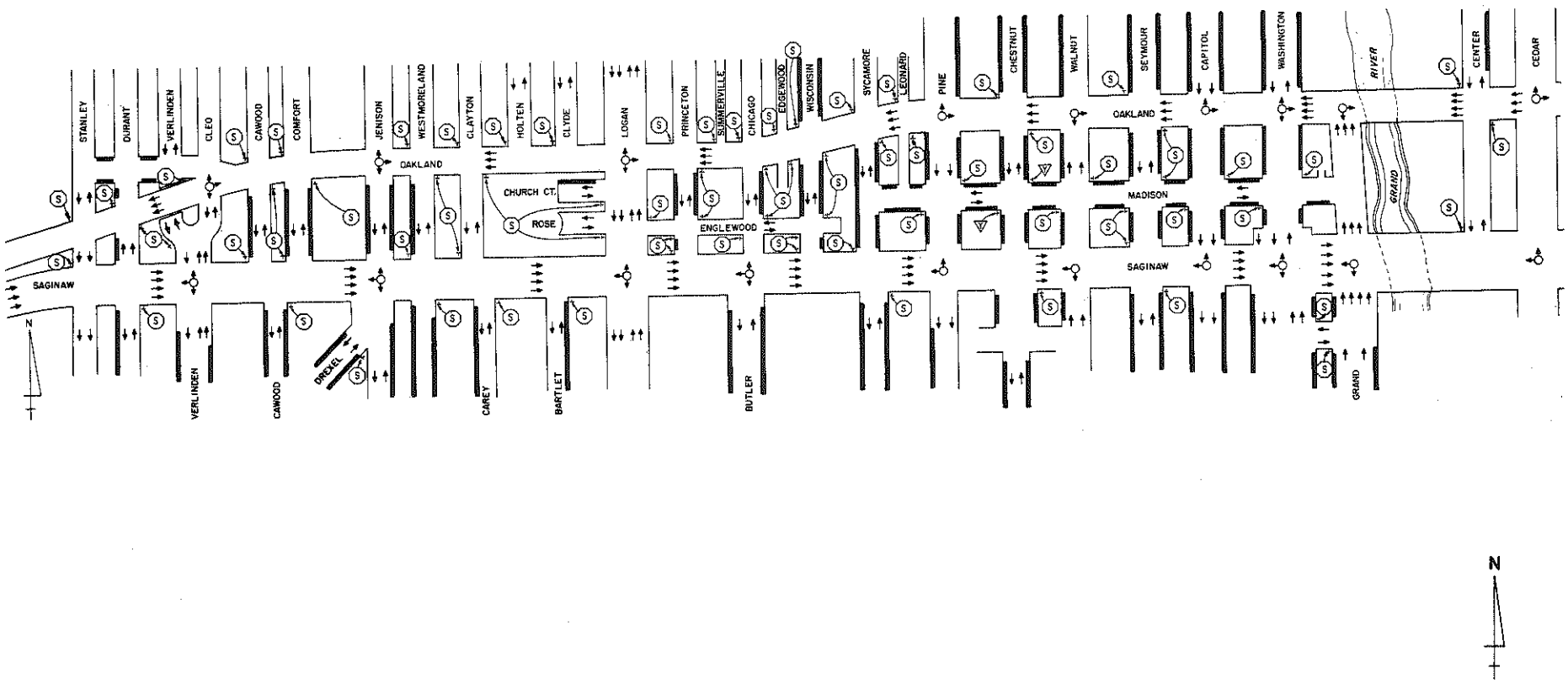


FIGURE 11- CITY OF LANSING: INVENTORY OF STREETS AND TRAFFIC CONTROL
ONE-WAY OPERATION - INITIAL PHASE



LEGEND

- PARKING AT ALL TIMES
- TRAFFIC SIGNAL
- ONE LANE OF TRAFFIC
- (S) STOP SIGN
- YIELD RIGHT OF WAY SIGN

FIGURE 12 – CITY OF LANSING: INVENTORY OF STREETS AND TRAFFIC CONTROL
ONE-WAY OPERATION – FINAL PHASE

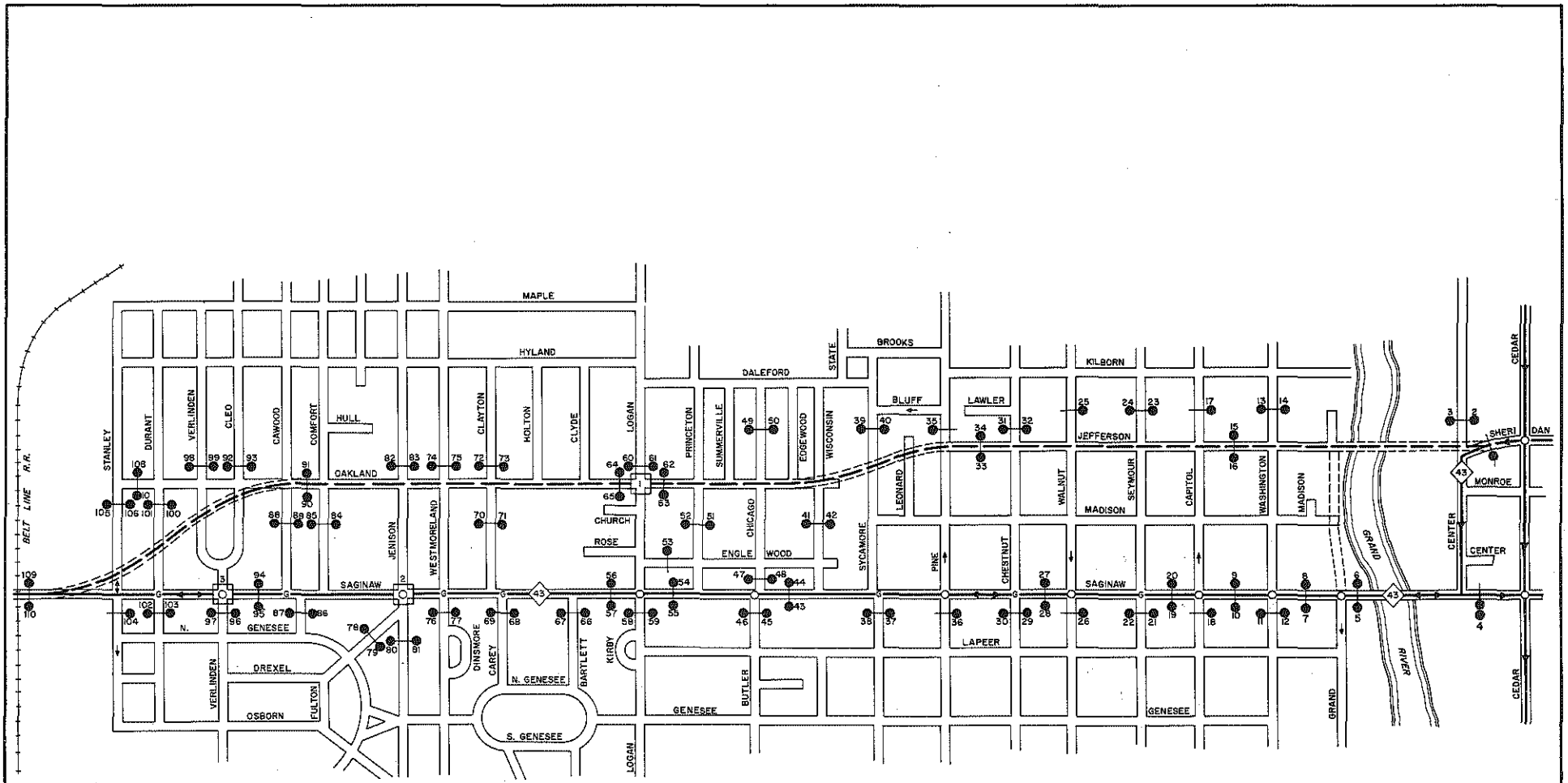


FIGURE 13 – CITY OF LANSING: TRAFFIC & GAP SURVEY STATIONS

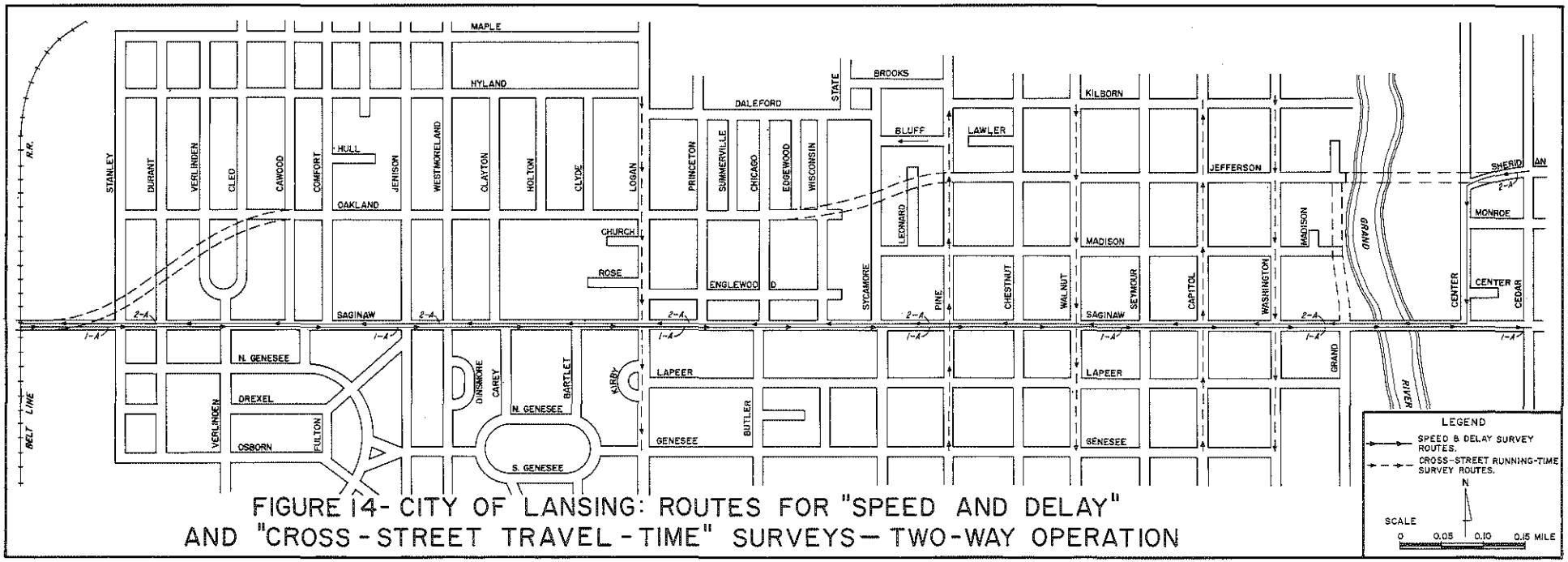


FIGURE 14- CITY OF LANSING: ROUTES FOR "SPEED AND DELAY" AND "CROSS-STREET TRAVEL-TIME" SURVEYS— TWO-WAY OPERATION

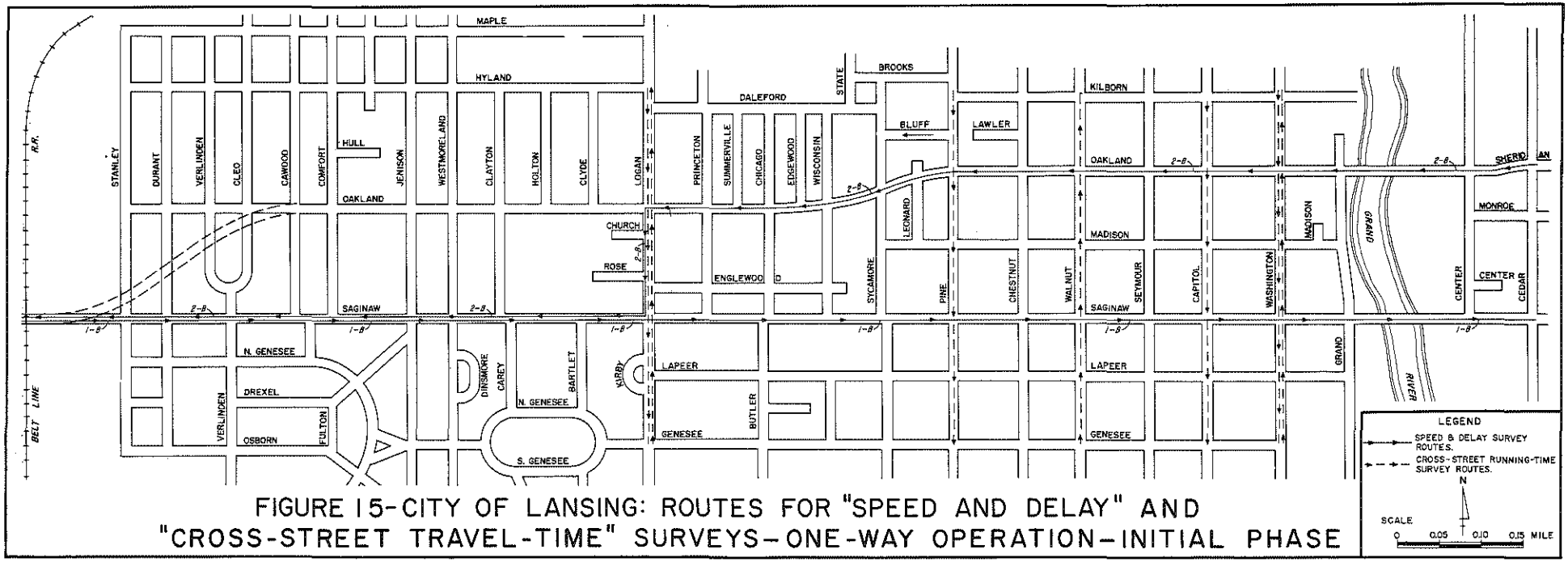
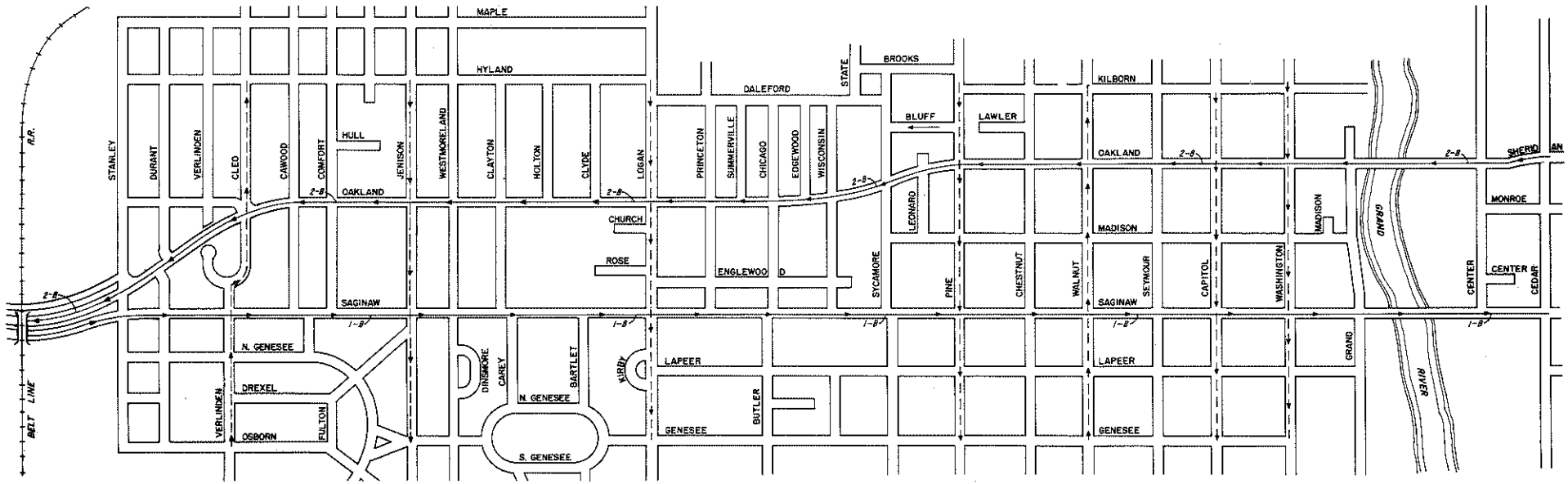


FIGURE 15-CITY OF LANSING: ROUTES FOR "SPEED AND DELAY" AND "CROSS-STREET TRAVEL-TIME" SURVEYS-ONE-WAY OPERATION-INITIAL PHASE



LEGEND

SPEED & DELAY SURVEY ROUTES.

CROSS-STREET TRAVEL TIME SURVEY ROUTES.

N

0 0.05 0.10 0.15 MILE

SCALE

FIGURE 16 - CITY OF LANSING: ROUTES FOR "SPEED AND DELAY" AND "CROSS-STREET TRAVEL TIME" SURVEYS - ONE-WAY OPERATION - FINAL PHASE.

the completion of the east-west freeway through Lansing. Thus, Pine Street and Capitol Avenue became one-way southbound, and Walnut Street and Grand Avenue became one-way northbound.

The Lansing study included an evaluation of the final phase of the one-way operation which went into effect in the fall of 1968. The westbound traffic then continued along reconstructed Oakland Avenue west of Logan Street up to the west city limits. It took several more months, however, until the structure carrying the Belt Line Railroad over the highway was opened to traffic. General cleaning up of the construction area and installing pavement markings were completed on May 13, 1969. Figure 9 shows this final phase of the operation.

Figures 10, 11 and 12 show the laneage, parking and other traffic controls in the area during each of the three phases of the study.

TRAFFIC SURVEYS IN LANSING

Surveys for the sampling of the two-way trunk line operation were taken between July 8 and July 30, 1964. Initial-phase surveys for the one-way operation were taken between June 28 and July 8, 1966; and the final phase surveys were taken between June 30 and August 1, 1969. Figure 13 shows the survey stations. Full descriptions will again be found in Appendix 1.

Traffic gap surveys, similar to those in Kalamazoo, were conducted at the following seven intersections of Saginaw Street: Seymour, Chestnut, Sycamore, Clayton-Carey, Westmoreland, Cawood and Durant.

Six hours of turning-movement counts, similar to those in Kalamazoo, were also recorded at the intersections of Oakland and Logan, Saginaw and Jenison, and Saginaw and Verlinden. Delays caused by traffic waiting to turn left were also recorded.

Speed-and-delay survey runs on the trunk lines, and the cross-street runs for the three phases of the study are shown on Figures 14 through 16.

ACCIDENT DATA FOR LANSING

Accident reports from Lansing City Police, compiled by the City Traffic Engineer, were studies for the three study phases. As in Kalamazoo, each accident study period covered one full year. All streets in the area which might have been affected by the one-way trunk line were examined. A full description of these streets will be found in Appendix 12. The extent of detail required for each accident was the same as in the Kalamazoo study.

PONTIAC STUDY AREA

The Pontiac study area is the corridor along US-10 Business Route northwest of the central business district. During the "before" phase of the study, Oakland Avenue was a two-way state trunk line between its intersection with Cass Avenue – Montcalm Street and Wide Track Drive (Figure 17). During the "after" phase, Cass Avenue, two blocks to the southwest, was developed into a southeastbound one-way state trunk line, and Oakland Avenue became one-way northwestbound. Channelizing islands were constructed at each end of Oakland Avenue to accommodate the transitions to two-way operation.

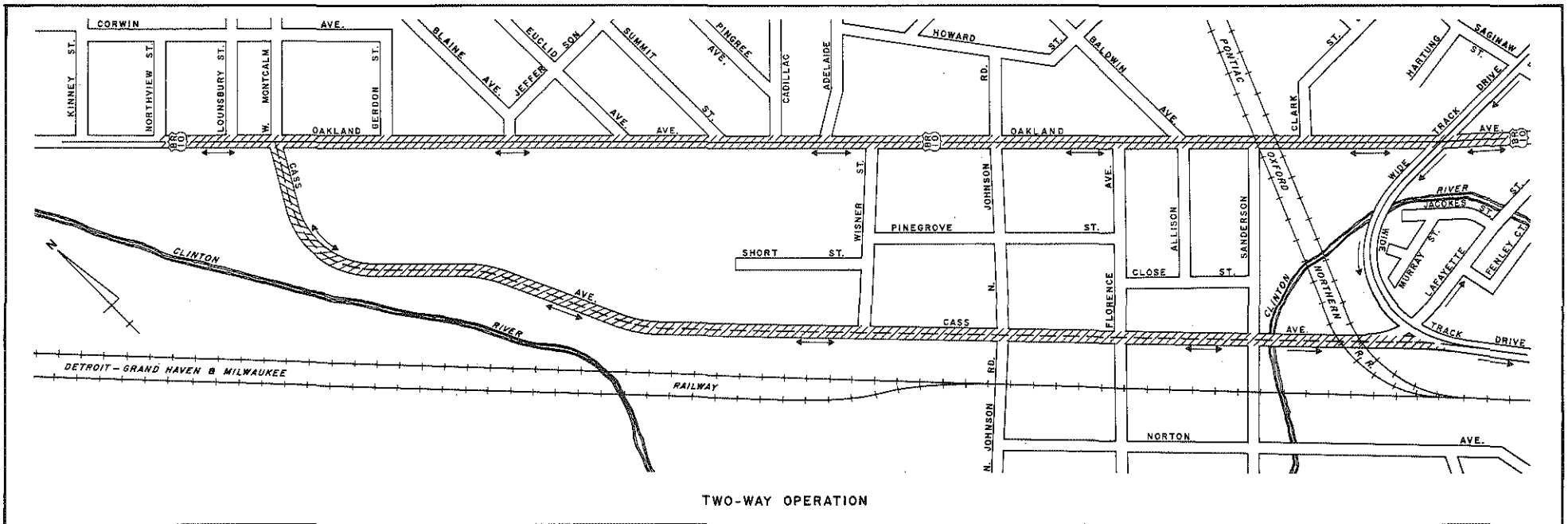
Figure 18 is an inventory map of the study area representing the two phases of the operation. The change to one-way was effected on May 18, 1967. However, interconnection of traffic signals by electrical cables for good progression was delayed until April 5, 1968.

TRAFFIC SURVEYS IN PONTIAC

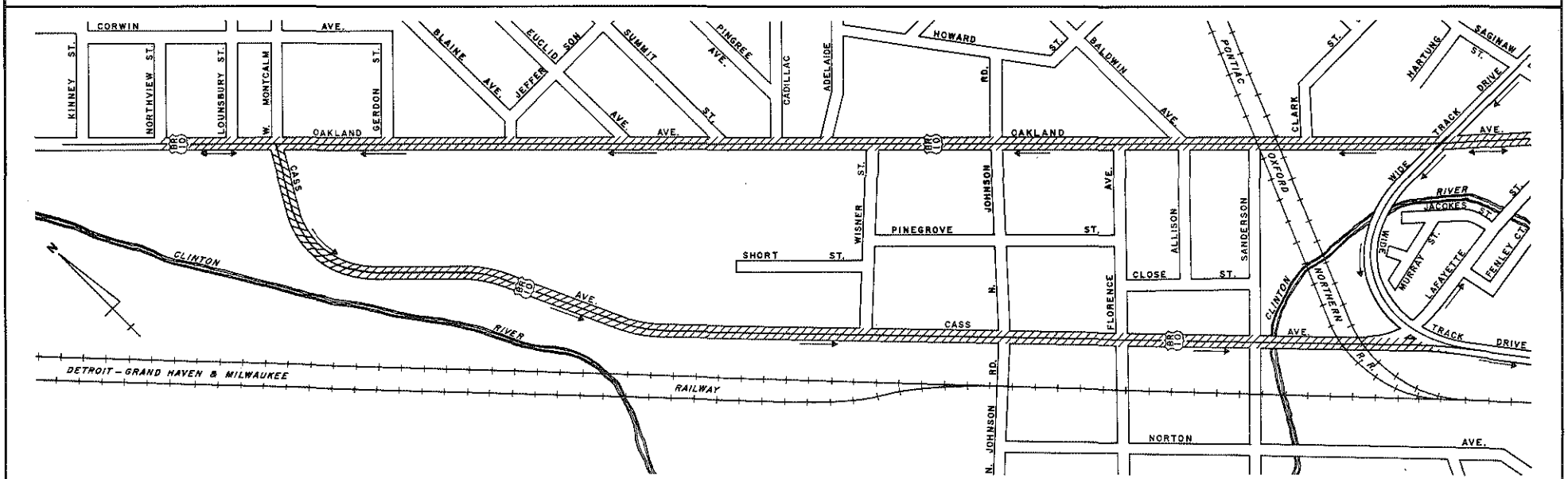
Traffic surveys to represent the conditions under the two-way operation were taken during August of 1964. Figure 19 indicates the locations where volume, turning-movement and gap surveys were taken. Figure 20 shows the speed-and-delay study runs.

Corresponding surveys to reflect the one-way operation were first taken during August of 1967. However, as already mentioned in the preceding section, optimum signal progression proved not to have been attained at that time because the signals were not interconnected. This made it

(Text continued on p. 39)



TWO-WAY OPERATION



ONE-WAY OPERATION

LEGEND

SURVEY ROUTES

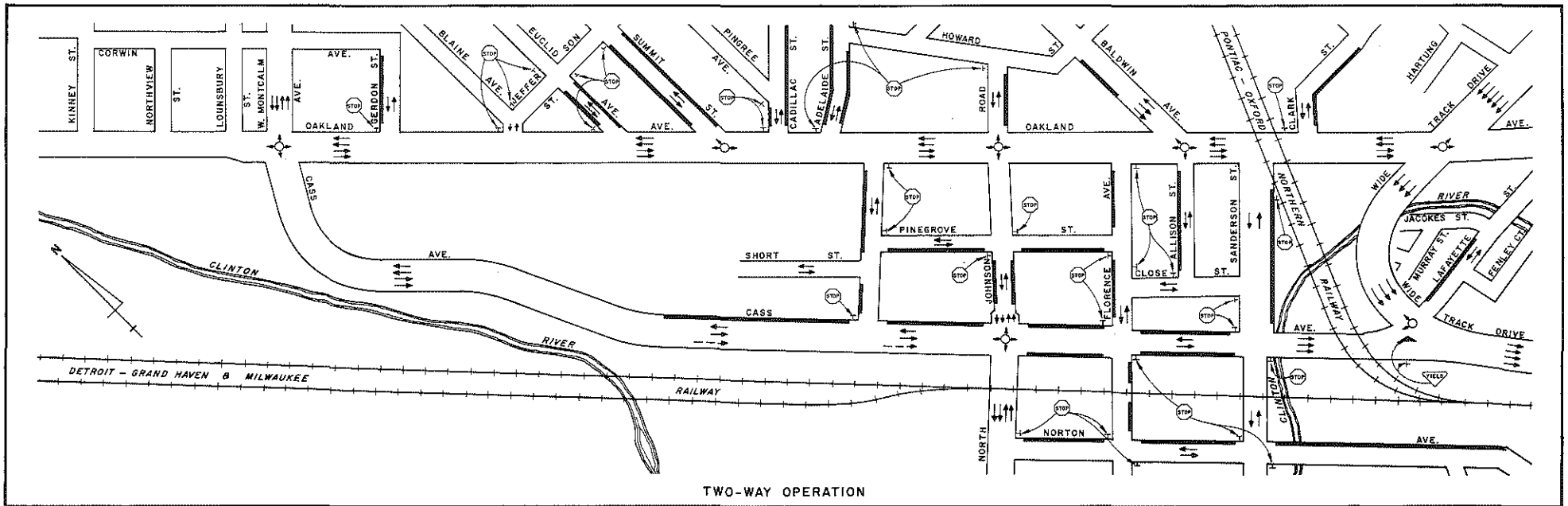
EXISTING TRUNKLINES

EXISTING STREET TO BE MADE TRUNKLINE.

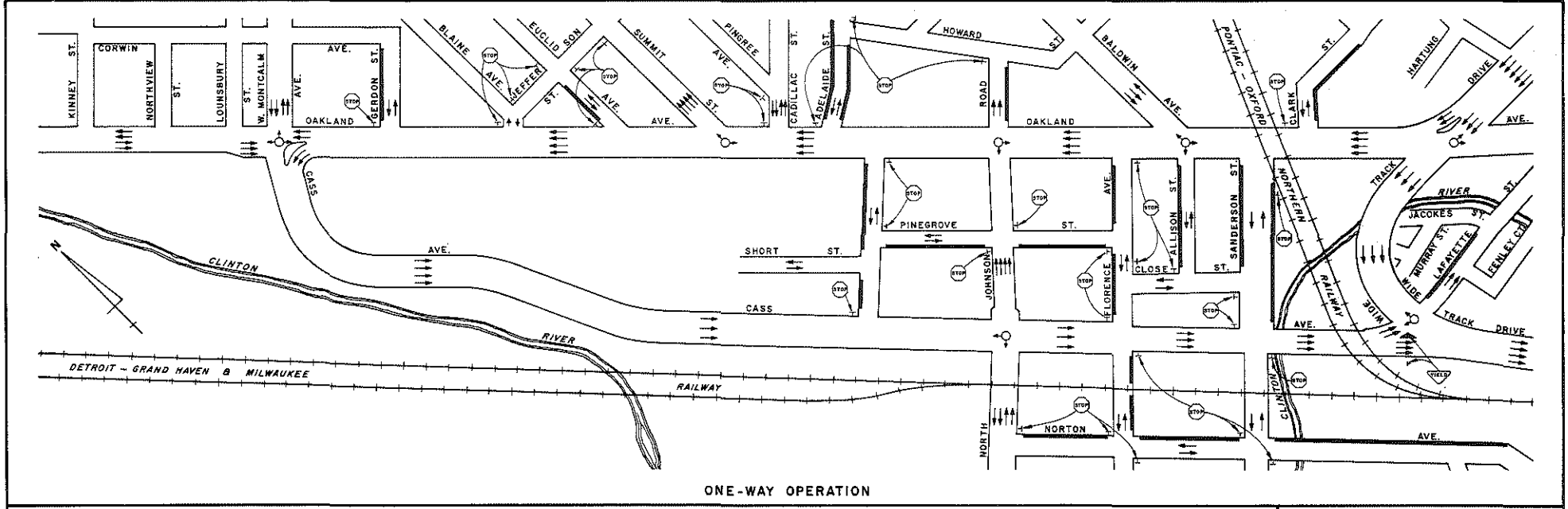
SCALE

0 0.05 0.10 0.15 Miles

FIGURE 17 - CITY OF PONTIAC:
STUDY AREA AND SURVEY ROUTES.



TWO-WAY OPERATION



ONE-WAY OPERATION

FIGURE 18 - CITY OF PONTIAC: INVENTORY OF STREETS AND TRAFFIC CONTROL.

LEGEND

- PARKING AT ALL TIMES.
- NO PARKING TRAFFIC LANE (3-6 P.M.)
- TRAFFIC SIGNAL
- ONE LANE OF TRAFFIC
- STOP SIGN
- YIELD RIGHT OF WAY SIGN

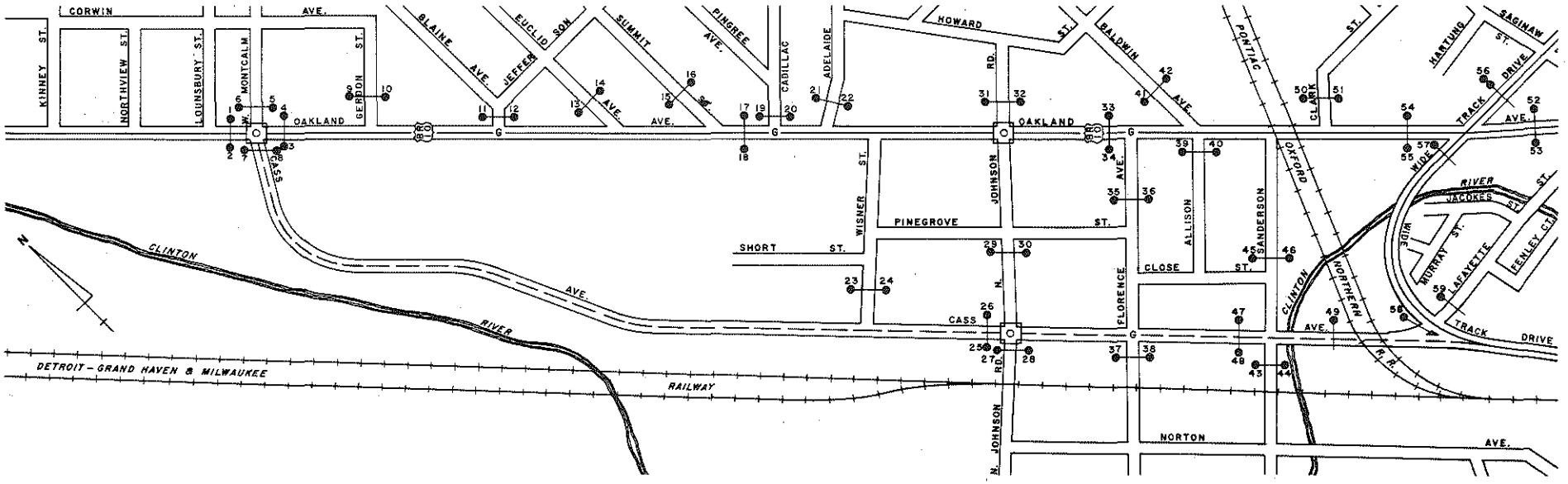
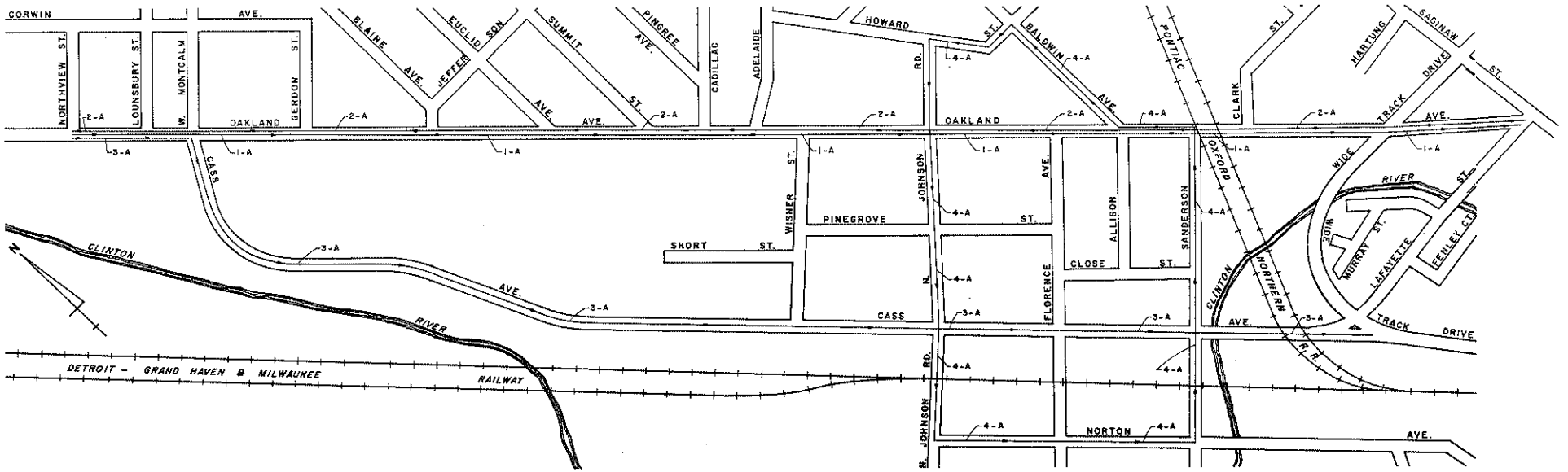


FIGURE 19 - CITY OF PONTIAC:
TRAFFIC AND GAP SURVEY STATIONS

LEGEND
- EXISTING TRUNKLINES
- EXISTING STREETS TO BE MADE TRUNKLINES
- VOLUME COUNTS
- TURNING MOVEMENT COUNTS
- G GAP STUDIES
- TRAFFIC SIGNAL

SCALE
0 0.05 0.10 0.15 Miles

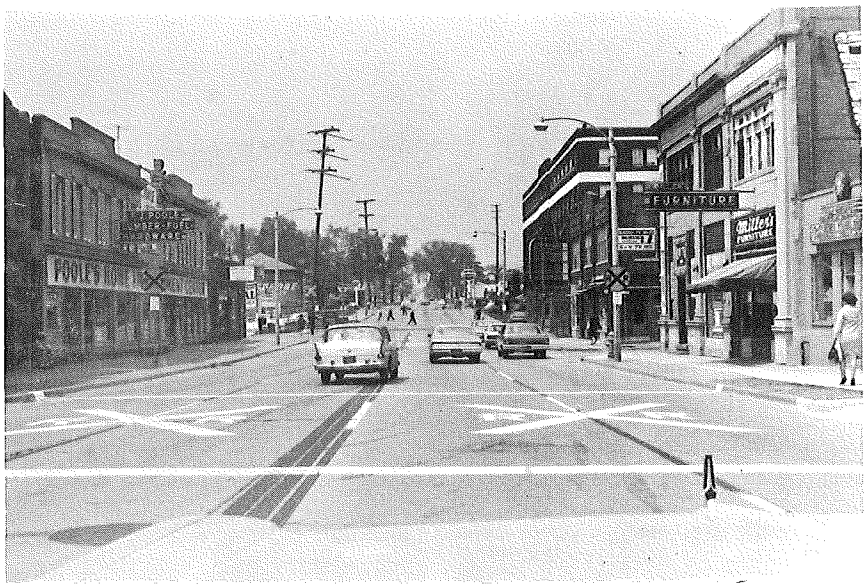


TWO-WAY OPERATION

ONE-WAY OPERATION

FIGURE 20 - CITY OF PONTIAC: ROUTES FOR "SPEED AND DELAY" SURVEYS.

LEGEND
Speed & Delay Survey Routes.
SCALE
0 0.05 0.10 0.15 Miles



PONTIAC: One-way Oakland Avenue northwest of Clark Street

PONTIAC: Oakland Avenue looking northwest from vicinity of Cadillac Street

necessary to repeat the "after" surveys the following year, and they were taken from August 5 to 15, 1968. Survey details are included in Appendix 1.

ACCIDENT DATA FOR PONTIAC

Accident data were recorded from the file of accident reports at the Pontiac Police Department. A list of the streets examined, and the details of the "before" and "after" one-year periods will be found in Appendix 18.

PORT HURON STUDY AREA

The change over to one-way traffic operation in

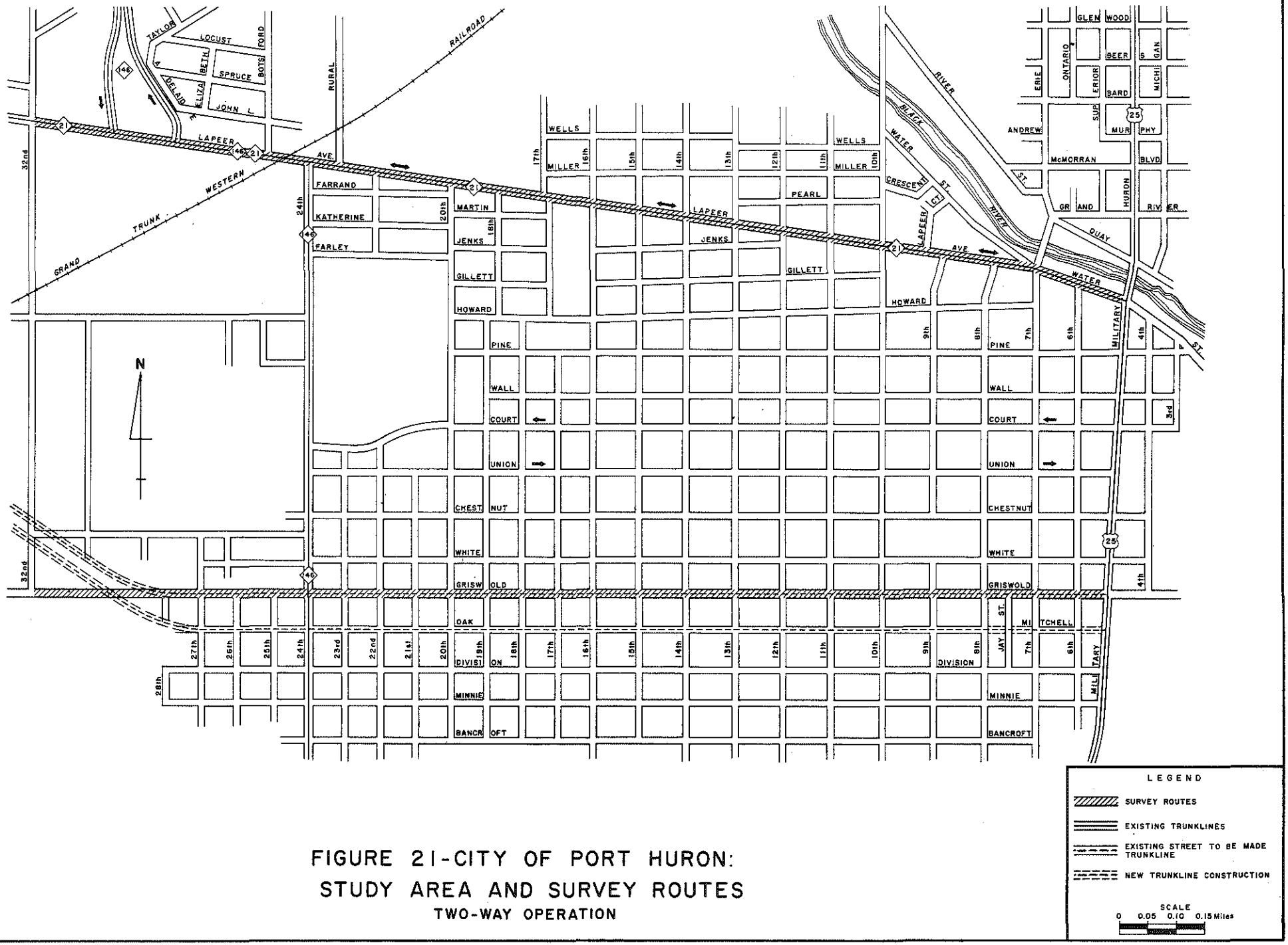
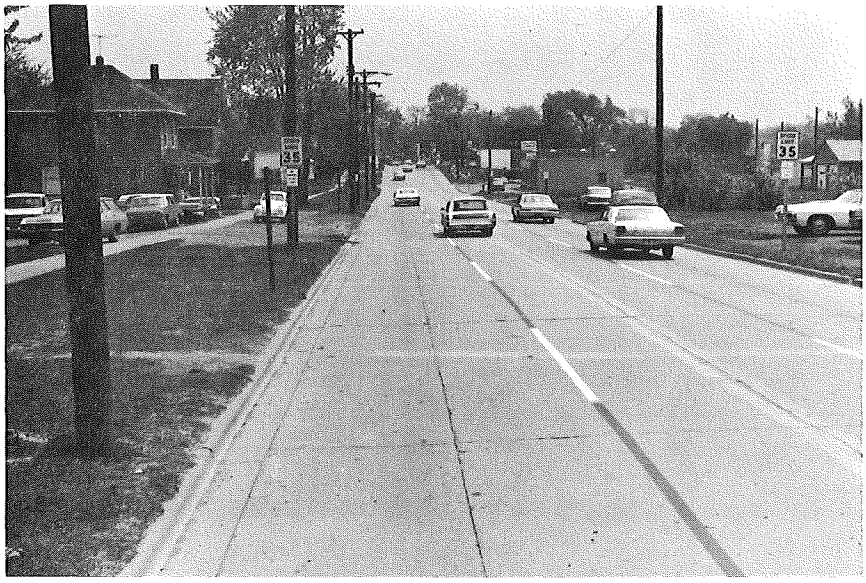


FIGURE 21-CITY OF PORT HURON:
STUDY AREA AND SURVEY ROUTES
TWO-WAY OPERATION

Port Huron was in essence different from the other three cities examined in this study. As already indicated in describing those three study areas, basically the existing state trunk line in each city was converted to one-way operation, and a paralled street, no more than two to three blocks away was used for the trunk line traffic in the opposing direction. In Port Huron the existing state trunk line was turned back to the city, and a new corridor approximately 3/4 mile away was selected for the one-way pair.

Figure 21 shows the layout of the state trunk lines and the city streets during two-way operation. Michigan Route 21 followed Lapeer and Water Streets. Port Huron's central business

PONTIAC: Four-lane section of one-way Cass Avenue looking southeast



PONTIAC: Three-lane section of one-way Cass Avenue looking southeast

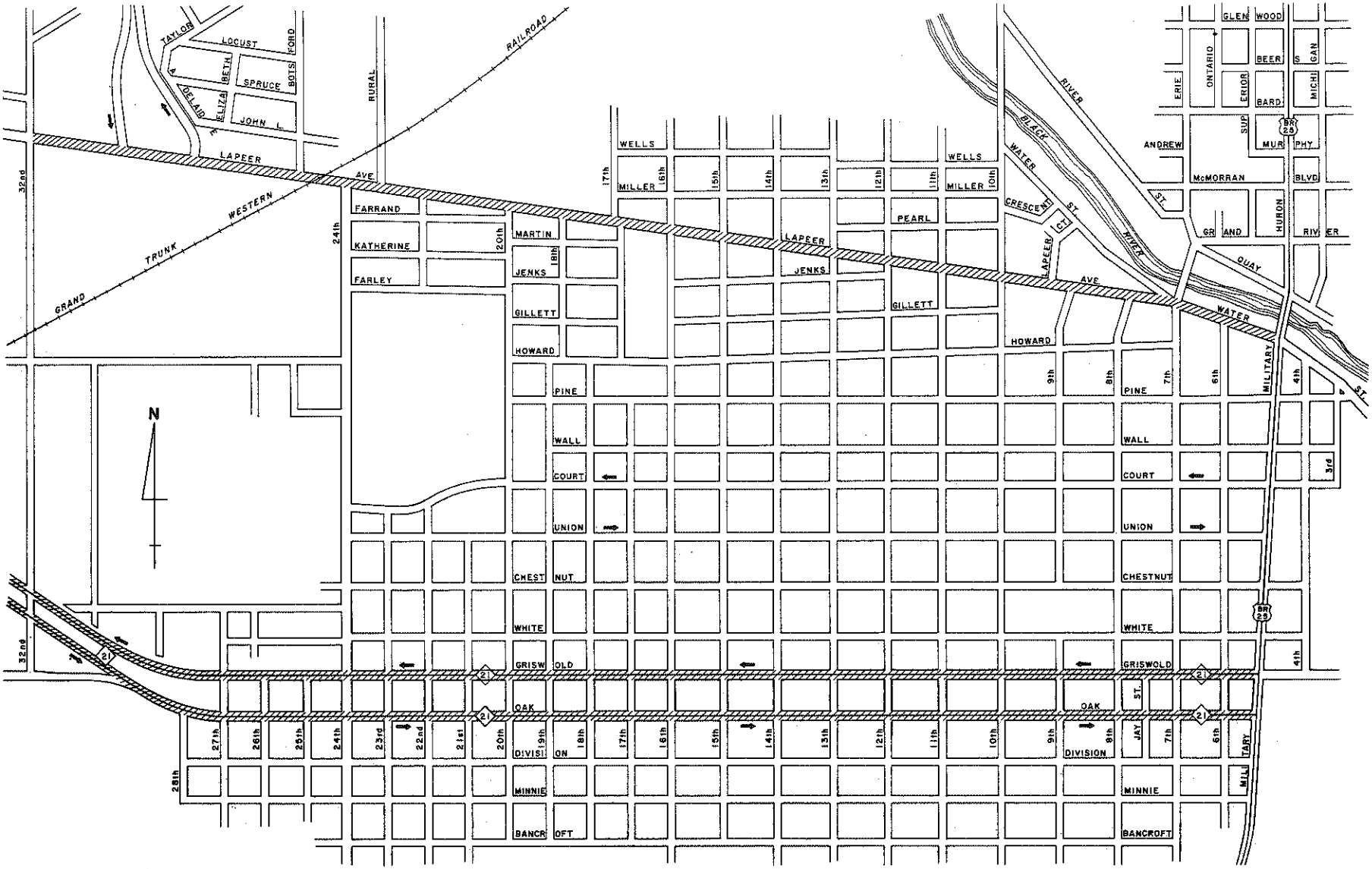
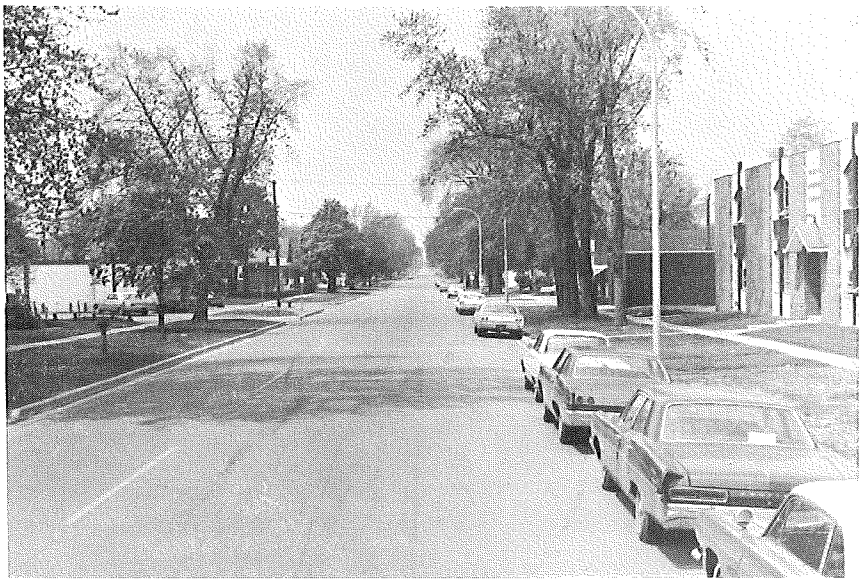
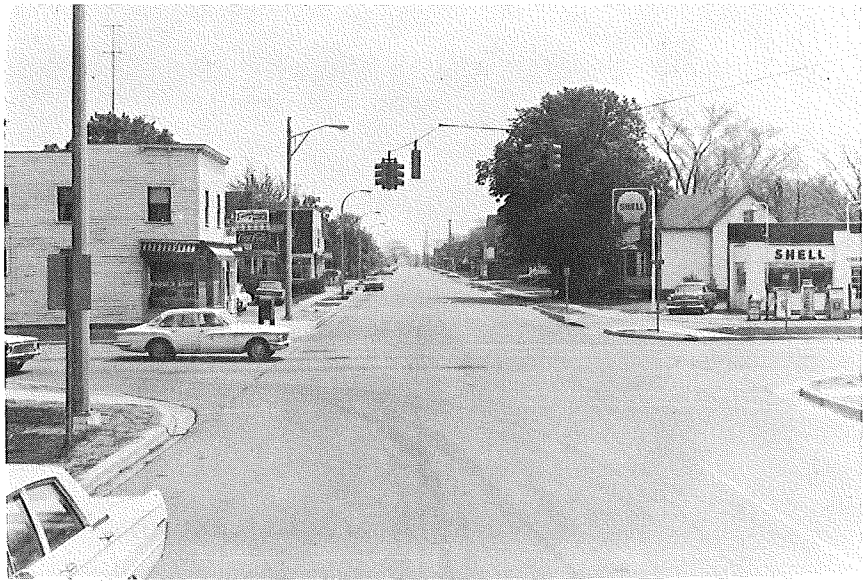


FIGURE 22-CITY OF PORT HURON:
STUDY AREA AND SURVEY ROUTES
ONE-WAY OPERATION

district starts near the east end of this route and extends to the north. Most of Lapeer Street is in a residential area, with industrial zones near the west city limits. The new trunk line corridor is the Griswold-Oak pair to the south, Griswold Street running westbound, and Oak Street eastbound (Figure 22). The area is mainly residential. These two streets, especially Oak Street, were widened and reconstructed to serve the state trunk line traffic. Mitchell Street to the east was also rebuilt and connected to Oak. The new one-way pair transitioned to the new limited access highway near the west city limits which joins with the existing two-lane section of M-21 to the northwest, leading to Imlay City.



PORT HURON: One-way Griswold Street west of 10th Street



PORT HURON: One-way Griswold Street looking east at the 10th Street intersection

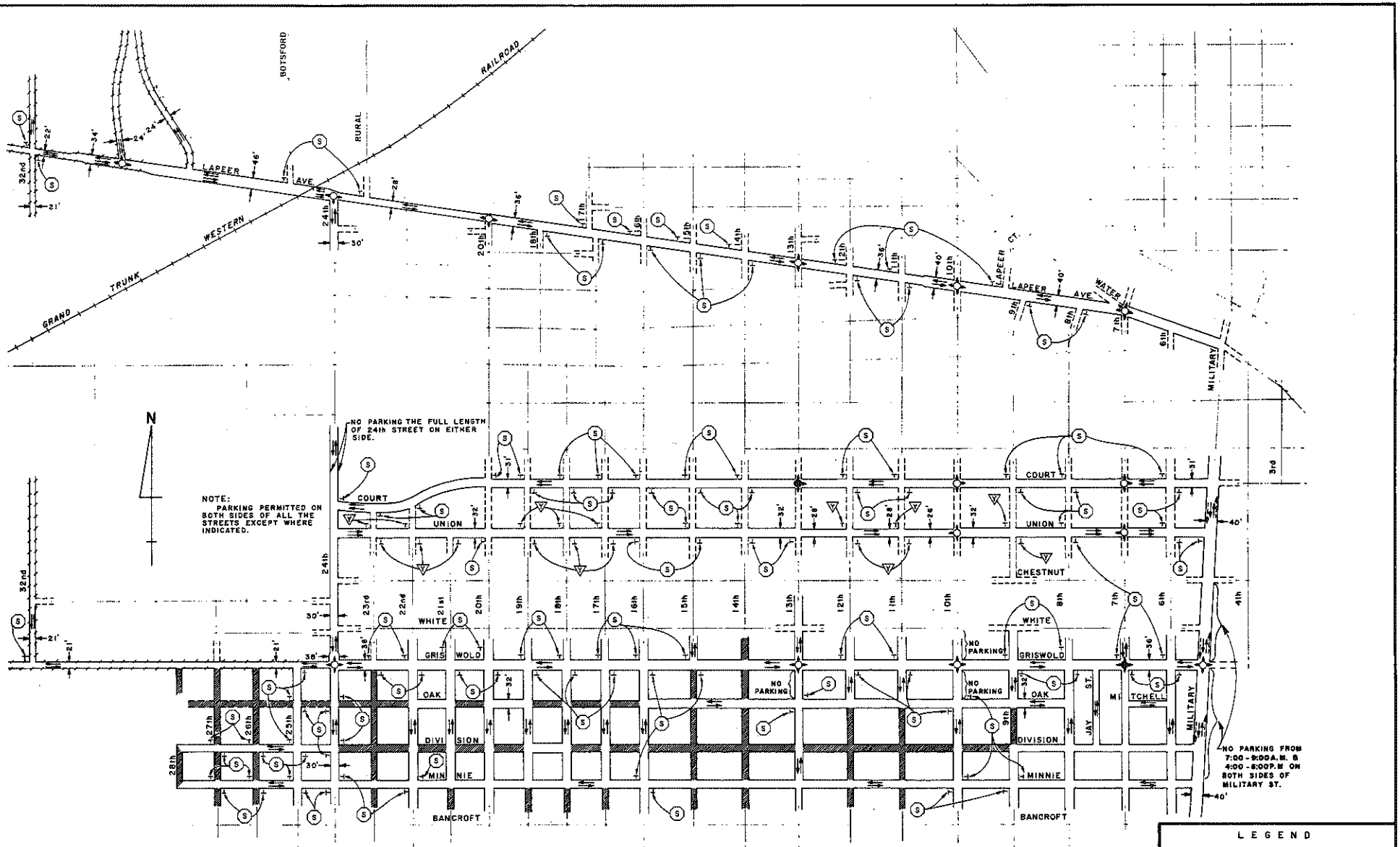


FIGURE 23-CITY OF PORT HURON: INVENTORY OF STREETS AND TRAFFIC CONTROL

TWO-WAY OPERATION

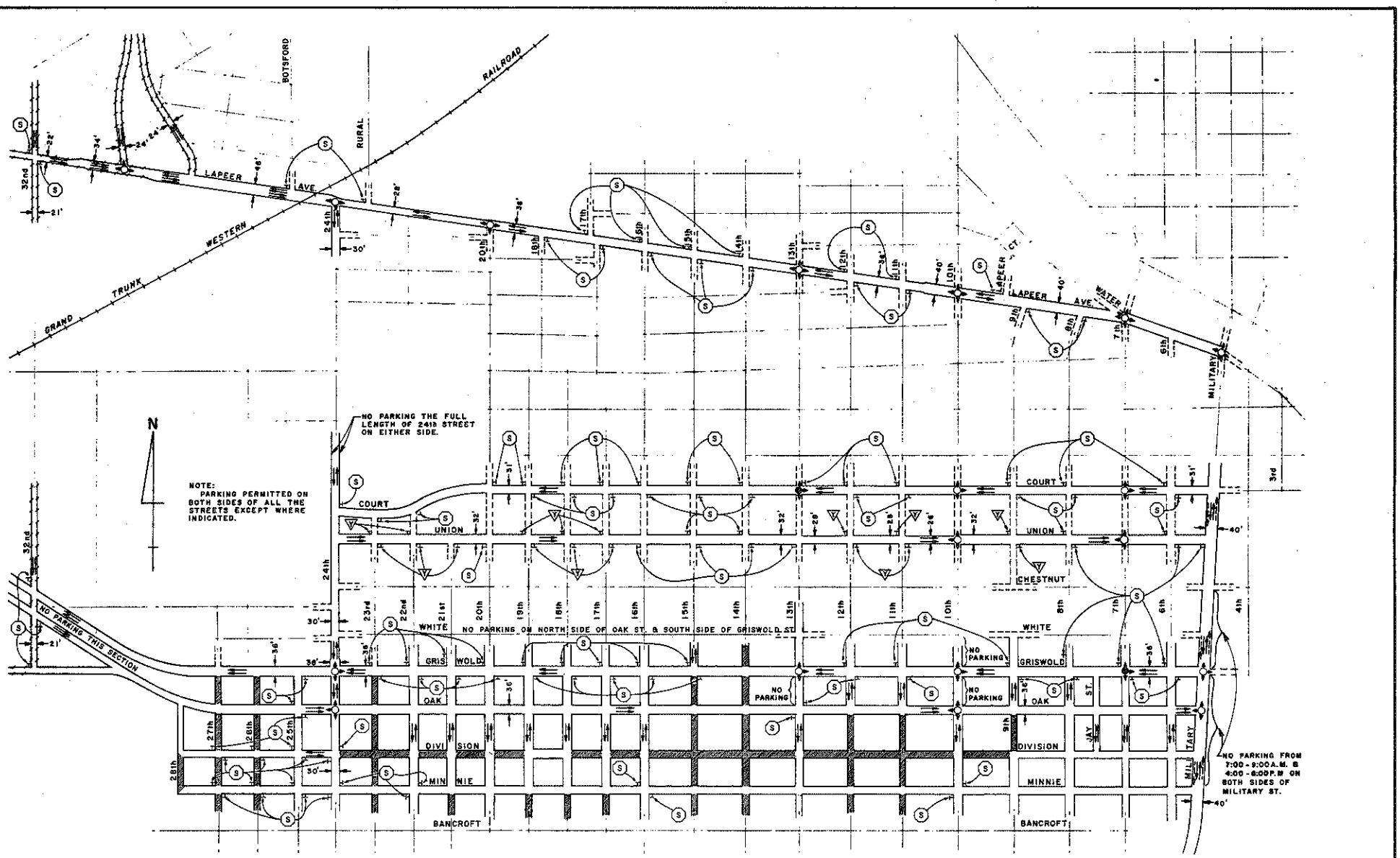


FIGURE 24-CITY OF PORT HURON: INVENTORY OF STREETS AND TRAFFIC CONTROL

ONE-WAY OPERATION

Figures 23 and 24 show the street and traffic control inventory in the study area during the two-way and the one-way phases of the project, respectively. The Union and Court Streets corridor is also included here because this was an earlier established one-way pair in this city, and was used as a control in the study.

The Griswold-Oak pair was opened to traffic as a state trunk line on October 19, 1966.

TRAFFIC SURVEYS IN PORT HURON

Surveys were taken from August 31 to September 11, 1964 for the before phase, and from September

(Text continued on p. 50)

PORT HURON; One-way Oak Street at the 24th Street intersection

PORT HURON: One-way Oak Street looking east at the 16th Street intersection

FIGURE 25-CITY OF PORT HURON:
TRAFFIC AND GAP SURVEY STATIONS

LEGEND
STATE TRUNKLINE
VOLUME COUNT
TURNING MOVEMENT COUNT
G GAP STUDIES
SCALE
0 0.05 0.10 0.15 Miles

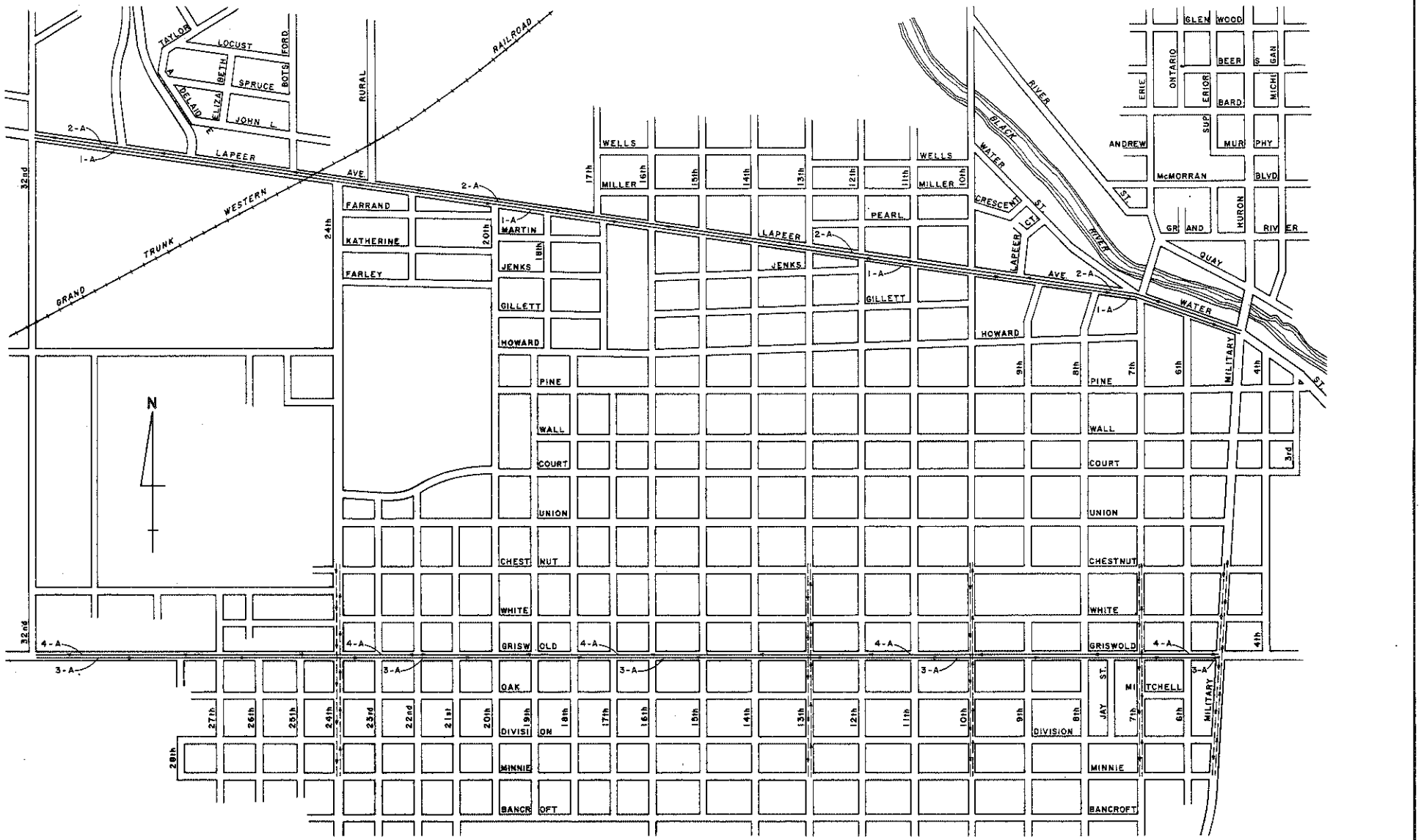


FIGURE 26-CITY OF PORT HURON: ROUTES FOR
"SPEED AND DELAY" AND "CROSS-STREET TRAVEL TIME" SURVEYS
TWO-WAY OPERATION

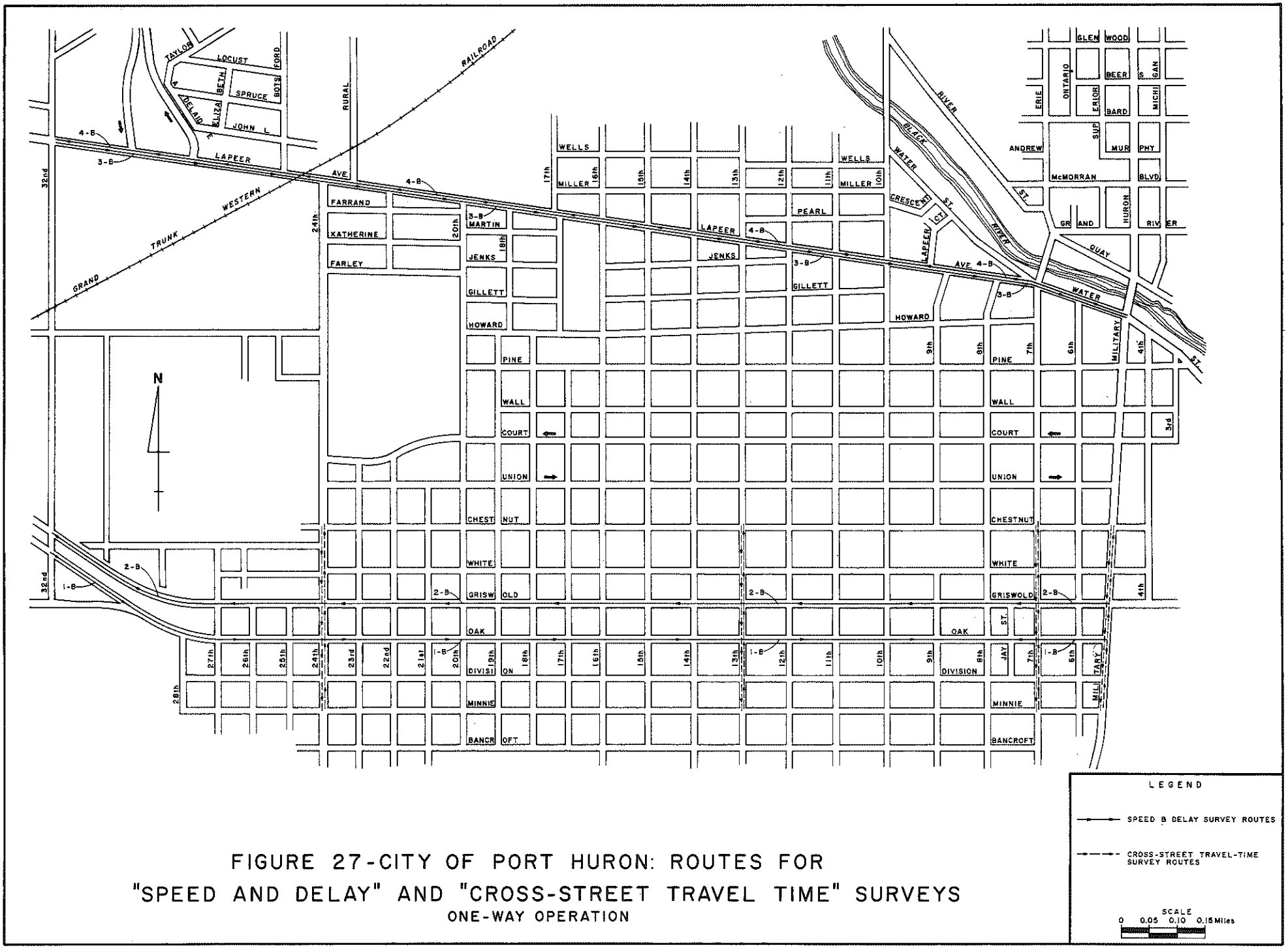


FIGURE 27-CITY OF PORT HURON: ROUTES FOR "SPEED AND DELAY" AND "CROSS-STREET TRAVEL TIME" SURVEYS
ONE-WAY OPERATION

11 to 21, 1967 for the after phase. Volume, turning-movement and gap survey stations are shown on Figure 25, and speed-and-delay and cross-street travel-time survey routes are shown on Figures 26 and 27. Survey details are included in Appendix 1.

ACCIDENT DATA FOR PORT HURON

Accidents along three main corridors were studied on a before-and-after basis. These are the Lapeer-Water Street corridor, the Union-Court one-way pair corridor, and the Griswold-Oak pair corridor. Accidents on the cross-streets intersecting the first and third of these corridors were also studied for one block north and south from these intersections. Accidents on the cross-streets intersecting Union and Court Streets were not examined except for the immediate intersection approaches. A full list of the streets for the accident study is given in Appendix 21.

The one-year "before" period in the Port Huron study was terminated 21 months before opening to traffic of the new one-way pair, because of construction activities affecting traffic operation. Thus, although the opening date was October 19, 1966, the accident study period was taken from January 19, 1964 through January 18, 1965. The "after" period started, as in the other cities, three months after the new system was opened to traffic.

ANALYSIS OF RESULTS

This study was designed to evaluate the operational changes in the traffic of an urban area which is directly affected by the change from two-way to one-way state trunk lines in that immediate area. The changes in the traffic characteristics of the state trunk lines themselves and of the adjacent cross-streets have been examined. The trunk lines have been studied in greater detail.

The quality of a traffic service in general can be measured by the parameters of time, convenience, safety, distance and cost (2). The present study mainly deals with the first three. No data have been compiled to include a study of trip distances as affected by the one-way system, such as origin-destination surveys, driver interviews or questionnaires. An indirect exploration was, however, made to examine whether or not any excessive travel was taking place within the confined areas which are being studied. No cost information is included in this study.

In an over-all evaluation of a street system such as the ones examined in this project, the results are bound to reflect the effects of a whole set of conditions and circumstances in addition to the uni- or bi-directional character of the trunk line traffic. Optimum adjustment of the traffic signals and other traffic control measures, temporal changes in the intensity of land use and in the age and social-group brackets of drivers using the facilities are but a few of these conditions. This should be kept in mind in reviewing the results of the study.

SPEED AND DELAY STUDY RESULTS

The results of speed and delay studies in Kalamazoo are presented in Table 1. This table lists, on the left, six different traffic survey routes used during two-way operation along the then current state trunk lines and the proposed additions that would form the new east-west one-way pair. The middle portion of the table lists the travel routes that were followed during the one-way operation which most nearly correspond to the earlier routes. Differences in the results obtained between the "before" and the "after" routes are shown at the right. Statistical significance of the changes in over-all speed and number of stops was examined as explained in in Appendix 27, and indicated in Table 1.

Averages of several runs (described in Appendix 1) for each peak traffic period are given in Table 1. The first four columns after the route descriptions, in both the two-way and one-way sections, are self explanatory. "Average Travel Time" is the average, for each peak period, of the total time spent between the beginning and end of the trip. "Average Over-all Speed" is the average of the over-all speeds of the several trips, which are calculated by dividing trip length by travel time. "Average Number of Stops" is the average of the number of stops for each trip. "Average Delay" is the average, for the several trips, of the total delay or stopped time divided by the trip length. "% Delay Time" is calculated by dividing average stopped time by average travel time.

In calculating average results, those survey trips which were delayed at railroad crossings because of the presence of trains were discarded because these trips would unjustly distort the before-and-after comparisons.

No corresponding "after" route is given in Table 1 for Route 1-A since it was no longer possible to repeat that trip eastbound on Kalamazoo Avenue during the one-way operation. The alternate route for the same origin and destination is Route 3-A which is compared with Route 3-B of the one-way operation (Figures 6 and 7).

Route 2-A was a westbound trip mostly on Kalazoo Avenue which was not a state trunk line during the two-way operation. During one-way operation this route (Route 2-B) became westbound M-43. In spite of heavier traffic volumes in the "after" period, it will be noticed that a gain of 8.9 miles per hour in average over-all speed was attained during morning peak traffic. 6.0 and 2.2 miles per hour were gained for the noon and afternoon peaks, respectively. Better signal progression was possible during one-way

TABLE 1

CITY OF KALAMAZOO

SPEED AND DELAY COMPARISONS

DURING TWO-WAY OPERATION										DURING ONE-WAY OPERATION										CHANGE IN:				
Route	Direction	Length (miles)	Date (1964)	Period	Average Travel Time	Average Over-All Speed(m.p.h.)	Average Number of Stops	Average Delay (sec./mi.)	% Delay Time	Route	Direction	Length (miles)	Date (1966)	Period	Average Travel Time	Average Over-All Speed(m.p.h.)	Average Number of Stops	Average Delay (sec./mi.)	% Delay Time	Average Travel Time	Average Over-All Speed(m.p.h.)	Average Number of Stops	Average Delay (sec./mi.)	% Delay Time
1-A																								
From Thompson St. to Harrison St. Via Main-Douglas-Kalamazoo-Michigan Sts.	EB	1.6	10/27-29	Morn.	4'47"	20.2	4.0	26	15															
" "	"	"	"	Noon	4'40"	20.7	4.0	25	14															
" "	"	"	"	Aft.	5'37"	17.4	5.4	39	18															
2-A										2-B														
From Harrison St. to Thompson St. Via Michigan-Kalamazoo-Douglas-Main Sts.	WB	1.6	10/27-29	Morn.	4'43"	20.6	2.7	27	16	From Harrison St. to Thompson St. Via Michigan-Kalamazoo-Douglas-Main Sts.	WB	1.6	5/4-6	Morn	3'16"	29.5	0.3	3	3	-1'27"	+8.9 (S)	-2.4 (S)	-24	-13
" "	"	"	"	Noon	4'46"	20.2	2.9	28	16	" "	"	"	5/3-5	Noon	3'40"	26.2	1.0	11	8	-1'06"	+6.0 (S)	-1.9 (S)	-17	-8
" "	"	"	"	Aft.	5'07"	19.1	2.9	34	18	" "	"	"	5/3-4	Aft.	4'38"	21.3	2.0	28	17	-0'29"	+2.2	-0.9	-6	-1
3-A										3-B														
From Thompson St. to Harrison St. Via Main-Michigan Sts.	EB	1.4	10/27,28	Morn.	4'17"	19.7	2.0	29	16	From Thompson St. to Harrison St. Via Main-Michigan Sts.	EB	1.4	5/4-6	Morn.	3'48"	22.4	1.6	23	14	-0'29"	+2.7	-0.4	-6	-2
" "	"	"	"	Noon	4'32"	18.7	3.0	36	18	" "	"	"	5/3-5	Noon	4'04"	20.8	1.6	25	14	-0'28"	+2.1	-1.4 (S)	-11	-4
" "	"	"	"	Aft.	5'09"	16.6	3.8	45	20	" "	"	"	5/3-4	Aft.	4'11"	20.4	1.8	30	17	-0'58"	+3.8 (S)	-2.0 (S)	-15	-3
4-A										2-B														
From Harrison St. to Thompson St. Via Michigan-Main Sts.	WB	1.4	10/27,28	Morn.	4'28"	18.9	4.0	28	15	From Harrison St. to Thompson St. Via Michigan-Kalamazoo-Douglas-Main Sts.	WB	1.6	5/4-6	Morn.	3'16"	29.5	0.3	3	3	-1'12"	+10.6 (S)	-3.7 (S)	-25	-12
" "	"	"	"	Noon	4'51"	17.4	4.0	34	16	" "	"	"	5/3-5	Noon	3'40"	26.2	1.0	11	8	-1'11"	+8.8 (S)	-3.0 (S)	-23	-8
" "	"	"	"	Aft.	5'49"	14.7	5.7	70	28	" "	"	"	5/3-4	Aft.	4'38"	21.3	2.0	28	17	-1'11"	+6.6 (S)	-3.7 (S)	-42	-11
5-A										5-B														
From Lovell St. to Harrison St. Via Michigan St.	EB	1.3	10/29	Morn.	3'58"	19.8	1.5	15	8	From Lovell St. to Harrison St. Via Michigan St.	EB	1.3	5/4-6	Morn.	3'03"	25.7	0.3	4	3	-0'55"	+5.9 (S)	-1.2 (S)	-11	-5
" "	"	"	"	Noon	3'40"	21.4	1.7	20	12	" "	"	"	5/3-5	Noon	3'40"	21.4	0.8	16	10	0	0	-0.9	-4	-2
" "	"	"	"	Aft.	4'32"	17.5	2.3	38	18	" "	"	"	5/3-4	Aft.	3'39"	21.5	1.2	20	12	-0'55"	+4.0 (S)	-1.1	-18	-6
6-A										7-B														
From Harrison St. to Lovell St. Via Michigan St.	WB	1.3	10/29	Morn	5'19"	14.7	5.7	71	29	From Harrison St. to Lovell St. Via Kalamazoo-New Rd.(Michikal)	WB	1.3	5/4-6	Morn	3'21"	23.5	0.7	11	7	-1'58"	+8.8 (S)	-5.0 (S)	-60	-22
" "	"	"	"	Noon	5'31"	14.2	6.3	73	29	" "	"	"	5/3-5	Noon	3'27"	22.8	1.0	17	11	-2'04"	+8.6 (S)	-5.3 (S)	-56	-18
" "	"	"	"	Aft.	5'15"	14.9	5.7	56	23	" "	"	"	5/3-4	Aft.	3'37"	21.9	1.4	22	13	-1'38"	+7.0 (S)	-4.3 (S)	-34	-10

(S) - The change is statistically significant.

operation, resulting in fewer stops which dropped from an average of 2.7 for morning peak trips to 0.3. Reductions in number of stops during noon and afternoon peaks were also experienced as will be seen in Table 1. Average delay per mile dropped from 27 seconds to 3 seconds, from 28 to 11, and from 34 to 28 for the morning, noon and afternoon peaks, respectively. Percent delay time dropped from 16 to 3, from 16 to 8, and from 18 to 17 for the various peaks.

In examining the amounts of over-all speed gains realized by the one-way operation, it should be remembered that there is a deliberate limit to travel speed through the business district, and in fact, this is an inherent function of the signal progression system.

Route 3-A was the eastbound route for M-43, and remained the same except that it became one-way (Route 3-B). In this eastbound trip, the greater gains in the speeds and in the delay reductions were experienced in the afternoon peak period where the over-all speed went up from 16.6 miles per hour to 20.4, number of stops dropped from 3.8 to 1.8, average delay from 45 seconds per mile to 30, and percent delay time from 20 to 17. The figures for the other peak periods can be seen in the table.

Route 4-A, westbound via Michigan Avenue, was the route followed by M-43 during two-way operation. In Table 1 this is compared with Route 2-B which is now westbound M-43. As it will be seen in the comparison columns, up to 10.6 miles per hour of over-all speed gain is accomplished. Even though Route 2-B was 0.2 mile longer than Route 4-A, average travel times decreased by more than one minute.

Routes 5-A and 5-B, for eastbound I-94 BL, are identical trips via Michigan Avenue except that the later is one-way for most of its length. Fifty-five seconds have been gained in both the morning and afternoon peak trips, and the over-all speed during the morning peak has improved by 5.9 miles per hour.

Route 6-A was the old westbound route for I-94 BL via Michigan Avenue. The new westbound I-94 BL follows Kalamazoo Avenue to its intersection with the newly built Michikal Street, then follows Michikal and Michigan southwestbound. Both routes are equal in length, but about two minutes of travel time are gained in the morning and noon trips, and almost as much in the afternoon trips. The gain in speed varies from 7.0 to 8.8 miles per hour.

Total travel time and its inverse measure of over-all speed serve to indicate the economy in time. Number of stops is important both for economy of vehicle operation and driver convenience and safety. Also, it is known that the automobile engine of today is inefficient in stop-and-go driving, and contributes more to air pollution. A smooth traffic flow is, therefore, very necessary where traffic is heavy. Another important consideration is traffic noise, which is also greatly reduced when traffic flow is uninterrupted. Amount of delay or actual stopped time has a psychological effect on drivers, and remaining stopped while on a trip is suspected to be more disturbing to a driver than moving slowly. The last three columns for trip evaluation in Table 1 are therefore highly significant in quantifying the level of traffic service. One-way trunk line operation in Kalamazoo has resulted in the elimination of up to five stops during peak periods on some of the study routes, and in a reduction in delays (stopped time) of up to one minute per mile of travel. During two-way operation, the ratio of stopped time to travel time (% delay time) during peak traffic was found to be as high as 29 percent, whereas during one-way operation the highest ratio was found to be 17 percent even though travel time itself was also shorter.

Table 2 contains the results of the speed-and-delay surveys in Lansing. The upper portion represents the conditions during the two-way operation and during the initial phase of the one-way operation when Saginaw Street west of Logan Street was still operating two-way. Route 1-A was eastbound M-43 along Saginaw Street during the two-way operation. Route 1-B was the same trip after Saginaw became one-way east of Logan, but included the section of Saginaw Street west of Logan which was still a two-way trunk line. A gain in travel time of about 30 seconds has been attained on this trip. Optimum speeds of travel have been reached as indicated by average over-all speeds of up to 30 miles per hour, which is

TABLE 2

CITY OF LANSING

SPEED AND DELAY COMPARISONS

DURING TWO-WAY OPERATION										
Route	Direction	Length (miles)	Date (1964)	Period	Average Travel Time	Average Over-All Speed(m.p.h.)	Average Number of Stops	Average Delay (sec./mi.)	% Delay Time
1-A									
From Beltline RR to Cedar St. Via Saginaw St.	EB	1.9	7/14-16	Morn.	4'27"	26.0	1.9	15	10
" "	"	"	"	Noon	4'33"	25.2	2.3	18	12
" "	"	"	"	Aft.	5'00"	23.2	3.4	22	14
2-A									
From Cedar St. to Beltline RR Via Sheridan-Center-Saginaw Sts.	WB	2.1	7/14-16	Morn.	4'48"	26.3	1.8	10	7
" "	"	"	"	Noon	4'53"	25.9	1.8	9	6
" "	"	"	"	Aft.	5'07"	25.0	2.0	12	8

DURING ONE-WAY OPERATION - INITIAL PHASE									
Route	Direction	Length (miles)	Date (1966)	Period	Average Travel Time	Average Over-All Speed(m.p.h.)	Average Number of Stops	Average Delay (sec./mi.)	% Delay Time
1-B									
From Beltline RR to Cedar St. Via Saginaw St.	EB	1.9	6/29-30, 7/1	Morn.	3'53"	30.0	1.0	9	8
" "	"	"	"	Noon	4'03"	28.3	1.3	12	9
" "	"	"	6/28	Aft.	4'36"	25.4	2.0	17	12
2-B									
From Cedar St. to Beltline RR Via Oakland-Logan-Saginaw Sts.	WB	2.1	6/29-30, 7/1	Morn.	4'29"	28.4	1.1	8	6
" "	"	"	"	Noon	4'06"	30.7	0.2	1	0
" "	"	"	6/29-30	Aft.	4'47"	26.0	1.5	11	8

CHANGE IN:				
Average Travel Time	Average Over-All Speed(m.p.h.)	Average Number of Stops	Average Delay (sec./mi.)	% Delay Time
-34"	(S) +4.0	(S) -0.9	-6	-2
-30"	(S) +3.1	-1.0	-6	-3
-24"	+2.2	-1.4	-5	-2
-19"	(S) +2.1	-0.7	-2	-1
-47"	(S) +4.8	(S) -1.6	-8	-6
-20"	+1.0	-0.5	-1	0

DURING ONE-WAY OPERATION - FINAL PHASE									
			(1969)						
1-B									
From Beltline RR to Cedar St. Via Saginaw St.	EB	1.90	7/23,28	Morn.	4'13"	27.2	0.8	8	6
" "	"	"	7/23-25	Noon	4'11"	27.3	0.9	10	8
" "	"	"	7/22,24	Aft.	3'57"	29.1	0.3	6	5
2-B									
From Cedar St. to Beltline RR Via Oakland St.	WB	1.94	7/23,28	Morn	4'03"	29.1	0.3	7	6
" "	"	"	7/23-25	Noon	3'52"	30.4	0.4	4	3
" "	"	"	7/22,24	Aft.	4'13"	28.0	0.8	10	8

CHANGE IN:				
Average Travel Time	Average Over-All Speed(m.p.h.)	Average Number of Stops	Average Delay (sec./mi.)	% Delay Time

(S) = Change is Statistically Significant.

the legal speed limit, during the one-way phase. Sizeable reductions in number of stops, duration of stops and ratio of delay time are seen in Table 2.

Route 2-A for Lansing was westbound M-43 via Saginaw. With the initial one-way system, this was replaced by 2-B via Oakland Avenue. From the intersection of Oakland and Logan on trip 2-B, the rest of the trip was along two-way streets. Even under this partial one-way operation, and considering the devious route necessitated by the use of Logan Street as a detour between Oakland and Saginaw, a comparison of the before and after data reveals substantial improvement. Travel speeds have approached the optimum, and delays have been reduced for all trips. Almost ideal signal progression was present between Cedar and Logan Streets as evidenced from the field data where only one out of the total of 27 westbound runs had any stops on this one-way section.

In the lower portion of Table 2, travel conditions are shown as determined by survey-vehicle runs during the final phase of the one-way operation. No attempt is made in the table to compare these results with the earlier phases because a rather long period of time had elapsed, substantially changing the traffic volumes and patterns. However, average over-all speeds, number of stops and delays are not much different from the initial one-way phase of three years before.

Table 3 portrays the speed-and-delay study in Pontiac. Routes 1-A and 1-B are the southeastbound state trunk line routes during the two-way and one-way operation, respectively. The latter route, via Cass Avenue, has resulted in gains of 3 miles per hour or better during the peak periods, compared with the two-way Oakland Avenue route. However, no similar improvement was observed in the northwestbound direction (Routes 2-A and 2-B). Average over-all speed has not shown any significant change in this direction except an increase of 1.9 miles per hour during the noon peak when traffic volume is relatively light compared with the morning and afternoon peaks. There is some evidence of reduction in the number of stops, but the seconds of stopped delay have increased. Examination of field data reveals that stopped-delays occurred only at the Wide Track Drive intersection and at the Cass-Montcalm intersection during the one-way operation, whereas with the two-way operation many intermediate signalized locations were causing delays. Traffic growth on Wide Track Drive in four years, and heavier traffic routed through Cass Avenue necessitated longer green time to be allocated to these streets, causing delay in the northwestbound direction.

The lack of general improvement in the northwestbound traffic flow is also blamed on the constrictive effect of the Oakland-Cass-Montcalm intersection where through-movement is confined to two lanes (Figure 18). A traffic island was added to this intersection in preparation for the one-way operation. This island channelizes two of Oakland Avenue's four lanes into two left-turn lanes onto Cass Avenue, leaving only two lanes for through and right-turn movements. Turning-movement counts taken at this intersection indicate only 385 vehicles turning left in six hours from northwestbound Oakland, with a maximum rate of 112 vehicles per hour. Such a low turning movement would not necessitate two lanes, but no more than two lanes could be allowed for through traffic because only two northwestbound lanes existed northwest of the intersection. Straight-through movement in six hours was counted to be 2936, with a maximum rate of 1152 per hour. On the other hand, the maximum rate of right-turn movement is only 128 per hour. In general, drivers intending to go straight prefer to avoid the right lane which might be impeded by some turning vehicles. This tends to funnel through-traffic into one lane which would be loaded above capacity with the 1152 vehicles per hour.

The constricting effect of funneling the northwestbound traffic down to two, or even one lane, would also cause internal turbulence in the traffic considerably upstream of the intersection, due to lane changes for getting in the proper lane. This condition may be alleviated to some extent if another lane can be added for Oakland Avenue through-traffic.

In the southeastbound direction, comparing Route 3-A with 1-B, a slight decrease in the average speeds, and significant increase in the number of

TABLE 3

CITY OF PONTIAC

SPEED AND DELAY COMPARISONS

DURING TWO-WAY OPERATION										DURING ONE-WAY OPERATION										CHANGE IN:				
Route	Direction	Length (Miles)	Date (1964)	Period	Aveage Travel Time	Average Over-All Speed(mph)	Average Number of Stops	Average Delay (sec./mi.)	% Delay Time	Route	Direction	Length (Miles)	Date (1968)	Period	Average Travel Time	Average Over-All Speed(mph)	Average Number of Stops	Average Delay (sec./mi.)	% Delay Time	Average Travel Time	Average Over-All Speed(mph)	Average Number of Stops	Average Delay (sec./mi.)	% Delay Time
1-A From Northview to Saginaw Via Oakland Ave.	SE Bd	1.3	8/18-20	Morn.	3'34"	22.0	1.9	18	11	1-B From Northview to Wide Track Drive Via Cass Ave.	SE Bd	1.3	8/13-15	Morn.	3'09"	25.0	1.8	14	10	-25"	(S) +3.0	-0.1	- 4	- 1
" "	"	"	"	Noon	3'32"	22.3	2.2	23	14	" "	"	"	"	Noon	3'07"	25.3	1.8	19	13	-25"	+3.0	-0.4	- 4	- 1
" "	"	"	8/17-19	Aft.	3'43"	21.1	2.3	22	13	" "	"	"	"	Aft.	3'10"	24.8	1.9	16	11	-33"	(S) +3.7	-0.4	- 6	- 2
2-A From Saginaw to Northview Via Oakland Ave.	NW Bd	1.3	8/18-20	Morn.	3'28"	22.9	1.6	15	9	2-B From Saginaw to Northview Via Oakland Ave.	NW Bd	1.3	8/13-15	Morn.	3'34"	22.3	1.6	31	19	+ 6"	-0.6	0.0	+16	+10
" "	"	"	"	Noon	3'44"	21.0	2.5	22	13	" "	"	"	"	Noon	3'25"	22.9	1.7	29	19	-19"	(S) +1.9	(S) -0.8	+ 7	+ 6
" "	"	"	8/17-19	Aft.	3'43"	21.1	2.3	25	14	" "	"	"	"	Aft.	3'41"	21.2	2.0	32	19	- 2"	+0.1	-0.3	+ 7	+ 5
3-A From Northview to Wide Track Drive Via Cass Ave.	SE Bd	1.3	8/18-20	Morn.	3'02"	25.9	1.0	11	8	1-B From Northview to Wide Track Drive Via Cass Ave.	SE Bd	1.3	8/13-15	Morn.	3'09"	25.0	1.8	14	10	+ 7"	-0.9	(S) +0.8	+ 3	+ 2
" "	"	"	"	Noon	3'02"	26.0	1.2	11	8	" "	"	"	"	Noon	3'07"	25.3	1.8	19	13	+ 5"	-0.7	+0.6	+ 6	+ 5
" "	"	"	8/17-19	Aft.	3'01"	26.1	0.8	12	8	" "	"	"	"	Aft.	3'10"	24.8	1.9	16	11	+ 9"	-1.3	(S) +1.1	+ 4	+ 3
4-A Closed loop via Howard-Johnson Norton-Sanderson-Oakland & Baldwin.	Counter-Clockwise	1.2	8/18-20	Morn.	4'40"	16.0	3.8	52	22															
" "	"	"	"	Noon	4'11"	17.3	3.7	27	13															
" "	"	"	8/17-19	Aft.	4'32"	16.2	3.7	38	17															
										3-B Closed Loop Via Baldwin-Allison-Close-Sanderson-Norton-Johnson & Howard.	Clockwise	1.2	8/13-15	Morn.	4'57"	14.6	4.4	41	16					
										" "	"	"	"	Noon	4'45"	15.3	4.0	36	15					
										" "	"	"	"	Aft.	5'10"	14.0	4.6	54	21					

(S) = Change is Statistically Significant.

stops is noticed. Most of this increase in delay is attributed to the intersection with Wide Track Drive which had never caused any stops for the survey vehicle during the before runs on Cass Avenue.

Routes 4-A and 3-B, shown at the bottom of Table 3, are not on the trunk line corridor, but are two closed loops crossing the one-way pair at two locations. These test runs were made to detect the extent of any delay that the new one-way pair may cause on cross traffic. The direction of travel on the loop originally planned and run during the before period had, however, to be reversed during the after period because in the meantime the City of Pontiac had converted Johnson Avenue into a northeastbound one-way street. This made it impossible to make a direct comparison of the before and after travel conditions on the same streets. In general, a slightly inferior operation in the traffic is indicated on this loop during the after period.

Table 4 is an evaluation of the speed-and-delay study done in Port Huron. It was noted earlier that the one-way project in this city was different in concept from the other three because the city corridor in use as the east-west state trunk line was abandoned and an entirely new corridor several blocks south was selected to carry the one-way pair. The first comparison in Table 4 (Route 1-A vs. 1-B) is that of the eastbound trunk line runs, via Lapeer Street in the two-way phase of the study, and via Oak Street in the one-way phase. All peak-period evaluations of average number of stops indicate statistically significant advantages. The same observation holds true for the comparison of the westbound runs (Route 2-A vs. 2-B). The Griswold route in comparison with the Lapeer route was found to be significantly superior.

The remainder of Table 4 is of minor importance because it involves comparisons of routes where traffic conditions have changed due to changes in functions of the streets. Comparison of the eastbound trip on Griswold (3-A) with the one on Oak (1-B) is really not a fair one because traffic volumes are not alike and the character of Oak Street traffic as a one-way state artery is different from that which existed on Griswold Street when it was a two-way city street. Higher speeds, however, have resulted. Comparison of the westbound "before" and "after" trips on Griswold (4-A vs. 2-B) is similarly inadequate.

The last two sets of trip comparisons in Table 4 involve the Lapeer Street corridor alone. The eastbound trips are 1-A and 3-B, and the westbound ones are 2-A and 4-B. The comparisons show a general deterioration of the quality of traffic flow after Lapeer and Water Streets reverted to city jurisdiction. It is not clear whether this was a reflection of change in traffic enforcement or is it due to insufficient data taken during the after period, because as indicated under Table 4, only one test run for each peak was made.

In order to make a general review of the results of speed-and-delay studies in all cities, an effort has been made in Table 5 to summarize some average values. The figures represent simple averages of the results obtained for the various study trips.

The most significant deduction from Table 5 is that the one-way operation has resulted in the largest speed increases and delay elimination in Kalamazoo. Lansing and Port Huron did not fare as well. Pontiac showed only negligible gain in speed, and a poor record in delays. It can also be said that traffic flow progession initially was better in Lansing and Port Huron than in Kalamazoo, and therefore, there was more room for improvement in the last city.

CROSS-STREET TRAVEL-TIME STUDY RESULTS

In a grid system of streets made up of state trunk lines and local streets, usual efforts to augment traffic capacity and speed along certain arteries result in some sacrifices in the traffic operation on local streets or other state trunk lines crossing the arteries in question. One of the parameters of the quality of traffic on a cross-street is travel time. To detect the possibility of having created any excessive delays on the cross-streets due to the one-way trunk line operation, cross-street travel time studies were made as outlined before.

TABLE 4

CITY OF PORT HURON

SPEED AND DELAY COMPARISONS

DURING TWO-WAY OPERATION										DURING ONE-WAY OPERATION										CHANGE IN:				
Route	Direction	Length (Miles)	Date (1964)	Period	Average Travel Time	Average Over-All Speed(mph)	Average Number of Stops	Average Delay (Sec./mi.)	% Delay Time	Route	Direction	Length (Miles)	Date (1967)	Period	Average Travel Time	Average Over-All Speed(mph)	Average Number of Stops	Average Delay (Sec./mi.)	% Delay Time	Average Travel Time	Average Over-All Speed(mph)	Average Number of Stops	Average Delay (Sec./mi.)	% Delay Time
1-A From 32nd St. to Military Via Lapeer & Water Sts.	EB	1.8	9/9-11	Morn.	5'07"	21.3	3.2	22	13	1-B From 32nd St. to Military Via Oak St.	EB	2.0	9/12, 20 & 21	Morn.	4'27"	27.4	1.6	20	15	-0'40"	+ 6.1 (S)	- 1.6 (S)	- 2	+ 2
" "	"	"	"	Noon	5'47"	19.0	3.9	34	18	" "	"	"	9/19-21	Noon	3'57"	30.7	1.2	10	8	-1'50"	+ 11.7 (S)	- 2.7 (S)	- 24	- 8
" "	"	"	9/8-10	Aft.	5'19"	20.6	3.0	24	13	" "	"	"	"	Aft.	4'22"	27.8	2.0	21	16	-0'57"	+ 7.2 (S)	- 1.0 (S)	- 3	+ 3
2-A From Military to 32nd St. Via Water & Lapeer Sts.	WB	1.8	9/9-11	Morn.	4'48"	22.6	2.7	17	11	2-B From Military to 32nd St. Via Griswold St.	WB	1.8	9/12, 20 & 21	Morn.	4'01"	27.0	1.0	8	6	-0'47"	+ 4.4 (S)	- 1.7 (S)	- 9	- 5
" "	"	"	"	Noon	5'07"	21.3	3.1	22	13	" "	"	"	9/19-21	Noon	3'58"	27.4	1.1	12	9	-1'09"	+ 6.1 (S)	- 2.0 (S)	- 10	- 4
" "	"	"	9/8-10	Aft.	5'15"	20.8	3.1	23	13	" "	"	"	"	Aft.	4'10"	26.1	1.3	14	10	-1'05"	+ 5.3 (S)	- 1.8 (S)	- 9	- 3
3-A From 32nd St. to Military Via Griswold St	EB	1.8	9/9-11	Morn.	4'01"	27.2	1.4	7	5	1-B From 32nd St. to Military Via Oak St.	EB	2.0	9/12, 20 & 21	Morn.	4'27"	27.4	1.6	20	15	+0'26"	+ 0.2	+0.2	+ 13	+10
" "	"	"	"	Noon	4'29"	24.2	1.6	13	9	" "	"	"	9/19-21	Noon	3'57"	30.7	1.2	10	8	-0'32"	+ 6.5 (S)	- 0.4	- 3	- 1
" "	"	"	9/8-10	Aft.	4'23"	25.1	1.4	13	9	" "	"	"	"	Aft.	4'22"	27.8	2.0	21	16	-0'01"	+ 2.7	+0.6	+ 8	+ 7
4-A From Military to 32nd St. Via Griswold St.	WB	1.8	9/9-11	Morn.	3'58"	27.3	1.2	9	7	2-B From Military to 32nd St. Via Griswold St.	WB	1.8	9/12, 20 & 21	Morn.	4'01"	27.0	1.0	8	6	+0'03"	- 0.3	-0.2	- 1	- 1
" "	"	"	"	Noon	4'13"	25.8	1.4	7	5	" "	"	"	9/19-21	Noon	3'58"	27.4	1.1	12	9	-0'15"	+ 1.6	-0.3	+ 5	+ 4
" "	"	"	9/8-10	Aft.	4'21"	24.9	1.2	10	7	" "	"	"	"	Aft.	4'10"	26.1	1.3	14	10	-0'11"	+ 1.2	+0.1	+ 4	+ 3
1-A From 32nd St. to Military Via Lapeer & Water Sts.	EB	1.8	9/9-11	Morn.	5'07"	21.3	3.2	22	13	3-B From 32nd St. to Military Via Lapeer & Water Sts.	EB	1.8	9/19	(*) Morn.	5'51"	18.5	3.0	37	19	+0'44"	- 2.8	-0.2	+ 15	+ 6
" "	"	"	"	Noon	5'47"	19.0	3.9	34	18	" "	"	"	"	(*) Noon	5'40"	19.1	5.0	42	22	-0'07"	+ 0.1	+1.1	+ 8	+ 4
" "	"	"	9/8-10	Aft.	5'19"	20.6	3.0	24	13	" "	"	"	"	(*) Aft.	5'59	18.1	4.0	48	24	+0'40"	- 2.5	+1.0	+ 24	+11
2-A From Military to 32nd St. Via Water & Lapeer Sts.	WB	1.8	9/9-11	Morn.	4'48"	22.6	2.7	17	11	4-B From Military to 32nd St. Via Water & Lapeer Sts.	WB	1.8	9/19	(*) Morn.	4'43"	22.9	1.0	17	11	-0'05"	+ 0.3	-1.7	0	0
" "	"	"	"	Noon	5'07"	21.3	3.1	22	13	" "	"	"	"	(*) Noon	5'58"	18.1	6.0	41	20	+0'51"	- 3.2	+2.9	+ 19	+ 7
" "	"	"	9/8-10	Aft.	5'15"	20.8	3.1	23	13	" "	"	"	"	(*) Aft.	5'34"	19.4	3.0	20	11	+0'19"	- 1.4	-0.1	- 3	- 2

(S)=Change is Statistically Significant. (*)=Only one run was made.

TABLE 5

SPEED AND DELAY SUMMARY

	Kalamazoo			Lansing			Pontiac			Port Huron		
	Two-Way	One-Way	Change	Two-Way	One-Way	Change	Two-Way	One-Way	Change	Two-Way	One-Way	Change
Average Over-all Speed (Miles per Hour)	18.1	23.1	+5.0	25.3	28.2 (28.5)	+2.9 (+3.2)	23.2	23.6	+0.4	23.3	27.7	+4.4
Average Stops per Mile	2.7	0.8	-1.9	1.1	0.6 (0.3)	-0.5 (-0.8)	1.3	1.4	+0.1	1.3	0.7	-0.6
Average Delay (Seconds per Mile)	39	17	-22	14	10 (8)	-4 (-6)	18	23	+5	17	14	-3
Average Delay Ratio	18%	11%	-7%	10%	7% (6%)	-3% (-4%)	11%	15%	+4%	10%	11%	+1%

NOTE: Numbers in parentheses indicate values for the final phase of one-way operation in Lansing.

Table 6 lists the average results obtained from the cross-street travel-time studies in Kalamazoo. It will be seen by examining the last column that the changes in average travel time vary all the way from a reduction of 62 seconds to an increase of 41 seconds. Results of a statistical analysis for significance of the changes are also indicated. No pattern seems to exist for these variations in the change in travel time. Timing of traffic signals to provide for the needed traffic capacity for conflicting street approaches and to provide for progression is the major factor affecting these travel times. Slight increase in some of the cross-street travel times is a small sacrifice that can be afforded to compensate for even smaller gains in travel time on the trunk lines, since these gains benefit much larger volumes of traffic. It can be said, nevertheless, that the introduction of the new one-way trunk line pair has not resulted in delays of any objectionable duration on the cross-streets.

Table 7 compares the average cross-street travel-times during the two-way operation with those during the initial phase of the one-way operation in Lansing. In this city, as mentioned earlier, changes in the directions of travel of the one-way streets crossing the state trunk lines were made concurrently with the operation of the new one-way state trunk lines. Consequently, in Table 7 some of the before-and-after comparisons relate to conditions of opposite traffic direction, and this makes those comparisons somewhat inconsistent since the peak traffic patterns are not comparable. However, the information as a whole is valuable again in revealing that no excessive delays have been caused by the new scheme. The last column contains a variety of shortening and lengthening of trip times varying from −10 seconds to +37 seconds.

Table 8 is a similar presentation of cross-street travel which includes the results of the second set of "after" surveys during the final phase in Lansing. As might be expected, travel times have lengthened because of heavier traffic volumes in 1969 as compared with 1964 or even 1966 (initial-phase of one-way surveys). One minute and four seconds is the largest increase, on Jenison Street, between the two-way and final one-way operation.

Cross-street travels in Port Huron are depicted in Table 9. Surveys were made on five streets in two directions. The largest increases in travel time were found to be 40 seconds during the morning peak, 26 seconds during the noon peak, and 37 seconds during the afternoon peak.

In Pontiac the test runs to compare cross-street travel were not done on a straight course like in the other cities but were made within a loop crossing the one-way system of streets. The results were already presented in Table 3 and discussed in the section titled "Speed-and-Delay Study Results".

For the sake of an over-all comparison of the results of the before and after surveys in three cities, simple averages of all the peak-period travel times have been shown in Table 10. A gain of 2.9 seconds is seen for Kalamazoo. A similar average for all of the off-peak trips in Kalamazoo (not shown in Table 10) yields 99.6 seconds for the two-way period and 95.1 seconds for the one-way. For Lansing, an over-all time loss of 10.6 seconds is indicated during the initial one-way phase. This is to be expected because another traffic artery, Oakland Avenue, which must be crossed by the traffic, has been added for the one-way operation. At every intersection of this added artery with the cross-streets, traffic signals were added, and these played a role in the resultant slight loss in travel time on the cross-streets. No off-peak trial runs have been made in Lansing or Port Huron. The 18.2 second increase in Port Huron is a natural result of heavier state trunk line traffic on Oak and Griswold Streets and the addition of signals on most of the cross-streets at their intersections with Oak.

RESULTS OF GAP STUDIES

The gap study is another test of the quality of traffic service on the streets intersecting the one-way trunk lines. This applies to streets controlled by stop signs. Any trunk line traffic improvement project cannot ignore its effect on the ease of access from minor streets. The phenomenon that controls this ease of access is the availability of gaps in the traffic stream on the major street. Earlier traffic engineering research (3) indicates that a gap of smaller size than six

(Text continued on p. 65)

TABLE 6

CITY OF KALAMAZOO

CROSS-STREET TRAVEL-TIME COMPARISONS

Run	TWO-WAY OPERATION			ONE-WAY OPERATION			CHANGE IN AVERAGE TRAVEL TIME
	Date (1964)	Period	Average Travel Time	Date (1966)	Period	Average Travel Time	
On Westnedge Ave. from Ransom to W. South Sts.	10/27-28	Morning Peak	1' 47"	5/10	Morning Peak	1' 45"	− 2"
" " " " " " " "	10/22	Morn. off "	1' 20"	5/4	Morn. off "	1' 25"	+ 5"
" " " " " " " "	"	Noon "	1' 16"	5/3,9	Noon "	1' 41"	+25" (S)
" " " " " " " "	10/28	Aft. off "	1' 09"	5/3-4	Aft. off "	1' 26"	+17"
" " " " " " " "	10/22,27	Afternoon "	1' 50"	5/5,9	Afternoon "	1' 51"	+ 1"
On Park St. from W. South to Ransom Sts.	10/27-28	Morning Peak	1' 55"	5/10	Morning Peak	1' 25"	−30"
" " " " " " " "	10/23	Morn. off "	1' 52"	5/4	Morn. off "	1' 40"	−12"
" " " " " " " "	10/22	Noon "	1' 35"	5/3,9	Noon "	1' 35"	0
" " " " " " " "	10/28	Aft. off "	1' 45"	5/3-4	Aft. off "	1' 26"	−19"
" " " " " " " "	10/22-27	Afternoon "	1' 55"	5/5,9	Afternoon "	1' 23"	−32" (S)
On Church St. from Ransom to Academy Sts.	10/27-28	Morning Peak	2' 03"	5/10	Morning Peak	1' 41"	−22"
" " " " " " " "	10/22	Morn. off "	1' 40"	5/4	Morn. off "	1' 50"	+10"
" " " " " " " "	"	Noon "	2' 06"	5/3,9	Noon "	2' 04"	− 2"
" " " " " " " "	10/28	Aft. off "	2' 03"	5/4	Aft. off "	1' 49"	−14"
" " " " " " " "	10/22,27	Afternoon "	2' 51"	5/5,9	Afternoon "	1' 49"	−62" (S)
On Rose St. from W. South to Ransom Sts.	10/27-28	Morning Peak	1' 38"	5/10	Morning Peak	1' 37"	− 1"
" " " " " " " "	10/22	Morn. off "	1' 48"	5/4	Morn. off "	1' 25"	−23"
" " " " " " " "	"	Noon "	1' 48"	5/3,9	Noon "	1' 29"	−19"
" " " " " " " "	10/28	Aft. off "	1' 59"	5/3	Aft. off "	1' 38"	−21"
" " " " " " " "	10/22,27	Afternoon "	1' 48"	5/5,9	Afternoon "	1'45"	− 3"
On Rose St. from Ranson to W. South Sts.	10/27-28	Morning Peak	1' 32"	5/10	Morning Peak	1' 50"	+18"
" " " " " " " "	10/22	Morn. off "	1' 58"	5/4	Morn. off "	1' 45"	−13"
" " " " " " " "	"	Noon "	1' 32"	5/9	Noon "	1' 50"	+18"
" " " " " " " "	10/28	Aft. off "	1' 13"	5/4	Aft. off "	1' 48"	+35"
" " " " " " " "	10/22,27	Afternoon "	1' 52"	5/5,9	Afternoon "	2' 11"	+19"
On Edwards St. from E. South to Ransom Sts.	10/27-28	Morning Peak	1' 29"	5/10	Morning Peak	1' 47"	+18"
" " " " " " " "	10/22	Morn. off "	1' 36"	5/4	Morn. off "	1' 43"	+ 7"
" " " " " " " "	10/27	Noon "	1' 31"	5/9	Noon "	1' 46"	+15"
" " " " " " " "	10/28	Aft. off "	2' 12"	5/3,4	Aft. off "	1' 51"	−21"
" " " " " " " "	10/22,27	Afternoon "	2' 10"	5/9	Afternoon "	1' 43"	−27"
On Pitcher St. from Ransom to E. South Sts.	10/27-28	Morning Peak	1' 44"	5/10	Morning Peak	1' 49"	+ 5"
" " " " " " " "	10/22	Morn. off "	1' 27"	5/4	Morn. off "	1' 12"	−15"
" " " " " " " "	"	Noon "	1' 13"	5/3,9	Noon "	1' 54"	+41" (S)
" " " " " " " "	10/28	Aft. off "	1' 13"	5/3-4	Aft. off "	1' 13"	0
" " " " " " " "	10/22,27	Afternoon "	1' 41"	5/9	Afternoon "	1' 20"	−21"

(S)- The change is statistically significant.

TABLE 7

CITY OF LANSING

CROSS-STREET TRAVEL-TIME COMPARISONS

(WITH INITIAL PHASE OPERATION)

Run	TWO-WAY OPERATION Date (1964)	Period	Average Travel Time	Run	ONE-WAY OPERATION INITIAL PHASE Date (1966)	Period	Average Travel Time	CHANGE IN AVERAGE TRAVEL TIME
On Washington Ave from Kilborn to Genesee Sts:	7/14-16	Morning Peak	1' 00"	On Washington Ave. from Kilborn to Genesee Sts.	6/29-30, 7/11	Morning Peak	1' 14"	+ 14" (S)
" "	"	Noon "	1' 00"	" "	"	Noon "	1' 18"	+ 18" (S)
" "	"	Afternoon "	1' 31"	" "	6/28-30	Afternoon "	1' 21"	- 10"
On Capitol Ave. from Genesee to Kilborn Sts.	7/14-16	Morning Peak	1' 02"	On Capitol Ave. from Kilborn to Genesee Sts. (*)	6/29-30, 7/1	Morning Peak	1' 35"	+ 33" (S)
" "	"	Noon "	1' 12"	" "	"	Noon "	1' 14"	+ 2"
" "	"	Afternoon "	1' 09"	" "	6/28-30	Afternoon "	1' 08"	- 1"
On Walnut St. from Kilborn to Genesee Sts.	7/14-16	Morning Peak	1' 07"	On Walnut St. from Genesee to Kilborn Sts. (*)	6/29-30, 7/1	Morning Peak	1' 08"	+ 1"
" "	"	Noon "	1' 08"	" "	"	Noon "	59"	- 9"
" "	"	Afternoon "	1' 12"	" "	6/28-30	Afternoon "	1' 05"	- 7"
On Pine St. from Genesee to Kilborn Sts.	7/14-16	Morning Peak	1' 12"	On Pine St. from Kilborn to Genesee Sts. (*)	6/29-30, 7/1	Morning Peak	1' 49"	+ 37" (S)
" "	"	Noon "	1' 14"	" "	"	Noon "	1' 24"	+ 10"
" "	"	Afternoon "	1' 24"	" "	6/28-30	Afternoon "	1' 30"	+ 6"
On Logan St. from Hyland to Genesee Sts.	7/14-16	Morning Peak	1' 02"	On Logan St. from Hyland to Genesee Sts.	6/29-30, 7/1	Morning Peak	1' 28"	+ 26" (S)
" "	"	Noon "	55"	" "	"	Noon "	1' 25"	+ 30" (S)
" "	"	Afternoon "	1' 03"	" "	6/28-30	Afternoon "	1' 19"	+ 16" (S)
				On Logan St. from Genesee to Hyland Sts.	6/29-30, 7/1	Morning Peak	1' 02"	
				" "	"	Noon "	1' 09"	
				" "	6/28-30	Afternoon "	1' 11"	
				On Washington Ave. from Genesee to Kilborn Sts.	6/29-30, 7/1	Morning Peak	1' 16"	
				" "	"	Noon "	55"	
				" "	6/28-30	Afternoon "	1' 08"	

(S)-The change is statistically significant.

(*)Travel direction was reversed in the "After" phase of the study.

TABLE 8

CITY OF LANSING

CROSS-STREET TRAVEL-TIME COMPARISONS (WITH FINAL PHASE OPERATION)

Run	TWO-WAY OPERATION Date (1964)	Period	Average Travel Time	Run	ONE-WAY OPERATION FINAL PHASE Date (1969)	Period	Average Travel Time	CHANGE IN AVERAGE TRAVEL TIME
On Washington Ave. from Kilborn to Genesee Sts.	7/14-16	Morning Peak	1' 00"	On Washington Ave. from Kilborn to Genesee Sts.	7/29-31	Morning Peak	1' 33"	+ 33" (S)
" "	"	Noon "	1' 00"	" "	7/28-30	Noon "	1' 34"	+ 34" (S)
" "	"	Afternoon "	1' 31"	" "	"	Afternoon "	1' 36"	+ 5"
On Capitol Ave. from Genesee to Kilborn Sts.	7/14-16	Morning Peak	1' 02"	On Capitol Ave. from Kilborn to Genesee Sts. (*)	7/29-31	Morning Peak	1' 51"	+ 49" (S)
" "	"	Noon "	1' 12"	" "	7/28-30	Noon "	1' 58"	+ 46" (S)
" "	"	Afternoon "	1' 09"	" "	"	Afternoon "	1' 40"	+ 31" (S)
On Walnut St. from Kilborn to Genesee Sts.	7/14-16	Morning Peak	1' 07"	On Walnut St. from Genesee to Kilborn Sts. (*)	7/29-31	Morning Peak	1' 53"	+ 46" (S)
" "	"	Noon "	1' 08"	" "	7/28-30	Noon "	1' 40"	+ 32" (S)
" "	"	Afternoon "	1' 12"	" "	"	Afternoon "	1' 40"	+ 28" (S)
On Pine St. from Genesee to Kilborn Sts.	7/14-16	Morning Peak	1' 12"	On Pine St. from Kilborn to Genesee Sts. (*)	7/29-31	Morning Peak	1' 41"	+ 29" (S)
" "	"	Noon "	1' 14"	" "	7/28-30	Noon "	1' 41"	+ 27" (S)
" "	"	Afternoon "	1' 24"	" "	"	Afternoon "	1' 50"	+ 26" (S)
On Logan St. from Hyland to Genesee Sts.	7/14-16	Morning Peak	1' 02"	On Logan St. from Hyland to Genesee Sts.	7/29-31	Morning Peak	1' 26"	+ 24" (S)
" "	"	Noon "	55"	" "	7/28-30	Noon "	1' 15"	+ 20" (S)
" "	"	Afternoon "	1' 03"	" "	"	Afternoon "	1' 31"	+ 28" (S)
On Jenison St. from Hyland to Genesee Sts.	7/14-16	Morning Peak	1' 12"	On Jenison St. from Hyland to Genesee Sts.	7/29-31	Morning Peak	1' 30"	+ 18"
" "	"	Noon "	1' 24"	" "	7/28-30	Noon "	1' 30"	+ 6"
" "	"	Afternoon "	1' 23"	" "	"	Afternoon "	2' 27"	+1' 04" (S)
On Verlinden St. from Osborn to Hyland Sts.	7/14-16	Morning Peak	1' 48"	On Verlinden & Cleo Sts. from Osborn to Hyland Sts.	7/29-31	Morning Peak	1' 38"	- 10"
" "	"	Noon "	1' 18"	" "	7/28-30	Noon "	1' 34"	+ 16"
" "	"	Afternoon "	1' 21"	" "	"	Afternoon "	2' 05"	+ 44" (S)

(S)-The change is statistically significant.

(*) Travel direction was reversed in the "After" phase of the study.

TABLE 9

CITY OF PORT HURON

CROSS-STREET TRAVEL-TIME COMPARISONS

Run	TWO-WAY OPERATION			Run	ONE-WAY OPERATION			CHANGE IN AVERAGE TRAVEL TIME
	Date (1964)	Period	Average Travel Time		Date (1967)	Period	Average Travel Time	
On Military from Minnie to Chestnut. (NB)	9/1-3	Morning Peak	50"	On Military from Minnie to Chestnut. (NB)	9/12,13, 14&18	Morning Peak	1' 07"	+17"
" "	"	Noon "	1' 01"	" "	9/12-14	Noon "	1' 04"	+03"
" "	"	Afternoon "	49"	" "	9/13,14,18	Afternoon "	1' 09"	+20" (S)
On Military from Chestnut to Minnie. (SB)	9/1-3	Morning Peak	43"	On Military from Chestnut to Minnie. (SB)	9/12,13, 14&18	Morning Peak	1' 14"	+31" (S)
" "	"	Noon "	48"	" "	9/12-14	Noon "	54"	+04"
" "	"	Afternoon "	55"	" "	9/13,14,18	Afternoon "	1' 00"	+05"
On 7th St. from Minnie to Chestnut. (NB)	9/1-3	Morning Peak	53"	On 7th St. from Minnie to Chestnut. (NB)	*	Morning Peak	1' 33"	+40" (S)
" "	"	Noon "	1' 00"	" "	*	Noon "	1' 22"	+22" (S)
" "	"	Afternoon "	54"	" "	*	Afternoon "	1' 21"	+27" (S)
On 7th St. from Chestnut to Minnie. (SB)	9/1-3	Morning Peak	54"	On 7th St. from Chestnut to Minnie. (SB)	*	Morning Peak	1' 20"	+26" (S)
" "	"	Noon "	1' 02"	" "	*	Noon "	1' 20"	+18" (S)
" "	"	Afternoon "	1' 02"	" "	*	Afternoon "	1' 17"	+15" (S)
On 10th St. from Minnie to Chestnut. (NB)	9/1-3	Morning Peak	1' 02"	On 10th St. from Minnie to Chestnut. (NB)	*	Morning Peak	1' 17"	+15" (S)
" "	"	Noon "	59"	" "	*	Noon "	1' 19"	+20" (S)
" "	"	Afternoon "	1' 11"	" "	*	Afternoon "	1' 25"	+14"
On 10th St. from Chestnut to Minnie. (SB)	9/1-3	Morning Peak	1' 08"	On 10th St. from Chestnut to Minnie. (SB)	*	Morning Peak	1' 14"	+06"
" "	"	Noon "	1' 10"	" "	*	Noon "	1' 16"	+06"
" "	"	Afternoon "	1' 09"	" "	*	Afternoon "	1' 31"	+22"
On 13th St. from Minnie to Chestnut. (NB)	9/1-3	Morning Peak	58"	On 13th St. from Minnie to Chestnut. (NB)	*	Morning Peak	1' 28"	+30" (S)
" "	"	Noon "	55"	" "	*	Noon "	1' 21"	+26" (S)
" "	"	Afternoon "	51"	" "	*	Afternoon "	1' 28"	+37" (S)
On 13th St. from Chestnut to Minnie. (SB)	9/1-3	Morning Peak	57"	On 13th St. from Chestnut to Minnie. (SB)	*	Morning Peak	1' 31"	+34" (S)
" "	"	Noon "	1' 05"	" "	*	Noon "	1' 26"	+21" (S)
" "	"	Afternoon "	1' 12"	" "	*	Afternoon "	1' 30"	+18" (S)
On 24th St. from Minnie to Chestnut. (NB)	9/1-3	Morning Peak	51"	On 24th St. from Minnie to Chestnut. (NB)	*	Morning Peak	53"	+02"
" "	"	Noon "	52"	" "	*	Noon "	1' 09"	+17" (S)
" "	"	Afternoon "	1' 14"	" "	*	Afternoon "	1' 19"	+05"
On 24th St. from Chestnut to Minnie. (SB)	9/1-3	Morning Peak	38"	On 24th St. from Chestnut to Minnie. (SB)	*	Morning Peak	1' 06"	+28" (S)
" "	"	Noon "	56"	" "	*	Noon "	1' 10"	+14"
" "	"	Afternoon "	1' 07"	" "	*	Afternoon "	1' 09"	+02"

* = Some field notes did not contain dates on them, but the surveys are known to have been taken between September 12 and 21.
(S) = The change is statistically significant.

TABLE 10

CROSS-STREET TRAVEL TIME OVER-ALL AVERAGES

(Peak Periods Only)

	Two-Way	One-Way	Change
Kalamazoo	106.5 sec.	103.6 sec.	- 2.9 sec.
Lansing			
Five Streets	69.0	79.6*	+10.6
Seven Streets	73.3	101.5**	+28.2
Port Huron	58.1	76.3	+18.2

* Initial Phase

**Final Phase

seconds is not utilized by the majority of drivers desiring to cross or to make a turn onto a street from a stopped position. Consequently, no gaps smaller than six seconds have been recorded or analyzed in this study.

Table 11-a shows the numbers and sizes of gaps as surveyed at three intersections east of Logan Street in Lansing. The "before" figures relate to the two-way, and the "after" figures relate to the initial and final phases of one-way operation on Saginaw Street. Hourly totals during the morning and afternoon peak periods, and 5-hour totals are given. Figure 28 is a graphical representation of the same information. Table 11-b shows the results of the gap studies on Saginaw Street west of Logan. The "Initial" columns of the after period are left blank in this table because one-way operation was not yet implemented west of Logan during the initial phase. Figure 29 is the graphical form of the same data.

These charts reveal two significant facts. The first is that more total gaps were available during a majority of the survey hours for either phase of the one-way operation. The second and more important fact is that there were more of the larger gaps during the one-way operation. It is apparent, therefore, that the one-way project has resulted in considerably better conditions for the side street traffic by shortening the time that drivers had to wait at stop-controlled intersections.

Another quantitative evaluation of this improvement can be made by calculating the extra traffic capacity that can be utilized by vehicles entering from the side streets. An approximate method of determining the number of vehicles that could utilize the various sizes of gaps is presented in Appendix 2. No distinction has been made, in this calculation, between vehicles desiring to go straight through or to make a turn. Also, it is assumed that no gap shorter than six seconds will be utilized, and that each car starting from a stopped position will use four seconds of headway. According to this analysis, the number of vehicles that can utilize the various gap-size groups is as follows:

Gap Size	Vehicles
6–10 seconds	1
10–15 seconds	2
15–20 seconds	3
>20 seconds	5

The above figures are for cars entering from one leg of the side street. For a full intersection these can be doubled to account for traffic from the opposite leg also.

(Text continued on p. 70)

TABLE IIa

CITY OF LANSING

VEHICLE GAP STUDY

(East of Logan Street.)

Hourly Totals of Various Sizes of Gaps

ON SAGINAW ST. AT SEYMOUR ST:

Gap Sizes (Seconds)	7-8 A.M.			8-9 A.M.			3-4 P.M.			4-5 P.M.			5-6 P.M.			Total for (5) Hours		
	Before	After		Before	After		Before	After		Before	After		Before	After		Before	After	
		Initial	Final		Initial	Final		Initial	Final		Initial	Final		Initial	Final		Initial	Final
6-10	40	40	45	62	39	61	58	37	50	49	43	63	39	44	48	248	203	267
10-15	18	29	27	31	22	24	22	34	25	13	30	20	27	32	23	111	147	119
15-20	13	19	16	10	18	10	5	18	21	5	21	7	9	13	14	42	89	68
Over 20	5	23	17	3	27	23	2	21	14	0	13	9	7	16	4	17	100	67
Total	76	111	105	106	106	118	87	110	110	67	107	99	82	105	89	418	539	521

ON SAGINAW ST. AT CHESTNUT ST:

Gap Sizes (Seconds)	7-8 A.M.			8-9 A.M.			3-4 P.M.			4-5 P.M.			5-6 P.M.			Total for (5) Hours		
	Before	After		Before	After		Before	After		Before	After		Before	After		Before	After	
		Initial	Final		Initial	Final		Initial	Final		Initial	Final		Initial	Final		Initial	Final
6-10	49	35	42	70	34	31	39	41	40	27	41	58	35	34	46	220	185	217
10-15	45	33	24	49	32	30	17	37	19	15	26	24	20	32	26	146	160	123
15-20	14	18	12	18	23	17	4	14	14	4	11	16	9	19	15	49	85	74
Over 20	6	24	29	7	30	24	0	27	30	0	32	20	3	32	24	16	145	127
Total	114	110	107	144	119	102	60	119	103	46	110	118	67	117	111	431	575	541

ON SAGINAW ST. AT SYCAMORE ST:

Gap Sizes (Seconds)	7-8 A.M.			8-9 A.M.			3-4 P.M.			4-5 P.M.			5-6 P.M.			Total for (5) Hours		
	Before	After		Before	After		Before	After		Before	After		Before	After		Before	After	
		Initial	Final		Initial	Final		Initial	Final		Initial	Final		Initial	Final		Initial	Final
6-10	56	42	33	57	51	23	50	40	41	56	47	44	58	52	48	277	232	189
10-15	21	36	22	27	27	23	23	40	27	20	34	23	22	50	51	113	187	146
15-20	12	13	11	25	14	17	7	12	17	5	18	20	3	19	22	52	76	87
Over 20	18	29	27	12	47	34	1	26	31	1	25	28	2	24	23	34	151	143
Total	107	120	93	121	139	97	81	118	116	82	124	115	85	145	144	476	646	565

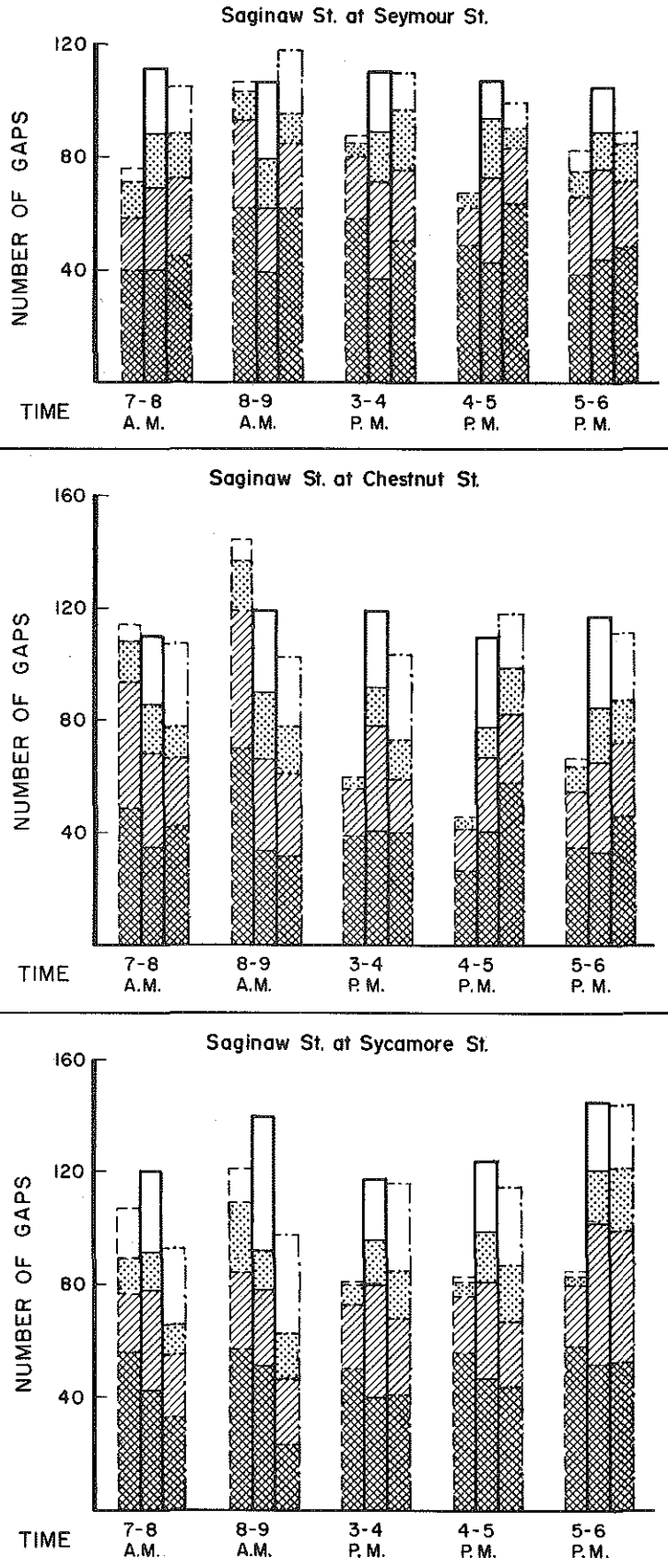


FIGURE 28 - CITY OF LANSING

TRAFFIC GAPS ON SAGINAW STREET (EAST OF LOGAN ST.)

TABLE IIb

CITY OF LANSING

VEHICLE GAP STUDY

(West of Logan Street.)

Hourly Totals of Various Sizes of Gaps

ON SAGINAW ST. AT CAREY & CLAYTON STS:

Gap Sizes (Seconds)	7-8 A.M.			8-9 A.M.			3-4 P.M.			4-5 P.M.			5-6 P.M.			Total for (5) Hours		
	Before	After		Before	After		Before	After		Before	After		Before	After		Before	After	
		Initial	Final		Initial	Final		Initial	Final		Initial	Final		Initial	Final		Initial	Final
6-10	72		63	75		47	53		57	52		38	61		39	313		244
10-15	29		26	44		19	12		19	18		27	25		21	128		112
15-20	11		14	17		16	9		17	8		15	11		10	56		72
Over 20	6		15	13		19	2		14	2		27	7		28	30		103
Total	118		118	149		101	76		107	80		107	104		98	527		531

ON SAGINAW ST. AT WESTMORELAND ST:

Gap Sizes (Seconds)	7-8 A.M.			8-9 A.M.			3-4 P.M.			4-5 P.M.			5-6 P.M.			Total for (5) Hours		
	Before	After		Before	After		Before	After		Before	After		Before	After		Before	After	
		Initial	Final		Initial	Final		Initial	Final		Initial	Final		Initial	Final		Initial	Final
6-10	53		49	53		43	53		39	47		40	35		50	241		221
10-15	25		47	23		38	29		31	22		28	27		27	126		171
15-20	20		13	12		22	7		27	9		24	12		15	60		101
Over 20	13		28	29		32	7		22	13		28	17		40	79		150
Total	111		137	117		135	96		119	91		120	91		132	506		643

ON SAGINAW ST. AT CAWOOD ST:

Gap Sizes (Seconds)	7-8 A.M.			8-9 A.M.			3-4 P.M.			4-5 P.M.			5-6 P.M.			Total for (5) Hours		
	Before	After		Before	After		Before	After		Before	After		Before	After		Before	After	
		Initial	Final		Initial	Final		Initial	Final		Initial	Final		Initial	Final		Initial	Final
6-10	68		36	68		40	74		47	58		62	53		69	321		254
10-15	45		24	32		42	26		31	22		52	33		52	158		201
15-20	13		18	21		21	6		13	2		27	18		37	60		116
Over 20	8		25	16		33	1		18	3		36	2		24	30		136
Total	134		103	137		136	107		109	85		177	106		182	569		707

ON SAGINAW ST. AT DURANT ST:

Gap Sizes (Seconds)	7-8 A.M.			8-9 A.M.			3-4 P.M.			4-5 P.M.			5-6 P.M.			Total for (5) Hours		
	Before	After		Before	After		Before	After		Before	After		Before	After		Before	After	
		Initial	Final		Initial	Final		Initial	Final		Initial	Final		Initial	Final		Initial	Final
6-10	68		52	78		73	64		62	65		69	69		79	344		335
10-15	28		28	47		49	21		25	15		42	21		39	132		183
15-20	11		17	13		9	5		12	5		9	8		16	42		63
Over 20	7		10	17		7	3		3	1		13	2		12	30		45
Total	114		107	155		138	93		102	86		133	100		146	548		626

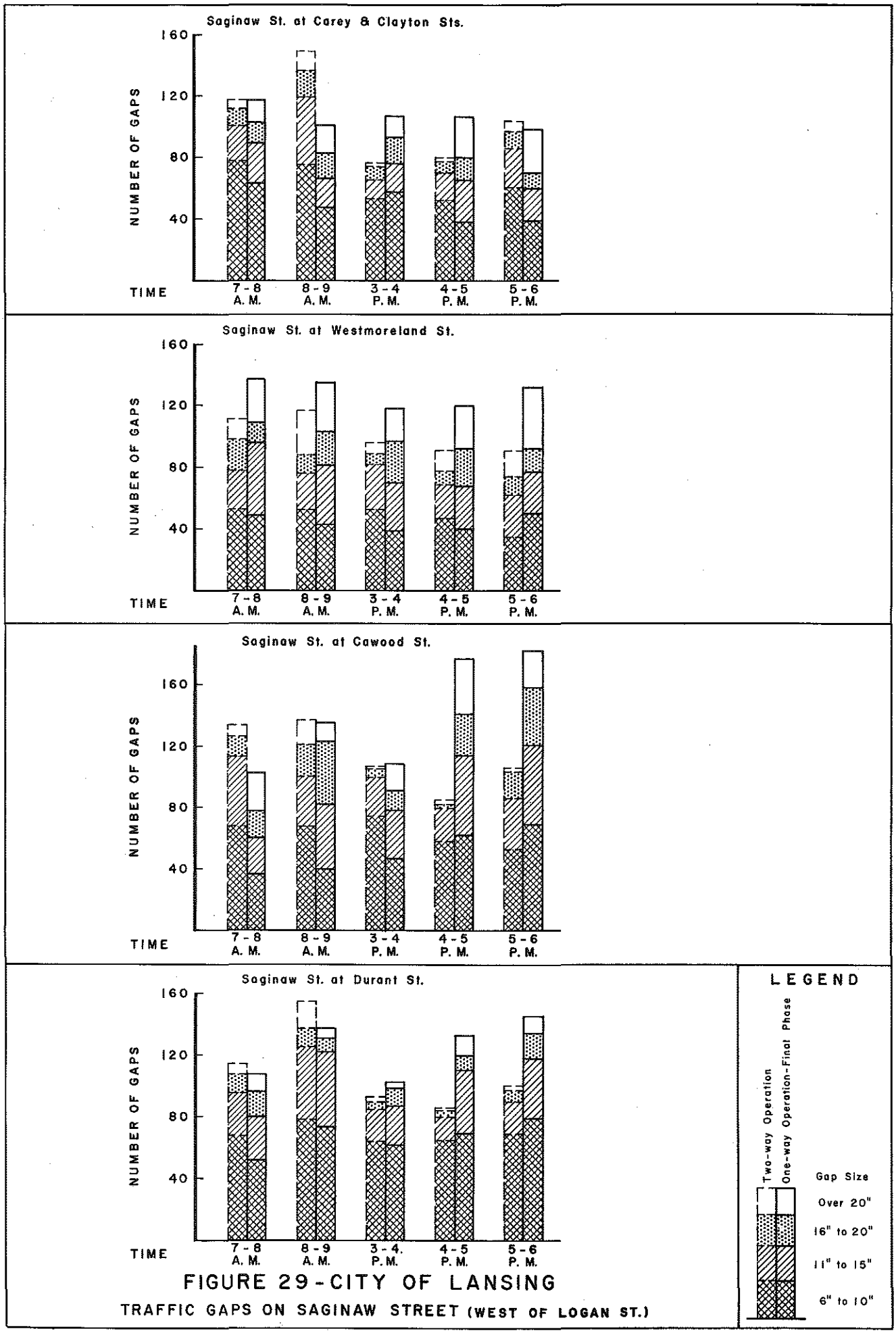


FIGURE 29 - CITY OF LANSING

TRAFFIC GAPS ON SAGINAW STREET (WEST OF LOGAN ST.)

Applying the above information to the initial-phase gap study results in Table 11-a, capacities added to the three intersections in Lansing during five hour peak traffic are shown in Table 12. This amounts to a total improvement in the capacity of the three streets of 4178 vehicles in five hours.

Table 13 gives the hourly and 5-hour totals for the number of various sizes of gaps at two intersections in Kalamazoo during the morning and afternoon peak traffic. A further breakdown of this data by 15-minute periods will be found in Tables 14 and 15. Figures 30 and 31 are graphical representations of the 15-minute gap information. They also include, at the upper part, traffic volumes that were counted during the gap surveys.

Figure 30 shows the gaps on Michigan Avenue at Church Street. When Michigan Avenue was a two-way trunk line, it carried more traffic than later when it became a one-way trunk line. The 15-minute volume variation graph in Figure 30 indicates, however, a larger peak in the morning during the one-way period. One would normally expect less and shorter traffic gaps as the volume increases, and yet, it is observed that even with higher volumes, the number and especially the sizes of gaps are larger with one-way traffic. This results from the fact that gaps depend on the directional split of the traffic flow as well as total volume, and when volumes are equal, a one-way street will allow more and larger gaps. Table 16 contains traffic volume data for this intersection.

Figure 31 is the gap and volume chart for Kalamazoo Avenue at Church Street. Volumes were in general lighter even with the two-way traffic during the "before" phase of the study. In spite of the heavier volumes, the one-way operation made available more and larger gaps as summarized in Table 13. Volume figures for this intersection are given in Table 17.

Table 18 shows the results of gap surveys in Pontiac. Figure 32 is the corresponding graphical presentation. Gaps on Cass Avenue at the Florence Avenue intersection, the bottom chart in Figure 32, indicate improvement in the total number of gaps and in all gap sizes except those of more than 20 seconds. This last size shows a slight decrease.

Total gaps on Oakland Avenue, the top three charts in Figure 32, do not show the general trend of increase as on Cass Avenue. The morning peak periods show definite improvement, and so does the 3:00–4:00 p.m. peak. The 4:00–5:00 p.m. peak manifests results varying with the particular location, and the 5:00–6:00 p.m. peak shows improvement in the most upstream location, Florence Avenue, and deterioration in the two downstream locations, at Blaine Avenue and at Cadillac Street. This may be due to the restrictive flow condition explained earlier under "Speed-and-Delay Study Results".

Table 19 and Figure 33 contain the gap study results in Port Huron. The data pertain to Griswold Street only. Although total traffic load on this street became lighter with one-way operation, traffic gaps during the one-way phase do not, in general, show improvement over the two-way phase. It is not known whether or not any changes in the turning-movement patterns at the gap-study intersections contributed to this lack of improvement, because no turning-movement counts were taken at these intersections.

RESULTS OF TRAFFIC VOLUME STUDIES

Volume count data in this study have been used to evaluate the capacity of a system of streets in an area, rather than of single streets or intersections, to move traffic in a unit of time. The areas in question in Lansing, Kalamazoo and Pontiac were the traffic corridors served by the state trunk lines already described. The same method of evaluation was not applicable to Port Huron because the traffic corridors under study were different.

A Burroughs B5500 computer was used to process the volume data. The raw data were received from the field in the form of paper tapes on which 15-minute volumes were printed by the traffic counters. Two different kinds of traffic counters were used during the several years' time involved in this study. In the earlier surveys the records were cumulative volumes by 15-minute increments up to a full hour and reset to zero on the hour. Later, all 15-minute counters in the Department of State Highways were converted so that they accumulated continually without resetting on the

(Text continued on p. 83)

TABLE 12

CITY OF LANSING

POSSIBLE UTILIZATION OF IMPROVED GAP AVAILABILITY
(During 5 Hours of Peak Traffic)

Gap Size (Seconds)	Number of Gaps AFTER*	Number of Gaps BEFORE	= Increase in No. of Gaps	× Vehicles Per Gap **	= Additional Vehicles Which Can Be Accommodated
On Saginaw St. at Seymour St.:					
6-10	203	248	- 45	2	-90
10-15	147	111	36	4	144
15-20	89	42	47	6	282
> 20	100	17	83	10	830
					1166
On Saginaw St. at Chestnut St.:					
6-10	185	220	- 35	2	-70
10-15	160	146	14	4	56
15-20	85	49	36	6	216
> 20	145	16	129	10	1290
					1492
On Saginaw St. at Sycamore St.:					
6-10	232	277	- 45	2	-90
10-15	187	113	74	4	296
15-20	76	52	24	6	144
> 20	151	34	117	10	1170
					1520
			Total on three Streets		4178

* Initial Phase of One-way Operation
**For two approaches of the minor road

TABLE 13

CITY OF KALAMAZOO

VEHICLE GAP STUDY

Hourly Totals of Various Sizes of Gaps.

ON MICHIGAN AVE. AT CHURCH ST.

Gap Sizes (Seconds)	7-8 A.M.		8-9 A.M.		3-4 P.M.		4-5 P.M.		5-6 P.M.		Total for (5) Hours	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
6-10	72	61	24	81	27	79	14	63	24	75	161	359
10-15	23	26	9	43	7	30	3	19	3	30	45	148
15-20	4	25	5	14	4	13	3	9	0	21	16	82
Over 20	5	19	1	18	1	12	0	7	1	18	8	74
Total	104	131	39	156	39	134	20	98	28	144	230	663

ON KALAMAZOO ST. AT CHURCH ST.

Gap Sizes (Seconds)	7-8 A.M.		8-9 A.M.		3-4 P.M.		4-5 P.M.		5-6 P.M.		Total for (5) Hours	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
6-10	70	39	74	27	77	47	71	34	54	35	346	182
10-15	43	18	15	30	23	51	31	51	30	44	142	194
15-20	19	23	6	13	2	30	16	16	15	13	58	95
Over 20	14	49	12	48	5	12	5	16	2	6	38	131
Total	146	129	107	118	107	140	123	117	101	98	584	602

TABLE 14

CITY OF KALAMAZOO

Number of Traffic Gaps of Various Sizes During 15-Minute Periods

On MICHIGAN AVENUE at CHURCH STREET.

PERIOD	GAP SIZES IN SECONDS								TOTAL GAPS	
	6 to 10 seconds		10 to 15 seconds		15 to 20 seconds		Over 20 seconds			
	Two-way	One-way	Two-way	One-way	Two-way	One-way	Two-way	One-way	Two-way	One-way
7:00-7:15 A.M.	35	15	7	7	2	10	4	10	48	42
7:15-7:30 A.M.	22	10	10	7	1	6	1	4	34	27
7:30-7:45 A.M.	13	21	6	9	1	7	0	4	20	41
7:45-8:00 A.M.	2	15	0	3	0	2	0	1	2	21
8:00-8:15 A.M.	3	27	2	12	0	3	0	3	5	45
8:15-8:30 A.M.	1	18	1	8	0	5	0	5	2	36
8:30-8:45 A.M.	12	14	2	15	4	3	0	7	18	39
8:45-9:00 A.M.	8	22	4	8	1	3	1	3	14	36
3:00-3:15 P.M.	15	26	0	7	2	0	1	3	18	36
3:15-3:30 P.M.	7	15	3	8	2	2	0	0	12	25
3:30-3:45 P.M.	4	23	3	6	0	6	0	5	7	40
3:45-4:00 P.M.	1	15	1	9	0	5	0	4	2	33
4:00-4:15 P.M.	3	17	1	4	1	4	0	0	5	25
4:15-4:30 P.M.	7	11	2	2	2	2	0	3	11	18
4:30-4:45 P.M.	1	18	0	7	0	1	0	3	1	29
4:45-5:00 P.M.	3	17	0	6	0	2	0	1	3	26
5:00-5:15 P.M.	2	17	0	7	0	1	0	3	2	28
5:15-5:30 P.M.	4	21	1	7	0	5	1	3	6	36
5:30-5:45 P.M.	4	18	0	6	0	8	0	5	4	37
5:45-6:00 P.M.	14	19	2	10	0	7	0	7	16	43
(5) Hour Total	161	359	45	148	16	82	8	74	230	663

TABLE 15

CITY OF KALAMAZOO

Number of Traffic Gaps of Various Sizes During 15-Minute Periods

On KALAMAZOO AVENUE at CHURCH STREET.

PERIOD	GAP SIZES IN SECONDS								TOTAL GAPS	
	6 to 10 seconds		10 to 15 seconds		15 to 20 seconds		Over 20 seconds			
	Two-way	One-way	Two-way	One-way	Two-way	One-way	Two-way	One-way	Two-way	One-way
7:00-7:15 A.M.	8	6	4	3	10	9	10	15	32	33
7:15-7:30 A.M.	13	6	25	5	8	4	3	15	49	30
7:30-7:45 A.M.	29	19	7	8	1	4	0	9	37	40
7:45-8:00 A.M.	20	8	7	2	0	6	1	10	28	26
8:00-8:15 A.M.	19	6	8	11	5	1	3	15	35	33
8:15-8:30 A.M.	17	7	2	4	1	5	1	10	21	26
8:30-8:45 A.M.	19	7	2	9	0	3	5	14	26	33
8:45-9:00 A.M.	19	7	3	6	0	4	3	9	25	26
3:00-3:15 P.M.	29	10	9	15	1	7	2	5	41	37
3:15-3:30 P.M.	11	6	6	11	1	5	1	4	19	26
3:30-3:45 P.M.	19	7	3	13	0	12	2	2	24	34
3:45-4:00 P.M.	18	24	5	12	0	6	0	1	23	43
4:00-4:15 P.M.	24	15	14	9	2	1	0	4	40	29
4:15-4:30 P.M.	21	4	6	15	8	8	2	5	37	32
4:30-4:45 P.M.	14	8	3	16	3	1	3	4	23	29
4:45-5:00 P.M.	12	7	8	11	3	6	0	3	23	27
5:00-5:15 P.M.	15	3	5	15	0	2	2	0	22	20
5:15-5:30 P.M.	13	10	3	12	3	4	0	0	19	26
5:30-5:45 P.M.	15	14	8	10	6	2	0	2	29	28
5:45-6:00 P.M.	11	8	14	7	6	5	0	4	31	24
(5) Hour Total	346	182	142	194	58	95	38	131	584	602

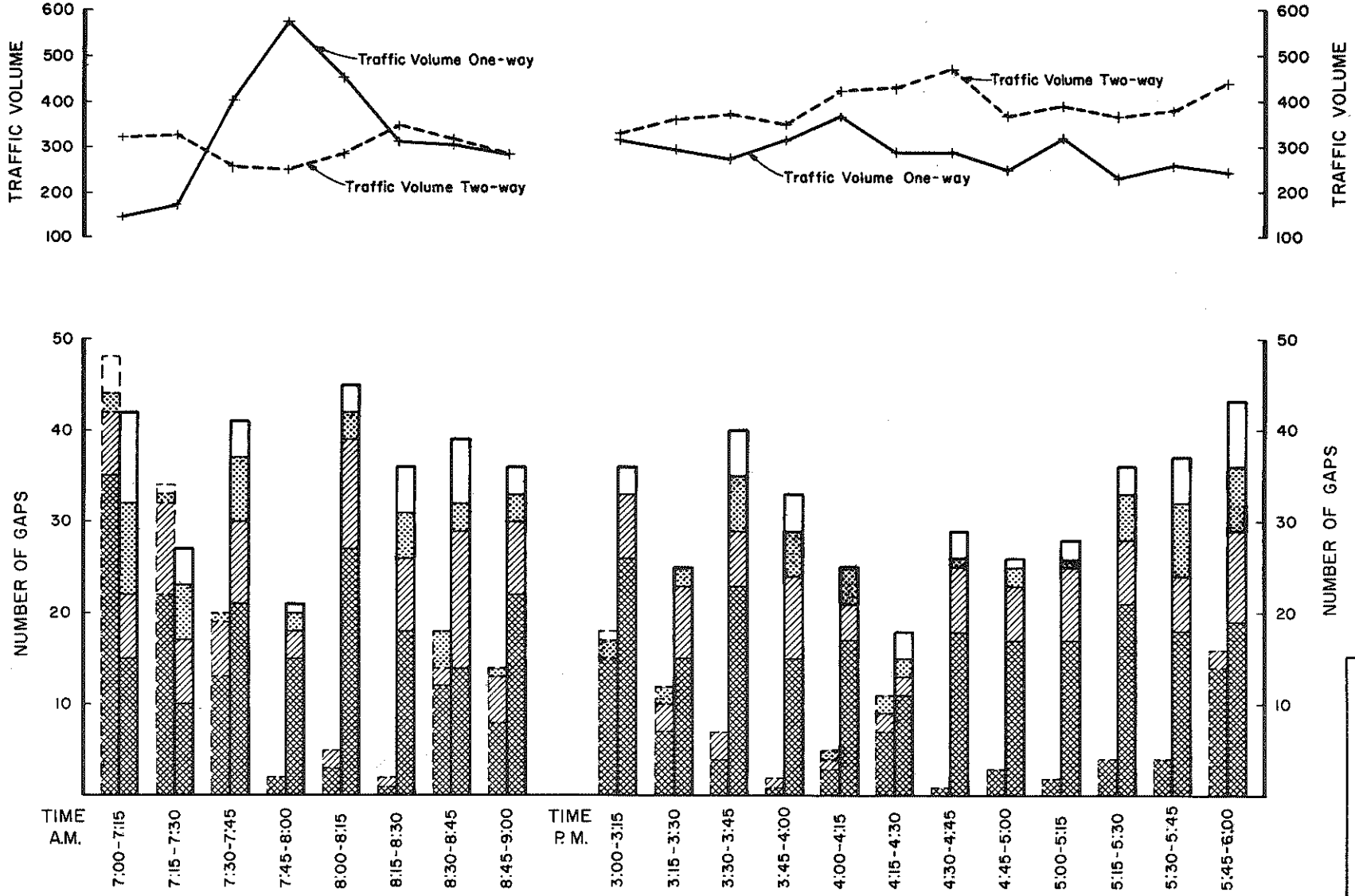


FIGURE 30 - CITY OF KALAMAZOO

TRAFFIC GAPS ON MICHIGAN AVE. AT CHURCH ST.

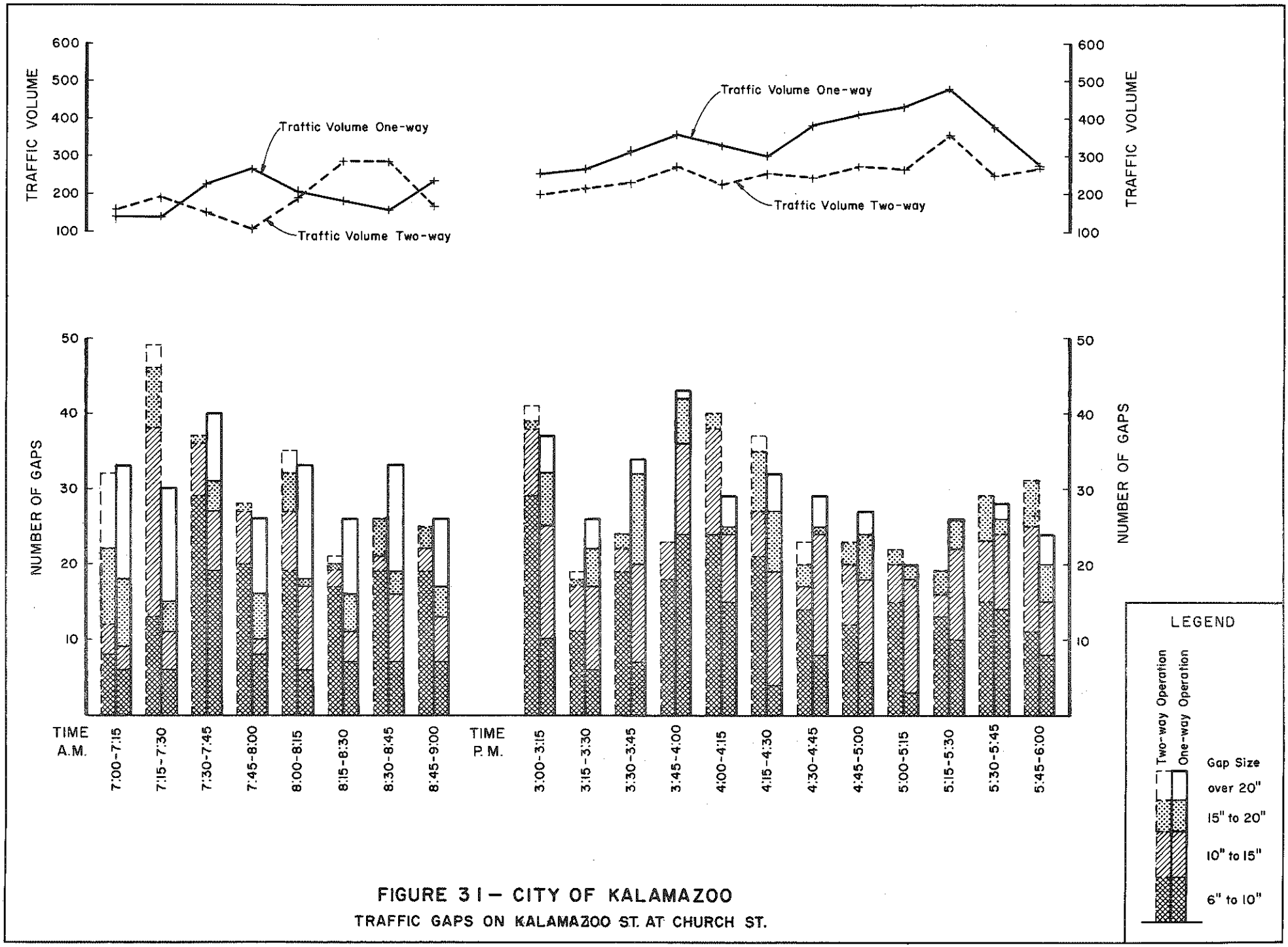


FIGURE 31 — CITY OF KALAMAZOO

TRAFFIC GAPS ON KALAMAZOO ST. AT CHURCH ST.

TABLE 16

CITY OF KALAMAZOO

Michigan Avenue at Church Street

15-Minute Traffic Volumes During Gap Surveys

Period	Volumes With Two-Way Operation (10-26-64)			Volumes With One-Way Operation (5-5-66)
	Eastbound	Westbound	Total	
7:00 – 7:15A	273	46	319	145
7:15 – 7:30	251	71	322	169
7:30 – 7:45	189	63	252	400
7:45 – 8:00	166	84	250	576
8:00 – 8:15	143	145	288	444
8:15 – 8:30	154	195	349	310
8:30 – 8:45	141	174	315	305
8:45 – 9:00	123	140	263	263
3:00 – 3:15P	186	146	332	318
3:15 – 3:30	192	170	362	292
3:30 – 3:45	205	172	377	273
3:45 – 4:00	182	161	343	316
4:00 – 4:15	225	199	424	367
4:15 – 4:30	223	204	427	293
4:30 – 4:45	252	225	477	293
4:45 – 5:00	181	189	370	252
5:00 – 5:15	165	230	395	321
5:15 – 5:30	143	223	366	231
5:30 – 5:45	138	242	380	262
5:45 – 6:00	145	294	439	243

TABLE 17

CITY OF KALAMAZOO

Kalamazoo Avenue at Church Street

15-Minute Traffic Volumes During Gap Surveys

Period	Volumes With Two-Way Operation (10-27-64)			Volumes With One-Way Operation (5-3-66)
	Eastbound	Westbound	Total	
7:00 – 7:15A	85	73	158	137
7:15 – 7:30	136	57	193	137
7:30 – 7:45	87	63	150	222
7:45 – 8:00	46	66	112	265
8:00 – 8:15	99	87	186	205
8:15 – 8:30	203	79	282	183
8:30 – 8:45	203	77	280	155
8:45 – 9:00	95	58	153	235
3:00 – 3:15P	91	109	200	256
3:15 – 3:30	97	116	213	265
3:30 – 3:45	107	122	229	316
3:45 – 4:00	91	186	277	359
4:00 – 4:15	95	129	224	329
4:15 – 4:30	114	141	255	303
4:30 – 4:45	102	144	246	383
4:45 – 5:00	92	185	277	413
5:00 – 5:15	108	157	265	437
5:15 – 5:30	127	228	355	479
5:30 – 5:45	88	159	247	378
5:45 – 6:00	115	150	265	276

TABLE 18

CITY OF PONTIAC

VEHICLE GAP STUDY

Hourly Totals of Various Sizes of Gaps.

ON OAKLAND AVE. AT BLAINE AVE:

Gap Sizes (Seconds)	7-8 A.M.		8-9 A.M.		3-4 P.M.		4-5 P.M.		5-6 P.M.		Total for (5) Hours	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
6-10 Sec.	39	71	49	100	31	88	45	97	41	59	205	415
10-15 Sec.	20	57	22	44	29	42	19	28	24	28	114	199
15-20 Sec.	12	26	12	25	14	14	10	5	19	2	67	72
Over 20 Sec.	46	38	37	41	26	5	35	7	28	1	172	92
Total	117	192	120	210	100	149	109	137	112	90	558	778

ON OAKLAND AVE. AT CADILLAC ST.

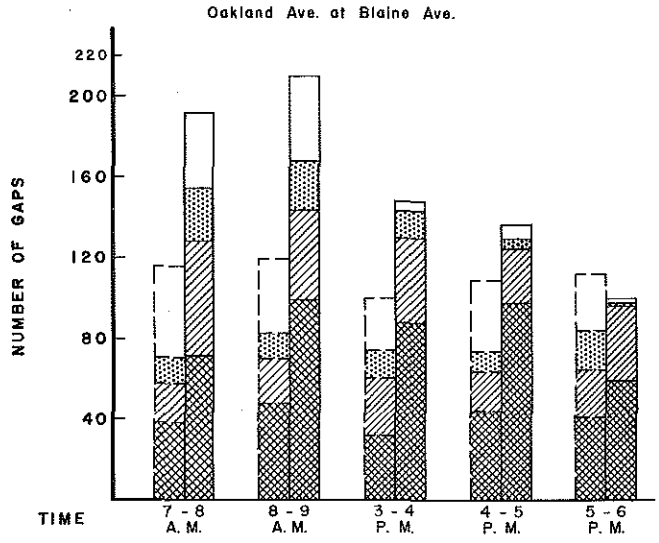
Gap Sizes (Seconds)	7-8 A.M.		8-9 A.M.		3-4 P.M.		4-5 P.M.		5-6 P.M.		Total for (5) Hours	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
6-10 Sec.	60	46	56	58	51	87	51	41	59	37	277	269
10-15 Sec.	31	44	32	40	31	64	28	25	35	17	157	190
15-20 Sec.	26	26	22	17	17	14	20	8	16	8	101	73
Over 20 Sec.	38	42	31	44	13	15	10	2	7	5	99	108
Total	155	158	141	159	112	180	109	76	117	67	634	640

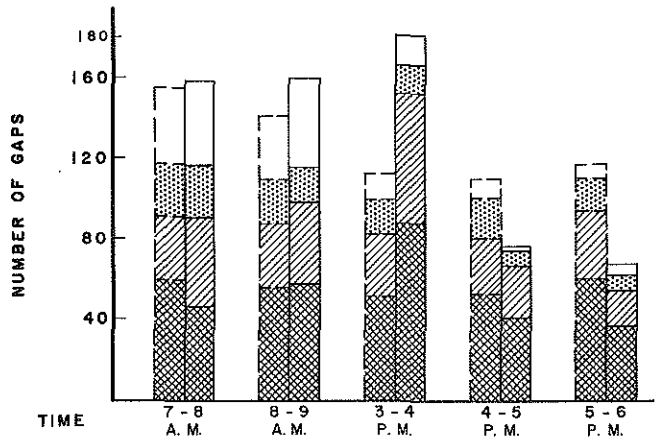
ON OAKLAND AVE. AT FLORENCE AVE.

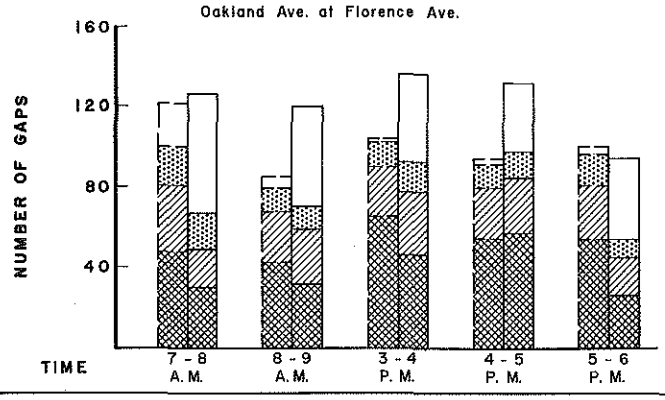
Gap Sizes (Seconds)	7-8A.M.		8-9 A.M.		3-4 P.M.		4-5 P.M.		5-6 P.M.		Total for (5) Hours	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
6-10 Sec.	47	30	42	31	64	46	54	57	54	26	261	190
10-15 Sec.	33	19	25	27	26	31	25	27	27	19	136	123
15-20 Sec.	19	18	12	12	12	15	12	13	15	9	70	67
Over 20 Sec.	22	59	6	50	1	43	3	34	4	40	36	226
Total	121	126	85	120	103	135	94	131	100	94	503	606

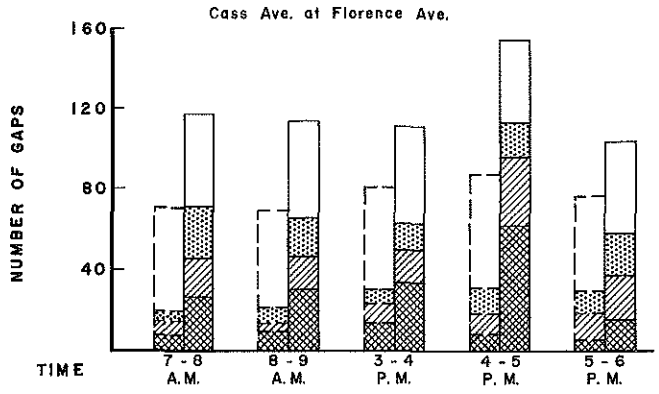
ON CASS AVE. AT FLORENCE AVE.

Gap Sizes (Seconds)	7-8 A.M.		8-9 A.M.		3-4 P.M.		4-5 P.M.		5-6 P.M.		Total for (5) Hours	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
6-10 Sec.	8	26	9	30	14	34	8	62	4	15	43	167
10-15 Sec.	6	20	4	16	9	16	10	34	14	22	43	108
15-20 Sec.	5	25	8	19	7	13	13	17	11	21	44	95
Over 20 Sec.	51	46	48	48	50	48	56	44	47	46	252	232
Total	70	117	69	113	80	111	87	157	76	104	382	602









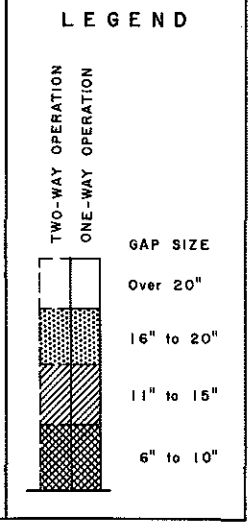


FIGURE 32 - CITY OF PONTIAC

TRAFFIC GAPS

TABLE 19

CITY OF PORT HURON

VEHICLE GAP STUDY

Hourly Totals of Various Sizes of Gaps.

ON GRISWOLD ST. AT 7th ST.

Gap Sizes (Seconds)	7-8 A.M.		8-9 A.M.		3-4 P.M.		4-5 P.M.		5-6 P.M.		Total for (5) Hours	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
6-10 Sec.	45	10	44	14	76	31	78	52	71	36	314	143
10-15 Sec.	23	10	26	17	54	31	54	33	36	23	193	114
15-20 Sec.	15	14	24	10	23	24	19	35	34	27	115	110
Over 20 Sec.	34	47	60	50	34	55	37	49	38	40	203	241
Total	117	81	154	91	187	141	188	169	179	126	825	608

ON GRISWOLD ST. AT 16th ST.

Gap Sizes (Seconds)	7-8 A.M.		8-9 A.M.		3-4 P.M.		4-5 P.M.		5-6 P.M.		Total for (5) Hours	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
6-10 Sec.	42	42	56	50	78	92	85	91	66	72	327	347
10-15 Sec.	44	25	43	28	51	52	45	45	23	33	206	183
15-20 Sec.	22	30	24	17	25	29	25	37	23	27	119	140
Over 20 Sec.	44	59	49	50	32	37	33	34	47	31	205	211
Total	152	156	172	145	186	210	188	207	159	163	857	881

ON GRISWOLD ST. AT 20th ST.

Gap Sizes (Seconds)	7-8 A.M.		8-9 A.M.		3-4 P.M.		4-5 P.M.		5-6 P.M.		Total for (5) Hours	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
6-10 Sec.	41	57	46	36	83	94	76	93	60	93	306	373
10-15 Sec.	36	38	42	32	57	55	45	53	38	42	218	220
15-20 Sec.	28	19	26	16	22	27	29	22	20	37	125	121
Over 20 Sec.	45	49	57	55	32	34	14	37	40	40	188	215
Total	150	163	171	139	194	210	164	205	158	212	837	929

ON GRISWOLD ST. AT 22nd ST.

Gap Sizes (Seconds)	7-8 A.M.		8-9 A.M.		3-4 P.M.		4-5 P.M.		5-6 P.M.		Total for (5) Hours	
	Before	After	Before	After	Before	After *	Before	After	Before	After	Before	After
6-10 Sec.	59	47	49	20	123	78	97	77	61	94	389	316
10-15 Sec.	50	39	40	25	35	29	56	35	47	48	228	176
15-20 Sec.	34	28	32	7	20	26	23	28	34	28	143	117
Over 20 Sec.	42	49	52	49	25	12	22	25	35	34	176	169
Total	185	163	173	101	203	145	198	165	177	204	936	778

* - Guard on Griswold St. stopping traffic for school children 3:00 P.M. - 4:00 P.M.

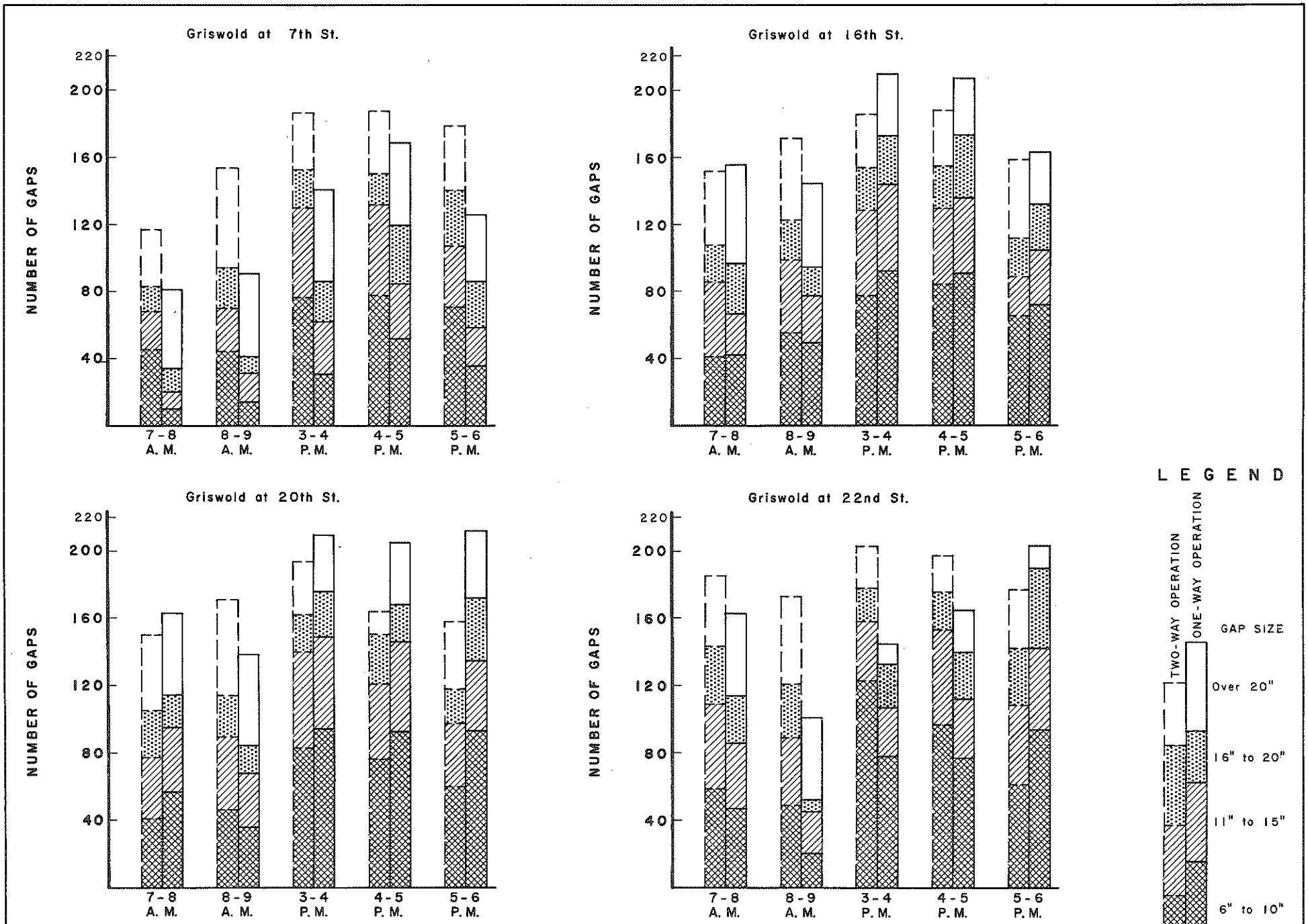


FIGURE 33 - CITY OF PORT HURON

TRAFFIC GAPS

hour. In the office, each count station was identified by key-punching a header card for each tape to show the identification number, station location, direction of flow, starting time, and other pertinent information. The volume records were punched consecutively on data cards following the header card in the deck and carrying the same identification number as the header card. Each data card contained 14 volume records.

The first part of the computer program developed for this study converted the cumulative count records of both the "before" and the "after" surveys to 15-minute volumes. Information on travel distances and the numbers of traffic lanes controlled by each count station during the before and the after phases were introduced into the computer by means of two sets of control cards. A flow chart showing the processing of the data is presented in Appendix 3.

Several tabulation printouts for the analyses of the 15-minute volumes and vehicle-miles of travel were obtained. Appendix 4 shows a sample page of a printout which contains all the basic information for the eight peak-traffic hours for the duration of the counts.

By using the basic information mentioned above, the computer was programmed to search the maximum values of the 15-minute vehicle-miles of travel for each station and then to add these up for all stations to yield an area-wide comparative table of vehicle-miles by 15-minute periods for the two-way and one-way operation phases. A sample of this information can be seen in Appendix 5.

By selecting those stations which counted traffic near the periphery of the study area, on an inbound and outbound basis, choosing the maximum occurring 15-minute volumes at those stations, and adding together yielded comparative tabulations of entering or leaving traffic totals by 15-minute periods (Appendix 6).

Additional programs processed the volume data to print out hourly volume information on a continuous 24-hour day basis. Also, vehicle-miles of travel, and entering and leaving traffic during a composite 24-hour day were obtained. Samples of the printouts pertaining to these tabulations can be seen in Appendices 7 to 9.

The purpose in processing the traffic volume data in the manner described above was to examine and compare the traffic flow and capacity characteristics of the study areas during the two-way and one-way phases. Three parameters were used to weigh these characteristics. The first parameter was the ability of the streets in the study area to receive traffic from adjacent areas during a short period of time. The second was the street system's capacity to move traffic within itself in a time period, and the third was the ability to discharge traffic to the adjacent area. The most accurate instantaneous measure of any fluctuating flow is a rate during infinitesimal time. The traffic counters recorded volumes by 15-minute periods, and this was used as the shortest interval of time in examining the volume fluctuations.

In Table 20-a, the summation of inbound traffic counted at the volume stations in Lansing during the two-way and the initial one-way phase is presented for each of the morning, noon and afternoon 15-minute traffic peaks; for a composite total of the maximum 15-minute volumes counted during eight hours of peak traffic; and for 24 hours of an average week day. The totals are broken down by state trunk lines and city streets. Under the category of trunk lines, both in the before and in the after periods, are included those streets which were not state trunk lines under the two-way operation but became trunk lines under the one-way operation.

Considering first the total newtork made up of state trunk lines and city streets, it is seen in Table 20-a that during an average day 66,920 vehicles entered the area in the before period. During the after period, this daily total of entering traffic was counted to be 72,585. This is a growth of 8.5 percent, as shown in the last column of Table 20-a, which took place during the intervening two years. Examination of the 15-minute morning peaks, however, discloses that maximum flow into the area changed from 1581 to 1835 vehicles, which is a rise of 16.1 percent.

Another way of examining these peak volumes would be to express them as ratios of the daily

Table 20-a

CITY OF LANSING

TRAFFIC VOLUMES ENTERING STUDY AREA *

(Initial Phase)

TIME	"BEFORE" PERIOD (July 1964)					"AFTER" PERIOD *** (June–July 1966)					% CHANGE		
	Trunklines		City Streets		System Total	Trunklines		City Streets		System Total	T.L.	City	System Total
15–Minute Peaks	Volume	% of System	Volume	% of System		Volume	% of System	Volume	% of System				
Morning Peak **	616	(39.0)	965	(61.0)	1581	827	(45.1)	1008	(54.9)	1835	+34.3	+4.5	+16.1
Noon Peak **	338	(25.9)	966	(74.1)	1304	513	(38.3)	825	(61.7)	1338	+51.8	–14.6	+ 2.6
5:00–5:15 P.M.	426	(20.3)	1672	(79.7)	2098	649	(31.5)	1411	(68.5)	2060	+52.3	–15.6	– 1.8
Composite 8–hr. Total	11,749	(32.0)	24,951	(68.0)	36,700	17,475	(42.4)	23,745	(57.6)	41,220	+48.7	– 4.8	+12.3
Average 24 Hours	21,583	(32.3)	45,337	(67.7)	66,920	30,260	(41.7)	42,325	(58.3)	72,585	+40.2	– 6.6	+ 8.5

* The study area used for this table does not include the area west of Logan Street.

** The 15-minute peak times are different in the "before" and "after" periods.

*** Initial phase of one-way operation.

volumes. During the before phase, the ratio of the morning 15-minute peak of entering traffic to the daily total was 1581/66,920 = 0.0236. During the after phase, it became 1835/72,585 = 0.0253. Normally, it is to be expected that as the populations of cities grow, the peaks in the traffic volumes become less accentuated (4). If no changes had been made in traffic facilities, it would be expected that, due to the growth of the greater Lansing area, the ratio of the peak flow would be smaller two years later; and yet, the opposite result is observed for the morning peak. This can be attributed to the over-all improvement in the capacity of the street system to receive a larger rate of flow of traffic.

Table 20-b is a similar comparison of the entering traffic during the two-way and the final phase of the one-way operation. Elapse of five years between these two periods, however, has somewhat reduced the impact of the comparison of the increase in peak traffic with the daily traffic: a growth of 26.3 percent in the morning peak, compared to 24.5 percent in the daily flow. It should be noted also that the study areas used in Table 20-a and Table 20-b are different.

Table 21-a, which is similar to Table 20-a, shows the total of vehicles counted as they leave the study area in Lansing, and indicates the initial comparison. It should be remembered during these discussions that the count stations in any of the cities, whether counting inbound or outbound traffic, were never complete enough to form a closed cordon around the area. This is the main reason why the daily totals for entering traffic (Table 20-a or 20-b) do not agree, for the same survey periods, with leaving traffic (Table 21-a or 21-b). This situation does not, however, detract from the value of the comparison of the before and after periods since the same stations were used each time although they did not provide 100 percent coverage. Another minor reason for disagreement between entering and leaving totals is, naturally, the fact that in most cases counts were not simultaneous but were taken during a span of two to four weeks.

Referring again to Table 21-a, the change in the 24-hour totals of traffic leaving the area was from 62,749 to 73,679, or a growth of 17.4 percent. The growth in each of the 15-minute peaks, however, was much higher, as will be seen in the last column, varying between 51.8 and 85.4 percent. This unusually high increase in the peak flows is an indication of the freedom of movement that the traffic experienced in traveling out of the area in shorter time as a direct result of better traffic service provided by the one-way trunk line operation.

Table 21-b is a similar comparison of leaving-traffic between the two-way and the final one-way phases. Here, although the noon and afternoon peaks do not show as much growth as the daily totals, increase in the morning peak (60.5 percent) still is larger than in the daily total (44.5 percent).

Table 22-a is a tabulation of the peak and daily travel totals within the Lansing study area, for the initial comparison, measured in vehicle-miles. Again, as in the case of inbound and outbound counts, these stations were not all-encompassing, but covered all the important streets quite extensively. The morning and afternoon peaks indicate, respectively, 19.5 and 13.4 percent of increase, The 24-hour increase is 22.9 percent which is comparable with the increases for the peak 15 minutes. In this table, even though the peak travel totals do not indicate a relatively sharper rise in comparison to the 24-hour travel totals, as was the case in "entering" and "leaving" traffic, there is no question but that the street network was able to move the peak loads which had increased substantially between the before and after phases of the study. Table 22-b is the later comparison of travel in Lansing and indicates increases of about 50 percent in the 15-minute peaks, the composite 8-hour totals and the daily totals. In the next section of this report, discussing average travel distances, a further thought will be presented for the evaluation of data relating to vehicle-miles of travel.

Figure 34-a shows three graphs depicting the 15-minute peak values, during eight highest hours, of total traffic entering the study area, leaving the area, and traveling within the area in Lansing. The "before" graphs are for the two-way phase (1964), and the "after" graphs are for the initial one-way phase (1966), all for the smaller study area. Almost all except some of the noon-period

(Text continued on p. 92)

Table 20-b

CITY OF LANSING

TRAFFIC VOLUMES ENTERING STUDY AREA *

(Final Phase)

TIME	"BEFORE" PERIOD (July 1964)					"AFTER" PERIOD *** (July 1969)					% CHANGE		
	Trunklines		City Streets		System Total	Trunklines		City Streets		System Total	T.L.	City	System Total
15– Minute Peaks	Volume	% of System	Volume	% of System		Volume	% of System	Volume	% of System				
7:30–7:45 A.M.	603	(32.9)	1,228	(67.1)	1,831	1,000	(43.2)	1,313	(56.8)	2,313	+65.8	+6.9	+26.3
Noon Peak **	370	(22.9)	1,249	(77.1)	1,619	607	(34.1)	1,173	(65.9)	1,780	+64.1	-6.1	+ 9.9
5:00–5:15 P.M.	393	(16.1)	2,046	(83.9)	2,439	734	(26.9)	1,994	(73.1)	2,728	+86.8	-2.5	+11.8
Composite 8–hr. Total	11,847	(26.0)	33,714	(74.0)	45,561	21,621	(39.9)	32,618	(60.1)	54,239	+82.5	-3.3	+19.0
Average 24 Hours	20,615	(26.4)	57,381	(73.6)	77,996	36,366	(37.4)	60,749	(62.6)	97,115	+76.4	+5.9	+24.5

* The study area used for this table includes the entire area east and west of Logan Street.

** The 15–minute peak times are different in the "before" and "after" periods.

*** Final phase of one-way operation.

Table 21-a

CITY OF LANSING

TRAFFIC VOLUMES LEAVING STUDY AREA *

(Initial Phase)

TIME	"BEFORE" PERIOD (July 1964)					"AFTER" PERIOD*** (June-July 1966)					% CHANGE		
	Trunklines		City Streets		System Total	Trunklines		City Streets		System Total	T.L.	City	System Total
15–Minute Peaks	Volume	% of System	Volume	% of System		Volume	% of System	Volume	% of System				
Morning Peak **	548	(36.7)	947	(63.3)	1495	1406	(61.9)	864	(38.1)	2270	+156.6	– 8.8	+51.8
12:00–12:15 P.M.	485	(41.4)	687	(58.6)	1172	1208	(55.6)	965	(44.4)	2173	+149.1	+40.5	+85.4
5:00–5:15 P.M.	858	(43.6)	1108	(56.4)	1966	1869	(54.6)	1552	(45.4)	3421	+117.8	+40.1	+74.0
Composite 8-hr. Total	14,687	(42.7)	19,729	(57.3)	34,416	23,826	(44.6)	29,602	(55.4)	53,428	+ 62.2	+50.0	+55.2
Average 24 Hours	26,652	(42.5)	36,097	(57.5)	62,749	27,566	(37.4)	46,113	(62.6)	73,679	+ 3.4	+27.7	+17.4

* The study area used for this table does not include the area west of Logan Street.

** The 15-minute peak times are different in the "before" and "after" periods.

*** Initial phase of one-way operation.

Table 21-b

CITY OF LANSING

TRAFFIC VOLUMES LEAVING STUDY AREA *

(Final Phase)

TIME	"BEFORE" PERIOD (July 1964)					"AFTER" PERIOD *** (July 1969)					% CHANGE		
	Trunklines		City Streets		System Total	Trunklines		City Streets		System Total	T.L.	City	System Total
15– Minute Peaks	Volume	% of System	Volume	% of System		Volume	% of System	Volume	% of System				
7:30–7:45 A.M.	547	(32.1)	1,158	(67.9)	1,705	841	(30.7)	1,895	(69.3)	2,736	+53.7	+63.6	+60.5
Noon Peak **	609	(40.7)	888	(59.3)	1,497	901	(43.8)	1,155	(56.2)	2,056	+47.9	+30.1	+37.3
5:00–5:15 P.M.	912	(39.1)	1,419	(60.9)	2,331	1,531	(49.9)	1,540	(50.1)	3,071	+67.9	+ 8.5	+31.7
Composite 8–hr. Total	14,931	(35.4)	27,279	(64.6)	42,210	26,211	(41.6)	36,796	(58.4)	63,007	+75.5	+34.9	+49.3
Average 24 Hours	25,917	(34.9)	48,346	(65.1)	74,263	43,278	(40.3)	64,050	(59.7)	107,328	+67.0	+32.5	+44.5

* The study area used for this table includes the entire area, east and west of Logan Street.

* * The 15–minute peak times are different in the "before" and "after" periods.

*** Final phase of one-way operation.

Table 22-a

CITY OF LANSING

VEHICLE–MILES OF TRAVEL WITHIN STUDY AREA *

(Initial Phase)

TIME	"BEFORE" PERIOD (July 1964)					"AFTER" PERIOD *** (June–July 1966)					% CHANGE		
	Trunklines		City Streets		System Total	Trunklines		City Streets		System Total	T.L.	City	System Total
15– Minute Peaks	Travel	% of System	Travel	% of System		Travel	% of System	Travel	% of System				
7:45–8:00 A.M.	648	(54.3)	546	(45.7)	1194	780	(54.7)	647	(45.3)	1427	+20.4	+18.5	+19.5
Noon Peak **	474	(52.6)	427	(47.4)	901	422	(46.1)	493	(53.9)	915	–11.0	+15.5	+ 1.6
5:00–5:15 P.M.	716	(47.4)	793	(52.6)	1509	926	(54.1)	785	(45.9)	1711	+29.3	– 1.0	+13.4
Composite 8–hr. Total	13,701	(51.4)	12,953	(48.6)	26,654	17,662	(54.6)	14,682	(45.4)	32,344	+28.9	+13.3	+21.3
Average 24 Hours	24,810	(51.4)	23,504	(48.6)	48,314	33,723	(56.7)	25,662	(43.3)	59,385	+ 35.9	+ 9.2	+ 22.9

* The study area used for this table does not include the area west of Logan Street.

** The 15–minute peak times are different in the "before" and "after" periods.

*** Initial phase of one-way operation

Table 22-b

CITY OF LANSING

VEHICLE–MILES OF TRAVEL WITHIN STUDY AREA *

(Final Phase)

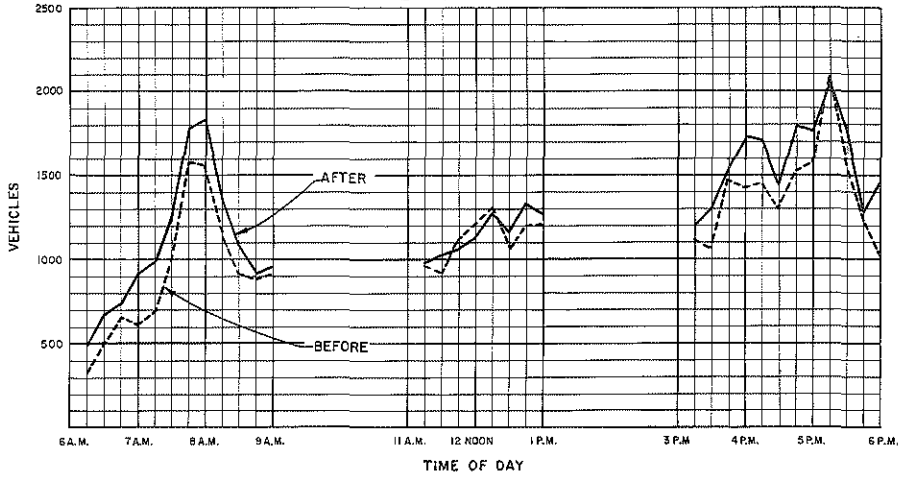
TIME	"BEFORE" PERIOD (July 1964)					"AFTER" PERIOD *** (July 1969)					% CHANGE		
	Trunklines		City Streets		System Total	Trunklines		City Streets		System Total	T.L.	City	System Total
15– Minute Peaks	Travel	% of System	Travel	% of System		Travel	% of System	Travel	% of System				
Morning Peak **	1,101	(63.6)	629	(36.4)	1,730	1,779	(66.7)	888	(33.3)	2,667	+61.6	+41.2	+54.2
Noon Peak *	841	(60.6)	546	(39.4)	1,387	1,405	(68.3)	651	(31.7)	2,056	+67.1	+19.2	+48.2
5:00–5:15 P.M.	1,214	(55.9)	958	(44.1)	2,172	1,935	(65.9)	1,001	(34.1)	2,936	+59.4	+ 4.5	+35.2
Composite 8–hr. Total	24,972	(60.8)	16,100	(39.2)	41,072	43,666	(69.6)	19,063	(30.4)	62,729	+74.9	+18.4	+52.7
Average 24 Hours	44,553	(60.6)	28,914	(39.4)	73,467	79,653	(71.4)	31,896	(28.6)	111,549	+78.8	+10.3	+51.8

* The study area used for this table include the entire area, east and west of Logan Street.

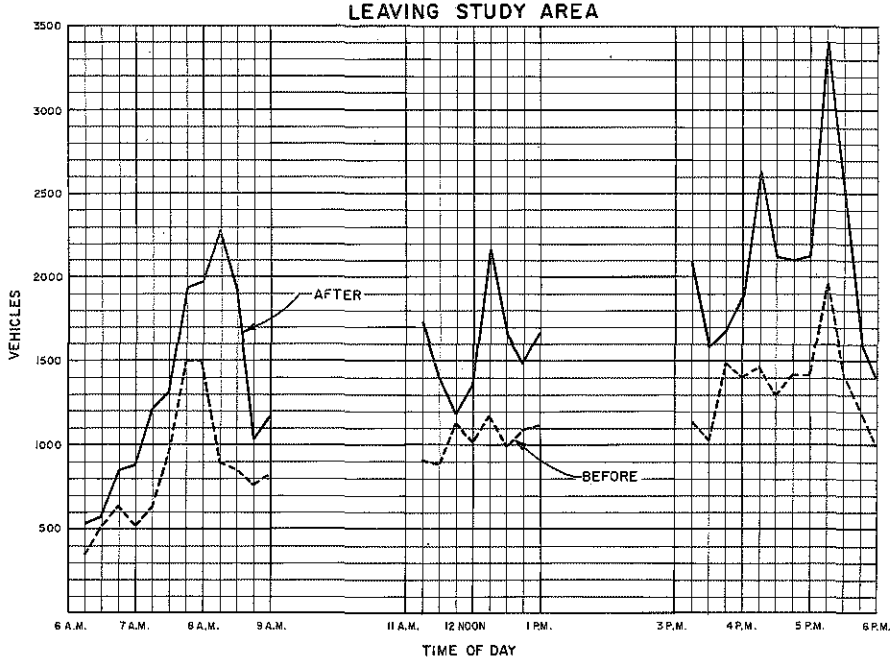
** The 15–minute peak times are different in the "before" and "after" periods.

*** Final phase of one-way operation.

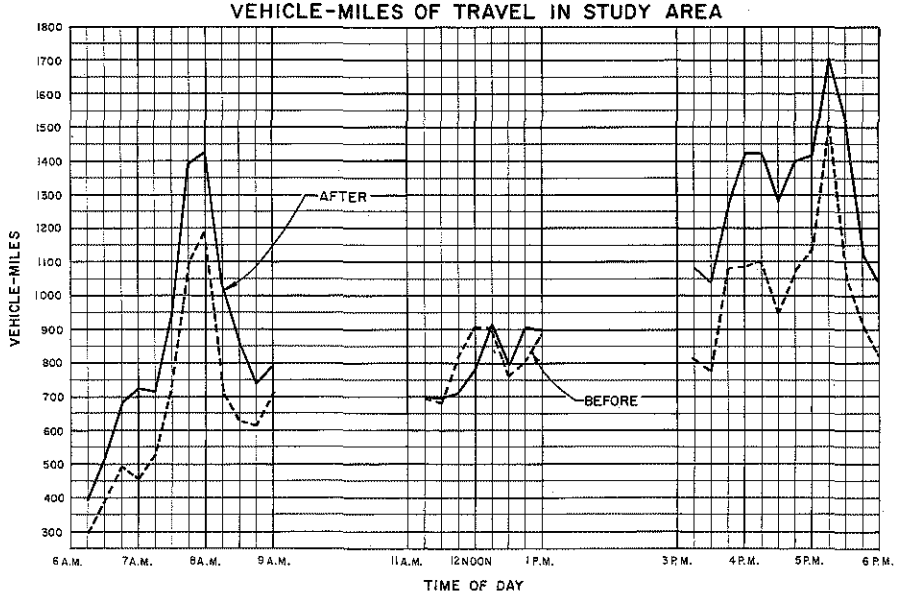
OBSERVED MAXIMUM 15-MINUTE TRAFFIC VOLUMES
ENTERING STUDY AREA



OBSERVED MAXIMUM 15-MINUTE TRAFFIC VOLUMES
LEAVING STUDY AREA



OBSERVED MAXIMUM 15-MINUTE TOTALS OF
VEHICLE-MILES OF TRAVEL IN STUDY AREA



NOTE:
The study area used for these charts does not include the area west of Logan Street.

FIGURE 34a - CITY OF LANSING: PEAK TRAFFIC (INITIAL PHASE)

peaks are found to be higher for the after period. The most significant differences between the before and after peaks are seen in the graph for leaving traffic.

Figure 34-b is a similar set of peak-traffic graphs, for the larger study area in Lansing, comparing the two-way (1964) with the final one-way (1969) operation. This comparison is only of casual interest because of too long a time lapse between the two periods.

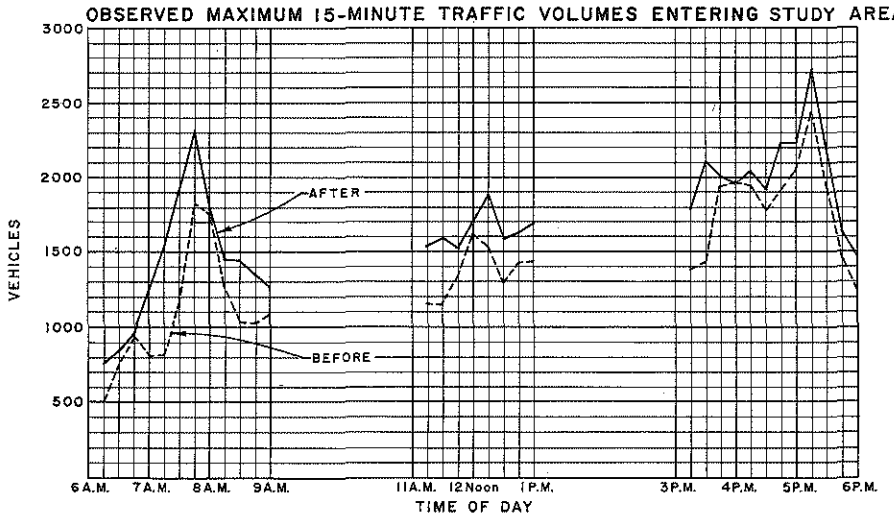
Figure 35-a compares the share which state trunk lines and city streets took in Lansing in carrying the traffic, as counted while entering and leaving the area and while circulating within the street network. The comparison is between the two-way and initial one-way periods. In all but a few minor cases, these sets of bar charts reveal that the percent of the traffic load carried by the state trunk line has increased. The most pronounced changes in this percentage are seen in the 15-minute peaks of traffic leaving the study area. For example, during the morning peak in the before period, the state trunk lines carried 36.7 percent of all traffic leaving the area, whereas in the after period they carried 61.9 percent of this load. This is a relief for the city streets since their burden is lightened by attracting the traffic to the state trunk lines during the rush hours. The same general trend for larger share of the load for state trunk lines is also observed in the final comparison shown in Figure 35-b.

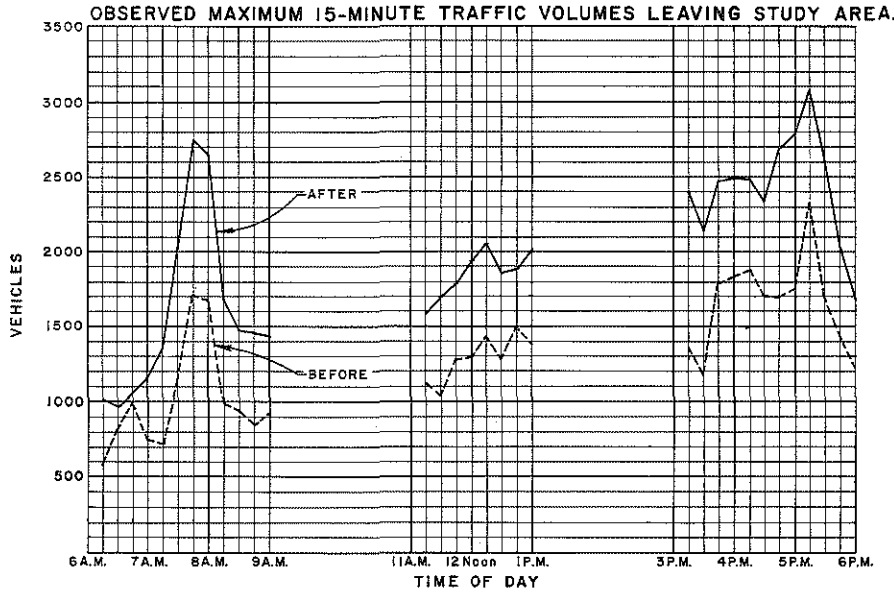
Surveys to reflect the "before" phase of the study in Kalamazoo were taken during October, 1964. The change over to one-way operation had to be delayed until October 10, 1965, since it depended on the completion of construction work. Even at that date, construction on some streets and intersections was incomplete. Considering this and the fact that more time would be needed for local drivers to become accustomed to the new conditions and for making further adjustments to the signals to obtain maximum operation, it was necessary to postpone the "after" surveys until the following year. On the other hand, with the intent of not delaying the after surveys any more than necessary, and relying on some past experience concerning seasonal variations of traffic volumes in Michigan cities, it was decided to conduct these surveys in May, 1966, this month having indicated volumes similar to the month of October. This decision was found to be invalid, however, in the light of subsequent detailed volume data. In other words, dissimilarities in the daily totals and especially in the peaking characteristics of traffic were found between the Fall and the Spring months. This has made impossible a full comparative evaluation of the volume data.

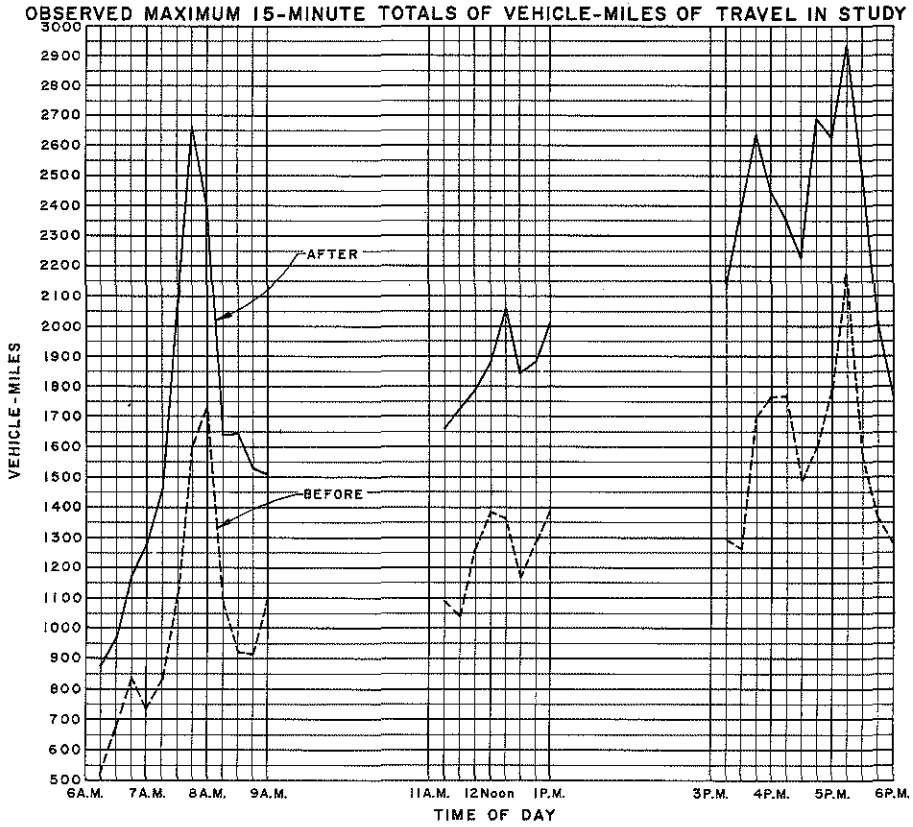
Tables 23-25 shows the analysis of peak traffic volumes entering, leaving and circulating within the Kalamazoo study area. Trunk line and city portions of these volumes are also indicated. As seen in Table 23, the "after" surveys show drops in all the peaks of total entering traffic. Nevertheless, the trunk line portion of the entering traffic does show gains in all peak periods, as in the case of Lansing. Unlike the total entering traffic, the 15-minute peaks of total leaving volumes in Table 24 are found to indicate increases in the after period. Table 25 represents the peak-period and 24-hour comparisons of travel in the area.

Figure 36 is a graphical representation of the observed maximum 15-minute values for the entering, leaving and circulating traffic totals for eight hours. The effect of the seasonal differences in the peaking characteristics is reflected in these graphs such that some peak volumes were considerably lower in the after period and some were higher. The decreases in the 15-minute volumes are certainly not caused by any deficiency in the traffic capacity of the system of streets but rather they are the result of lower traffic demand during the after surveys. This can be substantiated by the observation that such decreases have been experienced also during noon peaks, which are considerably lower than morning and afternoon peaks, and therefore, restraint due to lack of capacity should not be the reason for the lower flows.

Figure 37, which is a graphical representation of Tables 23-25, is interesting in showing once again that traffic entering or leaving the study area during peak periods has shifted to the use of state trunk lines from city streets, as witnessed by percentage figures depicting the shares of the two classes of streets.

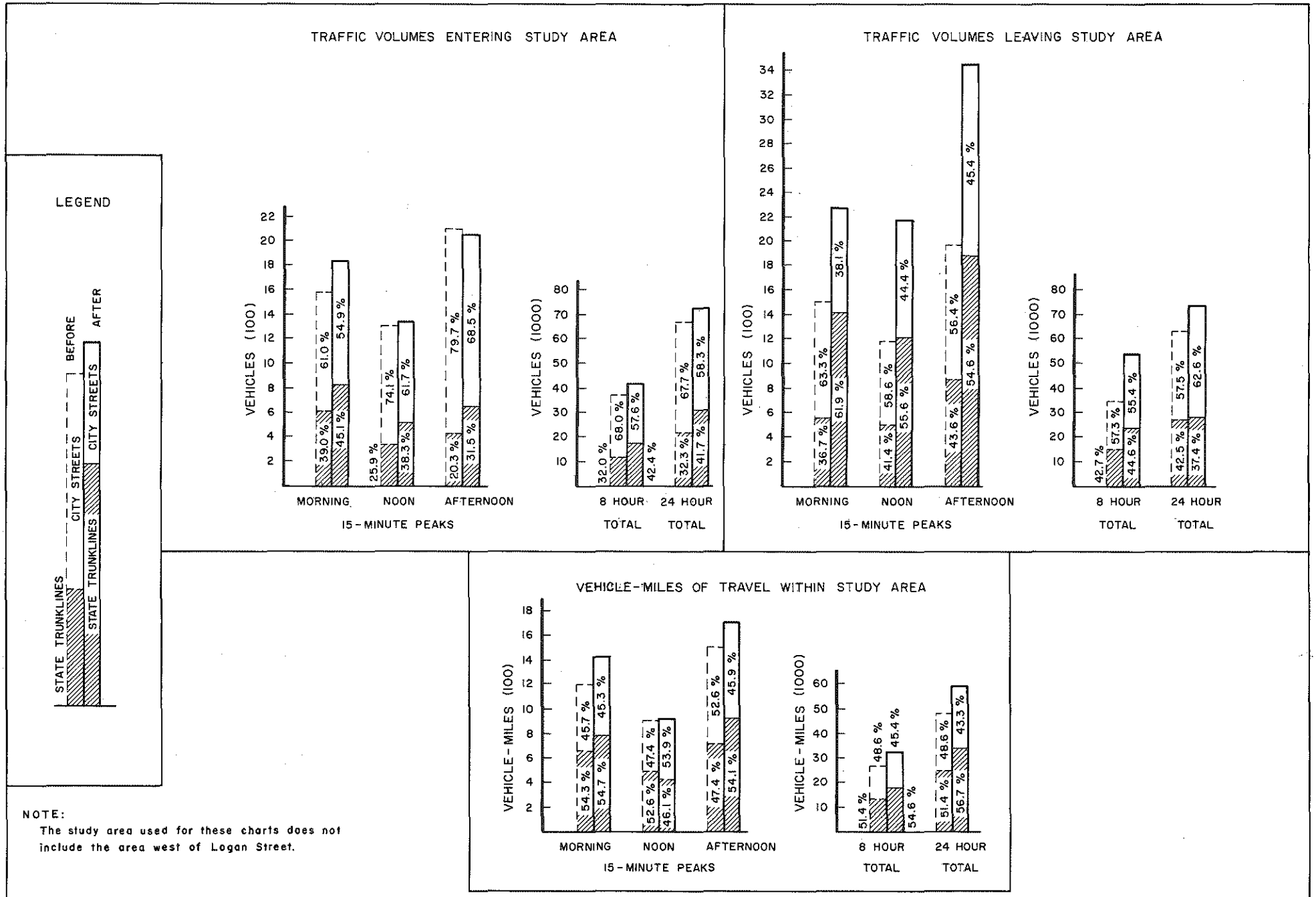






NOTE:
The study area used for these charts includes the entire area east and west of Logan Street.

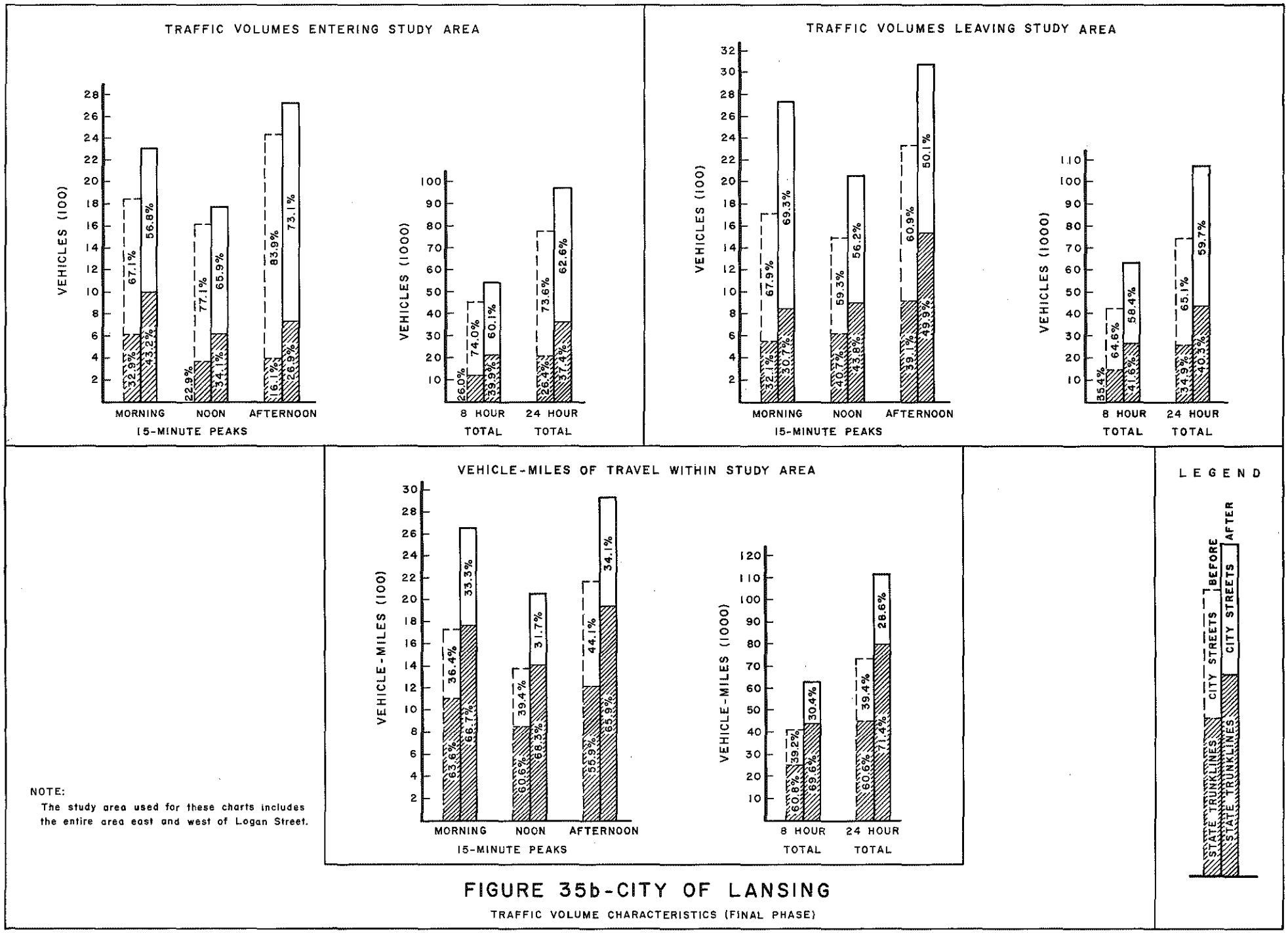
FIGURE 34b-CITY OF LANSING: PEAK TRAFFIC (FINAL PHASE)



NOTE:
The study area used for these charts does not include the area west of Logan Street.

FIGURE 35a – CITY OF LANSING

TRAFFIC VOLUME CHARACTERISTICS (INITIAL PHASE)



NOTE:
The study area used for these charts includes the entire area east and west of Logan Street.

FIGURE 35b-CITY OF LANSING

TRAFFIC VOLUME CHARACTERISTICS (FINAL PHASE)

Table 23

CITY OF KALAMAZOO

TRAFFIC VOLUMES ENTERING STUDY AREA

TIME	"BEFORE" PERIOD (Oct. 1964)					"AFTER" PERIOD (May 1966)					% CHANGE		
	Trunklines		City Streets		System Total	Trunklines		City Streets		System Total	T.L.	City	System Total
15–Minute Peaks	Volume	% of System	Volume	% of System		Volume	% of System	Volume	% of System				
7:45–8:00 A.M.	1340	(43.2)	1764	(56.8)	3104	1380	(49.3)	1419	(50.7)	2799	+3.0	– 19.6	– 9.8
Noon Peak *	678	(31.9)	1447	(68.1)	2125	1135	(54.3)	957	(45.7)	2092	+67.4	– 33.9	– 1.6
5:00–5:15 P.M.	926	(34.7)	1743	(65.3)	2669	1044	(42.0)	1439	(58.0)	2483	+12.7	– 17.4	– 7.0
Composite 8–hr. Total	24,901	(39.4)	38,242	(60.6)	63,143	27,496	(46.9)	31,086	(53.1)	58,582	+10.4	– 18.7	– 7.2
Average 24 Hours	38,967	(40.9)	56,380	(59.1)	95,347	44,999	(46.1)	52,664	(53.9)	97,663	+15.5	– 6.6	+ 2.4

* The 15–minute peak times are different in the "before" and the "after" periods.

Table 24

CITY OF KALAMAZOO

TRAFFIC VOLUMES LEAVING STUDY AREA

TIME	"BEFORE" PERIOD (Oct. 1964)					"AFTER" PERIOD (May 1966)					% CHANGE		
	Trunklines		City Streets		System Total	Trunklines		City Streets		System Total	T.L.	City	System Total
15–Minute Peaks	Volume	% of System	Volume	% of System		Volume	% of System	Volume	% of System				
7:45–8:00 A.M.	1038	(40.1)	1553	(59.9)	2591	1158	(42.1)	1591	(57.9)	2749	+11.6	+ 2.4	+ 6.1
11:45–12:00 A.M.	1008	(47.3)	1124	(52.7)	2132	1328	(54.9)	1090	(45.1)	2418	+31.7	– 3.0	+13.4
5:00–5:15 P.M.	1236	(42.6)	1664	(57.4)	2900	1395	(43.5)	1812	(56.5)	3207	+12.9	+ 8.9	+10.6
Composite 8–hr. Total	26,803	(43.6)	34,713	(56.4)	61,516	28,387	(44.6)	35,264	(55.4)	63,651	+ 5.9	+ 1.6	+ 3.5
Average 24 Hours	42,148	(42.8)	56,407	(57.2)	98,555	42,440	(40.8)	61,694	(59.2)	104,134	+ 0.7	+ 9.4	+ 5.7

Table 25

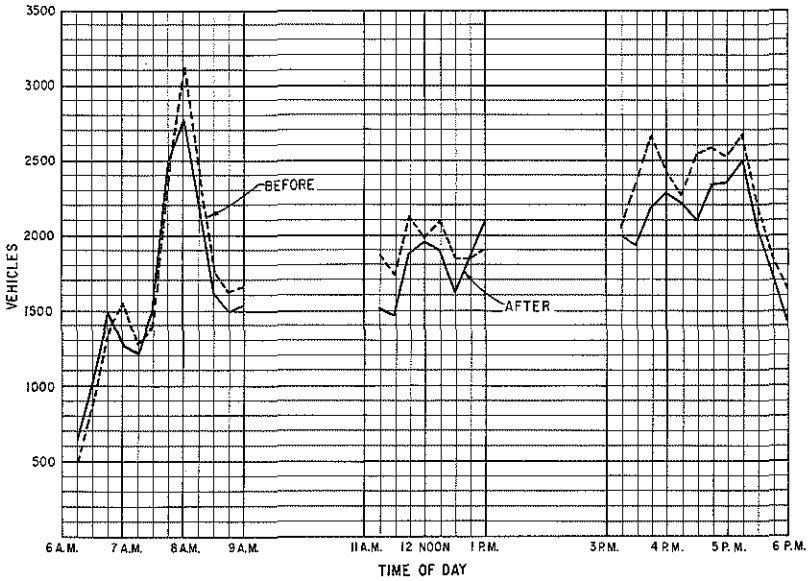
CITY OF KALAMAZOO

VEHICLE–MILES OF TRAVEL WITHIN STUDY AREA

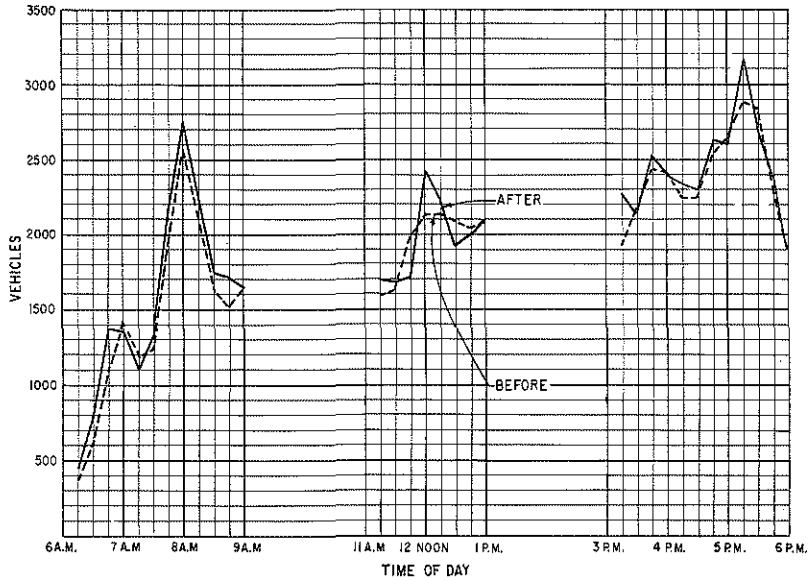
TIME	"BEFORE" PERIOD (Oct. 1964)					"AFTER" PERIOD (May 1966)					% CHANGE		
	Trunklines		City Streets		System Total	Trunklines		City Streets		System Total	T.L.	City	System Total
15– Minute Peaks	Travel	% of System	Travel	% of System		Travel	% of System	Travel	% of System				
7:45–8:00 A.M.	1279	(65.9)	661	(34.1)	1940	1431	(70.5)	599	(29.5)	2030	+11.9	– 9.4	+ 4.6
Noon Peak *	1062	(66.2)	542	(33.8)	1604	940	(63.0)	551	(37.0)	1491	–11.5	+ 1.7	– 7.0
5:00–5:15 P.M.	1342	(65.4)	710	(34.6)	2052	1462	(68.8)	662	(31.2)	2124	+ 8.9	– 6.8	+ 3.5
Composite 8-hr. Total	31,218	(66.7)	15,590	(33.3)	46,808	30,349	(68.4)	14,008	(31.6)	44,357	– 2.8	– 10.1	– 5.2
Average 24 Hours	50,515	(69.6)	22,108	(30.4)	72,623	50,773	(68.3)	23,642	(31.7)	74,416	+ 0.5	+ 6.9	+ 2.5

* The 15–minute peak times are different in the "before" and the "after" periods.

OBSERVED MAXIMUM 15-MINUTE TRAFFIC VOLUMES
ENTERING STUDY AREA



OBSERVED MAXIMUM 15-MINUTE TRAFFIC VOLUMES
LEAVING STUDY AREA



OBSERVED MAXIMUM 15-MINUTE TOTALS OF
VEHICLE-MILES OF TRAVEL IN STUDY AREA

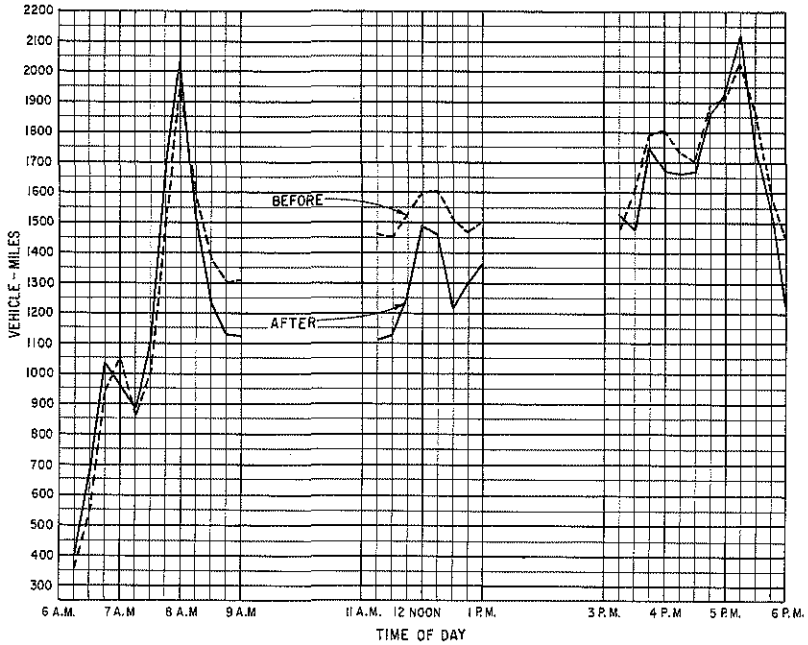


FIGURE 36- CITY OF KALAMAZOO: PEAK TRAFFIC

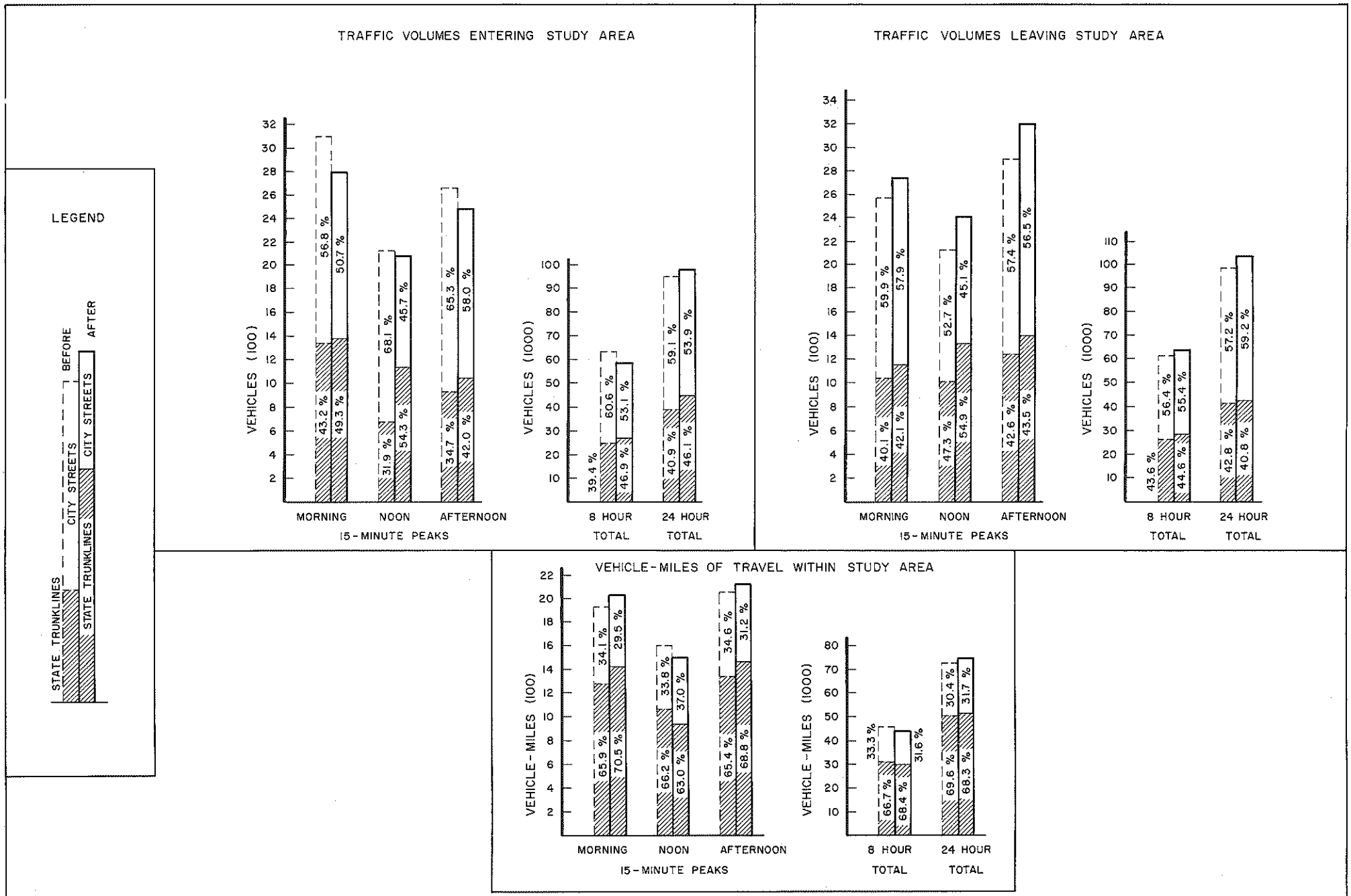


FIGURE 37-CITY OF KALAMAZOO

TRAFFIC VOLUME CHARACTERISTICS

Tables 26 through 28 and Figures 38 and 39 are the results of traffic volume analyses for Pontiac, done in the same manner as the previous two cities. As explained earlier in this report, a considerable time period of four years elapsed between the "before" and the final "after" surveys in this city. However, very little increase is indicated in the traffic load of the study area during this period.

In Tables 26 and 27, for the entering and leaving vehicles, respectively, higher percentages of rise for all except one 15-minute peak are observed than the percentages of rise for average 24 hours. This is similar to the findings in Lansing, except that traffic growth in Pontiac was lighter.

Travel within the Pontiac study area, as depicted in Table 28, shows a rise of 6.9 percent in the afternoon peak in comparison with 4.3 percent for the 24-hour total. The morning and noon peaks show a decrease in total travel.

Figure 39 again shows the characteristic trend for the state trunk line generally to carry a heavier portion of the traffic load during the one-way operation. This holds true for all 15-minute peaks and 8-hour totals, and all 24-hour totals except that for vehicle-miles of travel.

It was earlier mentioned that the method of analyzing traffic volumes in the typical city in this project was not applied to Port Huron. An attempt to examine the redistribution of traffic among the affected streets is shown in Figure 40. The state trunk line corridor was shifted from Lapeer Street to the new one-way pair made up of Griswold and Oak Streets. Union and Court Streets, located between these two traffic corridors, are two local streets which were already operating as a one-way pair when the change in the state trunk line was made. Volume counts were taken on this pair as a possible control section, and are included in Figure 40.

Abandonment of Lapeer Street as a state trunk line did not materially affect traffic volumes on this street. It lost roughly 3,000 vehicles per day, and the same amount was gained by the Griswold-Oak pair. Within the pair, Griswold, which was a two-way street before, lost about 2,000 vehicles per day to Oak.

Figure 40 also shows the ratios of maximum 15-minute volumes to daily flow in one direction. No significant change in these ratios occurred on Lapeer Street. Same is true for Court-Union pair except on that section of Union between 6th and 10th Streets where the peak traffic ratio doubled from 0.026 to 0.053. On Griswold Street considerable reduction in the ratios is observed between 10th and 16th Streets, from 0.049 to 0.030 west of 10th Street and to 0.026 east of 16th Street. Other sections of this street did not change materially. Volume counts on Oak Street were taken bi-directionally during the two-way phase so that no data exist on directional peaks for comparison with the one-way phase.

Traffic volume counts for this study were made by machines with pneumatic hoses extending across several lanes. No record of actual lane volumes could therefore be made. The rates of flow per lane were, however, computed by dividing the flow in any direction by the number of lanes used by the traffic. Table 29 gives the highest observed hourly flows per lane. An inspection of this Table reveals that higher maximum flows per lane existed in Port Huron than in the other cities, both under two-way and one-way operation. In Kalamazoo and Pontiac the maximum hourly flow per lane within the study area has increased, and in Lansing and Port Huron it has decreased.

AN APPROXIMATE COMPARISON OF AVERAGE TRAVEL DISTANCES

The average layman's first reaction to a change to one-way traffic usually is his dislike of the necessity to double back in the opposite direction for some of his usual trips in the city. Although no specific surveys were planned in this study to obtain data on this adverse travel distance, an indirect investigation using the traffic volume data has been made.

To explain the method used in this investigation, reference will be made to Figure 41. It is supposed that the rectangular area represents a study area in a city. There are four basic categories of trips that affect this area. These are (A) through trips, (B) trips into the area by commuters who

(Text continued on p. 110)

Table 26

CITY OF PONTIAC

TRAFFIC VOLUMES ENTERING STUDY AREA

TIME	"BEFORE" PERIOD (Aug. 1964)					"AFTER" PERIOD (Aug. 1968)					% CHANGE		
	Trunklines		City Streets		System Total	Trunklines		City Streets		System Total	T.L.	City	System Total
15– Minute Peaks	Volume	% of System	Volume	% of System		Volume	% of System	Volume	% of System				
7:45–8:00 A.M.	455	(54.0)	387	(46.0)	842	589	(65.8)	306	(34.2)	895	+29.5	-20.9	+6.3
Noon Peak *	318	(39.3)	492	(60.7)	810	433	(50.7)	421	(49.3)	854	+36.2	-14.4	+5.4
5:00–5:15 P.M.	513	(47.9)	558	(52.1)	1,071	581	(51.5)	548	(48.5)	1,129	+13.3	-1.8	+5.4
Composite 8–hr. Total	11,567	(49.8)	11,685	(50.2)	23,252	12,939	(52.8)	11,585	(47.2)	24,524	+11.9	-0.9	+5.5
Average 24 Hours	20,580	(48.6)	21,816	(51.4)	42,396	22,290	(51.6)	20,892	(48.4)	43,182	+ 8.3	-4.2	+1.9

* The 15–minute peak times are different in the "before" and "after" periods.

Table 27

CITY OF PONTIAC

TRAFFIC VOLUMES LEAVING STUDY AREA

TIME	"BEFORE" PERIOD (Aug. 1964)					"AFTER" PERIOD (Aug 1968)					% CHANGE		
	Trunklines		City Streets		System Total	Trunklines		City Streets		System Total	T.L.	City	System Total
15– Minute Peaks	Volume	% of System	Volume	% of System		Volume	% of System	Volume	% of System				
7:45–8:00 A.M.	406	(50.8)	393	(49.2)	799	497	(51.8)	463	(48.2)	960	+22.4	+17.8	+20.2
12:00–12:15 P.M.	451	(52.6)	407	(47.4)	858	500	(53.1)	441	(46.9)	941	+10.9	+ 8.4	+ 9.7
5:00–5:15 P.M.	582	(48.8)	611	(51.2	1,193	667	(55.5)	534	(44.5)	1,201	+14.6	– 12.6	+ 0.7
Composite 8–hr. Total	12,581	(51.8)	11,708	(48.2)	24,289	15,037	(57.3)	11,201	(42.7)	26,238	+19.5	– 4.3	+ 8.0
Average 24 Hours	20,930	(49.1)	21,672	(50.9)	42,602	23,465	(53.0)	20,807	(47.0)	44,272	+12.1	– 4.0	+ 3.9

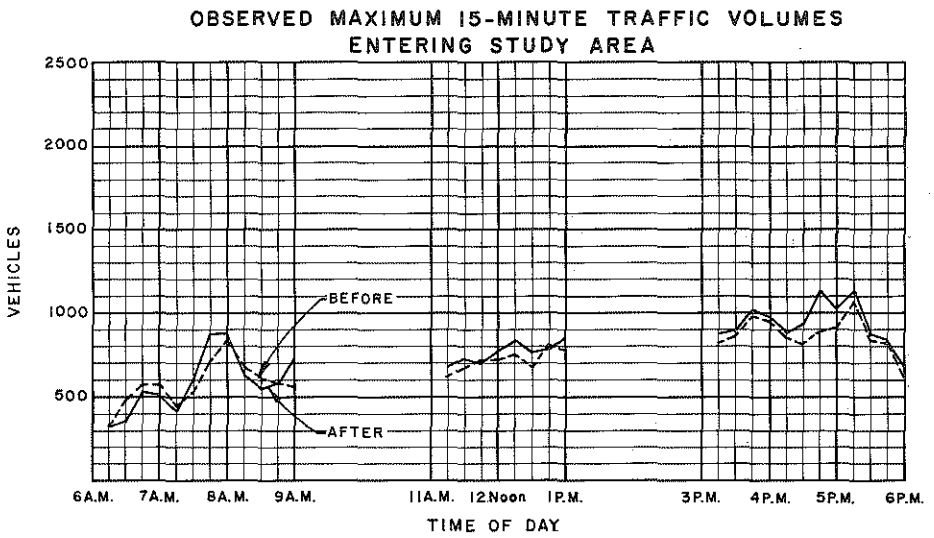
Table 28

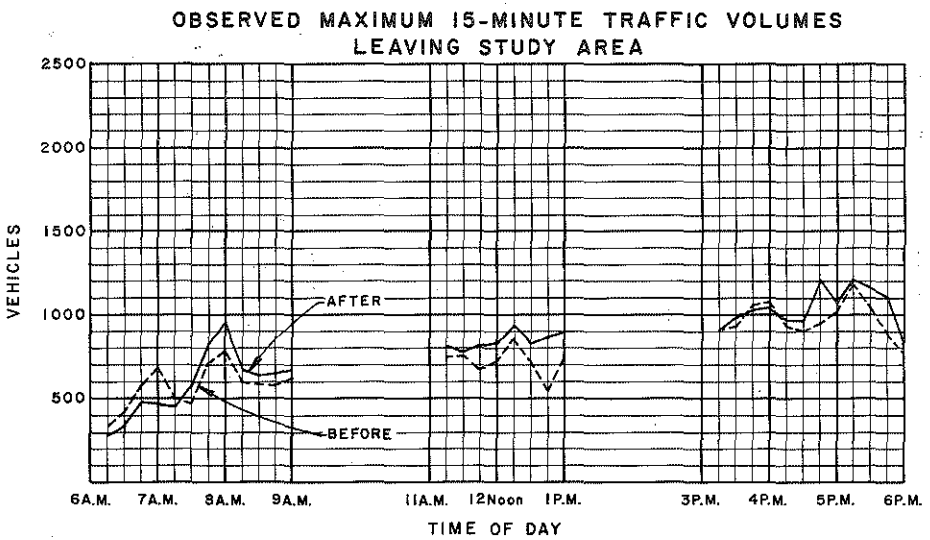
CITY OF PONTIAC

VEHICLE–MILES OF TRAVEL WITHIN STUDY AREA

TIME	"BEFORE" PERIOD (Aug. 1964)					"AFTER" PERIOD (Aug. 1968)					% CHANGE		
	Trunklines		City Streets		System Total	Trunklines		City Streets		System Total	T.L.	City	System Total
15– Minute Peaks	Travel	% of System	Travel	% of System		Travel	% of System	Travel	% of System				
7:45–8:00 A.M.	650	(83.5)	128	(16.5)	778	652	(83.9)	125	(16.1)	777	+0.3	- 2.3	-0.1
Noon Peak *	611	(80.6)	147	(19.4)	758	596	(83.2)	120	(16.8)	716	-2.5	-18.4	-5.5
5:00–5:15 P.M.	783	(79.5)	202	(20.5)	985	872	(82.8)	181	(17.2)	1,053	+11.1	-10.4	+6.9
Composite 8–hr. Total	17,155	(81.3)	3,936	(18.7)	21,091	17,345	(83.5)	3,439	(16.5)	20,784	+ 1.1	-12.6	-1.5
Average 24 Hours	29,815	(80.6)	7,198	(19.4)	37,013	30,556	(79.2)	8,038	(20.8)	38,594	+ 2.5	+11.7	+4.3

* The 15–minute peak times are different in the "before" and "after" periods.





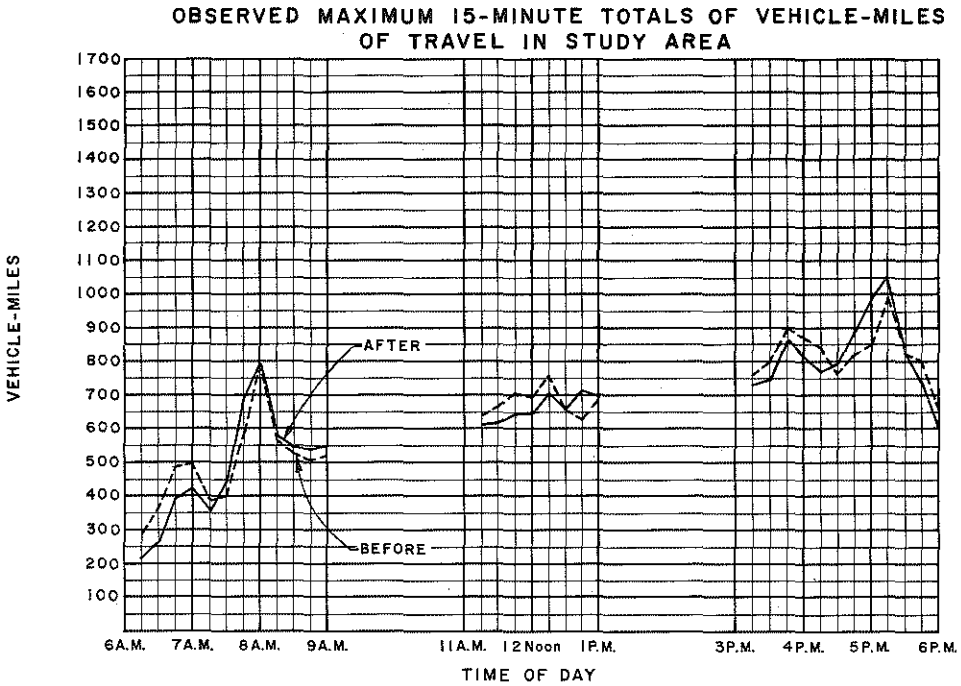


FIGURE 38-CITY OF PONTIAC: PEAK TRAFFIC

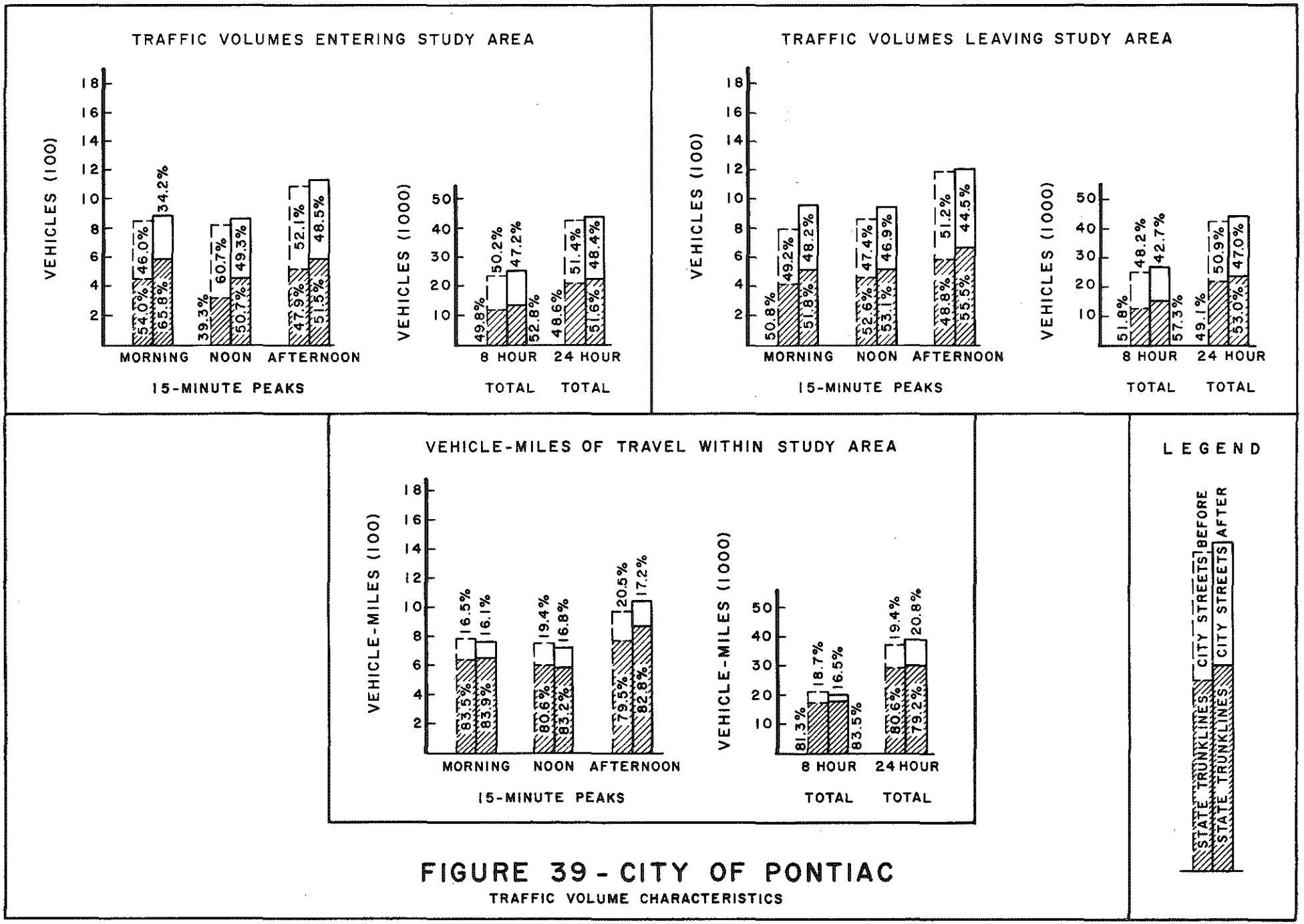


FIGURE 39 - CITY OF PONTIAC

TRAFFIC VOLUME CHARACTERISTICS

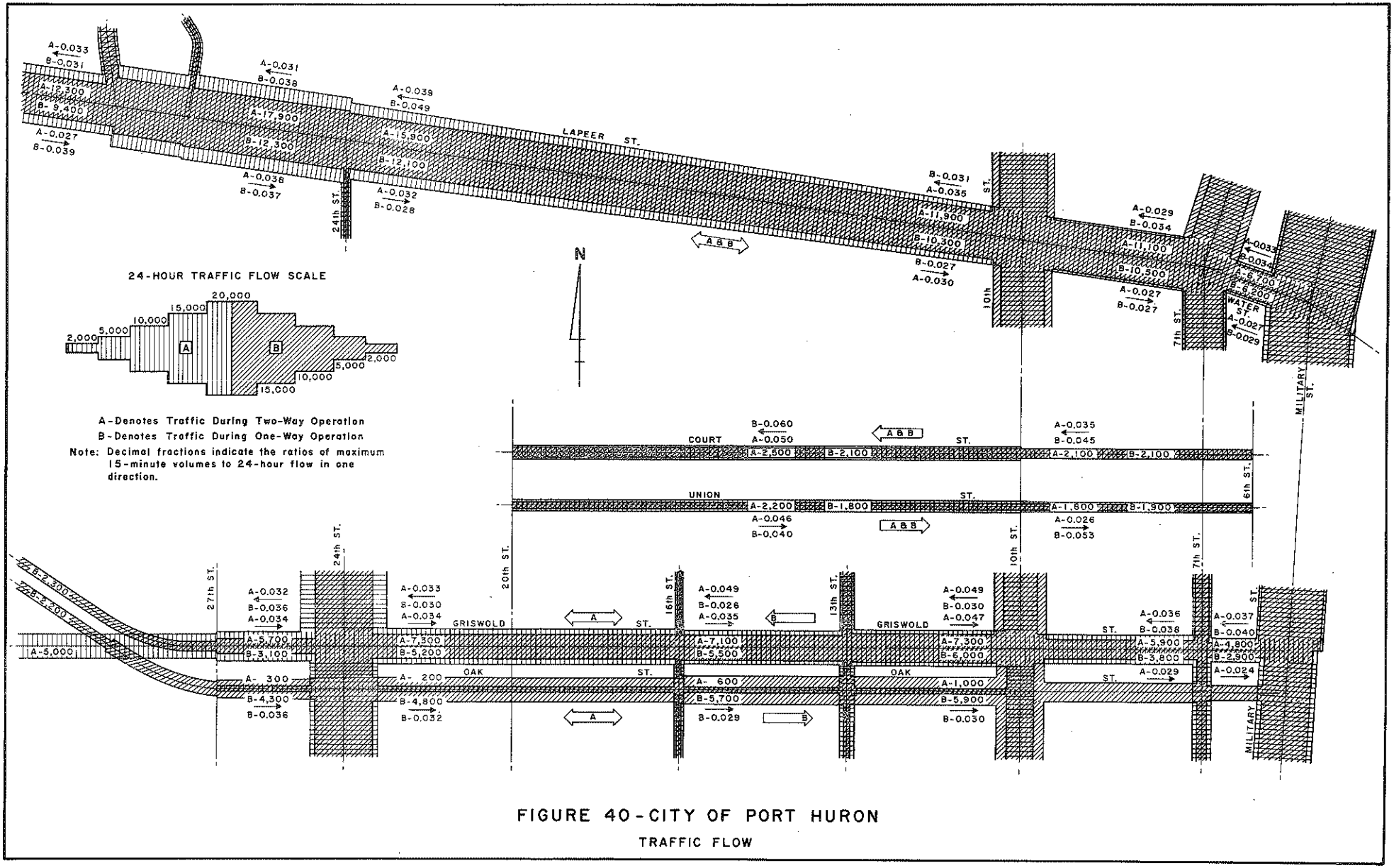


FIGURE 40 - CITY OF PORT HURON

TRAFFIC FLOW

TABLE 29

OBSERVED MAXIMUM HOURLY VOLUMES PER LANE

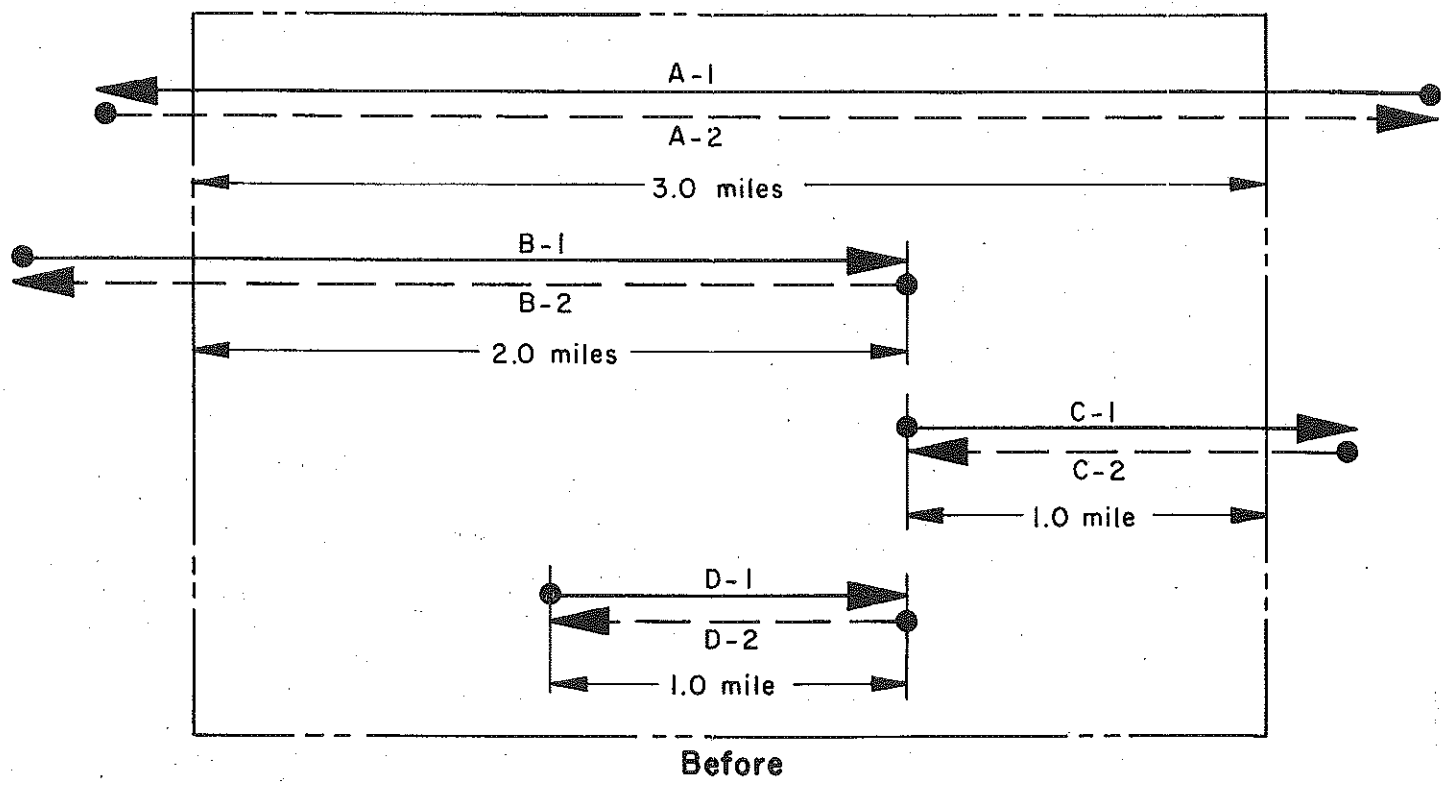
(Three Highest Values)

CITY	"BEFORE" PERIOD			"AFTER" PERIOD		
	Flow	Count Station	Time	Flow	Count Station	Time
KALAMAZOO	781	NWB Portage Ave. SE of Michigan Ave.	5P.M.	806	EB Michigan Ave. W of Harrison St.	6P.M.
	739	WB Kalamazoo Ave. W of Westnedge Ave.	12Noon	770	EB Michigan Ave. W of Harrison St.	5P.M.
	735	EB Michigan Ave. W of Harrison St.	6P.M.	734	EB Michigan Ave. W of Harrison St.	6P.M.
LANSING *	691	EB Saginaw St. W of Grand Ave.	6P.M.	639	NB Washington Ave. N of Jefferson St.	6P.M.
	666	NB Capitol Ave. S of Saginaw St.	6P.M.	620	NB Washington Ave. N of Jefferson St.	5P.M.
	656	EB Saginaw St. W of Washington Ave.	8A.M.	587	EB Saginaw St. W of Logan St.	5P.M.
PONTIAC	534	NWB Oakland Ave. NW of Montcalm	6P.M.	629	NWB Oakland Ave. NW of Montcalm	6P.M.
	508	NWB Oakland Ave. NW of Montcalm	6P.M.	625	NWB Oakland Ave. NW of Montcalm	6P.M.
	493	NWB Oakland Ave. NW of Wide Track Drive	5P.M.	600	NWB Oakland Ave. NW of Montcalm	6P.M.
PORT HURON	929	SB 24th St. N of Griswold St.	4P.M.	830	NB 24th St. N of Griswold St.	5P.M.
	879	WB Lapeer St. E of 24th St.	5P.M.	810	SB 24th St. S of Oak St.	8A.M.
	850	NB 24th St. N of Griswold St.	5P.M.	777	SB 24th St. S of Oak St.	4P.M.

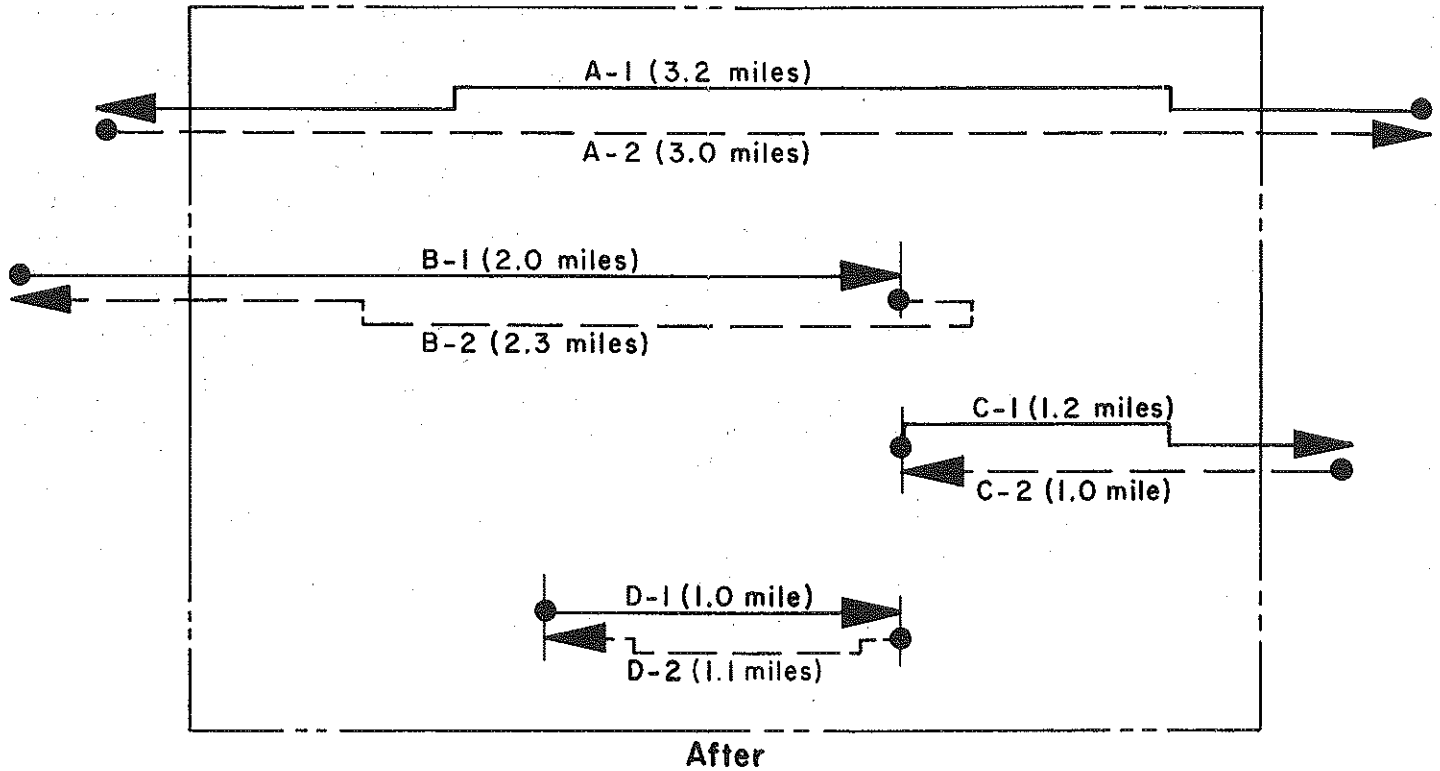
* - "After" period for Lansing refers to the initial One-Way phase.

Figure 41

TRIP PATTERNS IN AN AREA



Before



After

live outside the area and work within the area, (C) trips by commuters who live within the area and work outside, and (D) internal trips. To simplify the analysis, it will be assumed that there is one vehicle representing each of these trip categories, and that each vehicle makes two daily trips. Each trip is represented by a line, the full line representing the initial trip and the dashed line the return trip of each vehicle. Dots represent the origins and the arrowheads represent the destinations of these trips. The top sketch shows each of these eight trips and their assumed lengths within the study area.

In the bottom sketch it will be assumed that some new one-way streets were introduced and, hypothetically, this caused lengthening of some of the trips by the original four vehicles. These trip distances are shown in parentheses.

Remembering that each trip is caused by one vehicle only, a summation of daily vehicle-miles of travel within the area before the one-way operation would be as follows:

Trip	Vehicle-Miles of Travel in Area
A-1	3.0
A-2	3.0
B-1	2.0
B-2	2.0
C-1	1.0
C-2	1.0
D-1	1.0
D-2	1.0
Total Travel	14.0

In a real situation in a small area, trip category D will be very small in relation to total travel mileage, especially where major trunk line traffic traverses the area. In this study no surveys were conducted to count the number of internal trips (category D) although their flow was counted at internal volume-count stations together with the rest of the trips. Entering and leaving traffic was counted at the boundaries of the area and this was made up of category-A, B and C trips. Ignoring the negligible category-D trips in our fictitious area, it can be stated that 14.0 vehicle-miles of travel was the result of four entering and four leaving vehicles, or a total of eight daily vehicles. Average travel length generated by one vehicle counted at the area boundary would then be $14 \div 8 = 1.75$ miles.

In the after situation, the summation of the vehicle-miles of travel would be as follows:

Trip	Vehicle-Miles of Travel in Area
A-1	3.2
A-2	3.0
B-1	2.0
B-2	2.3
C-1	1.2
C-2	1.0
D-1	1.0
D-2	1.1
Total Travel	14.8

Average travel length generated by each vehicle counted at the area boundary would now be $14.8 \div 8 = 1.85$ miles. In this hypothetical case, then, there was 0.10 miles of "adverse" travel distance per vehicle in the after period as compared with the before period.

Applying this analysis now to the actual situation in Lansing, use will be made of the 24-hour totals of traffic in Tables 20-a, 21-a and 22-a which represent the changes during the initial study phase. In the before period, rounding the figures to the nearest thousand (since this approximation is within the degree of accuracy which is dependent on the coverage of the volume stations as earlier discussed), the total of entering and leaving traffic, from Tables 20-a and 21-a, was $67,000 + 63,000 = 130,000$ vehicles. Total travel, from Table 22-a, was 48,000 vehicle-miles. Consequently, the average travel length generated by each vehicle counted at the area boundary was $48,000 \div 130,000 = 0.37$ mile. Using the figures, from the same three tables, corresponding to the after period, the total of entering and leaving traffic was $73,000 + 74,000 = 147,000$, and total travel was 59,000. The new average travel length per vehicle was $59,000 \div 147,000 = 0.40$ mile or 0.03 mile more than the before figure. This is a difference of about 8 percent which is not excessive.

TABLE 30

CITY OF KALAMAZOO
CUMULATIVE DURATION OF LANE STOPPAGES DUE TO LEFT TURNS
Two-Way Operation
Intersection of Kalamazoo St. and Rose St.
(Extent of Delay in Seconds)

15 Min. Period	On Rose St.		On Kalamazoo St.	
	From N	From S	From E	From W
6-6:15A	4	0	0	0
30	8	0	0	0
45	15	5	10	4
7A	30	15	100	75
7-7:15A	10	0	43	0
30	25	21	10	0
45	50	10	90	40
8A	45	150	150	15
8-8:15A	15	55	170	20
30	20	10	30	10
45	20	0	10	10
9A	10	20	75	10
3-3:15P	15	110	60	20
30	50	80	130	25
45	70	160	120	20
4P	115	75	125	35
4-4:15P	25	130	110	5
30	55	140	115	35
45	120	115	105	85
5P	65	120	180	10
5-5:15P	130	230	175	90
30	85	175	80	60
45	5	120	0	40
6P	10	70	0	30
6 Hour Total	997	1711	1888	604

TABLE 31

CITY OF LANSING

CUMULATIVE DURATION OF LANE STOPPAGES DUE TO LEFT TURNS

Intersection of Saginaw St. and Verlinden Ave.

(Extent of Delay in Seconds)

15 Min. Period	From N. on Verlinden		From E. on Saginaw		From S. on Verlinden		From W. on Saginaw	
	Before	After	Before	After	Before	After	Before	After
6-6:15A	0	0	16		3		8	0
30	0	0	36		35		0	0
45	0	0	12		37		13	0
7A	0	5	5		9		8	0
7-7:15A	0	0	26	No traffic from E. on account of one-way operation	0	No left turn on account of one-way operation	6	0
30	5	7	69		10		0	0
45	20	36	115		25		14	0
8A	13	24	102		21		20	0
8-8:15A	12	15	10		2		12	0
30	3	0	22		0		0	0
45	0	10	6		0		14	0
9A	2	0	26		0		0	0
3-3:15P	2	0	25		9		63	0
30	3	0	57		4		36	0
45	47	0	70		73		193	0
4P	20	0	91		79		124	0
4-4:15P	24	0	97		189		171	0
30	59	0	88		32		22	0
45	7	0	19		31		34	0
5P	132	0	30		27		55	0
5-5:15P	14	0	7		21		141	0
30	8	0	9		25		26	0
45	6	0	5		2		58	0
6P	0	0	15		5		4	0
6 Hr. Total	377	97	958		639		1022	0

TABLE 32

CITY OF LANSING
CUMULATIVE DURATION OF LANE STOPPAGES DUE TO LEFT TURNS
Intersection of Saginaw St. and Jenison Ave.
(Extent of Delay in Seconds)

15 Min. Period	From N. on Jenison		From E. on Saginaw		From S. on Jenison		From W. on Saginaw	
	Before	After	Before	After	Before	After	Before	After
6-6:15A	0	0	0		0		0	0
30	0	9	5		11		0	0
45	0	0	7		24		0	0
7A	2	19	3		2		10	0
7-7:15A	4	14	0	No traffic from E. on account of one-way operation.	0	No left turn on account of one-way operation.	0	0
30	5	30	0		2		7	0
45	11	66	0		36		0	0
8A	12	44	65		18		54	0
8-8:15A	0	2	0		0		0	0
30	7	13	13		8		0	0
45	4	15	8		16		3	0
9A	0	17	4		3		0	0
3-3:15P	0	0	2		7		0	0
30	8	20	0		23		0	0
45	9	69	54		13		0	0
4P	15	36	92		31		4	0
4-4:15P	18	59	71		24		31	0
30	6	43	50		28		20	0
45	21	80	28		24		5	0
5P	8	80	39		7		8	0
5-5:15P	27	108	50		39		21	0
30	22	46	16		40		0	0
45	14	44	55		28		19	0
6P	10	30	7		11		4	0
6-Hr. Total	203	827	569		395		186	0

TABLE 33

CITY OF LANSING
CUMULATIVE DURATION OF LANE STOPPAGES DUE TO LEFT TURNS
Intersection of Oakland Ave. and Logan St.
(Extent of Delay in Seconds)

15 Min. Period	From N on Logan		From S on Logan		From W on Oakland	
	Before	After	Before	After*	Before	After
6-6:15A	0		0	0	0	
30	0		3	6	0	
45	0		15	41	0	
7A	0		12	53	0	
7-7:15A	0		7	27	0	
30	0		0	10	0	
45	0		30	70	0	
8A	0		17	65	0	
8-8:15A	0		21	67	0	
30	0		8	30	0	
45	2		6	56	0	
9A	0		4	34	0	
3-3:15P	0		0	45	0	
30	0		13	79	0	
45	0		20	117	0	
4P	0		15	92	0	
4-4:15P	0		49	75	0	
30	10		5	96	0	
45	0		15	65	0	
5P	0		19	110	0	
5-5:15P	0		80	160	0	
30	0		51	41	0	
45	0		47	73	0	
6P	0		9	35	0	
6-Hr. Total	12		446	1447	0	

No left turn on account of one-way operation

No traffic from W on account of one-way operation

NOTE: Oakland east of the intersection was closed to traffic during the "before" survey, and it was operating one-way during the "after" period.

* Final Phase

TABLE 34

CITY OF PONTIAC

CUMULATIVE DURATION OF LANE STOPPAGES DUE TO LEFT TURNS

Intersection of Oakland Ave., Cass Ave., and Montcalm St.

(Extent of Delay in Seconds)

15 Min. Period	From NW on Oakland		From SE on Oakland		From SW on Cass	
	Before	After	Before	After	Before	After
6-6:15A	11	0	0	0	0	
30	4	0	0	0	0	
45	50	0	17	0	0	
7A	58	0	0	0	15	
7-7:15A	21	0	0	0	23	
30	48	0	9	0	0	
45	40	60	0	0	12	
8A	47	90	12	0	11	
8-8:15A	28	0	18	0	12	
30	10	0	19	0	10	
45	24	0	15	0	0	
9A	30	0	22	0	28	
3-3:15P	126	0	17	0	64	
30	85	0	30	0	31	
45	124	0	28	0	98	
4P	95	420	50	0	82	
4-4:15P	140	90	0	0	28	
30	51	480	10	0	74	
45	58	540	0	0	151	
5P	143	360	10	0	101	
5-5:15P	293	330	7	0	118	
30	32	240	17	0	59	
45	123	270	0	0	109	
6P	106	60	17	0	57	
6-Hr. Total	1747	2940	298	0	1083	

No traffic from SW on account of one-way operation

NOTE: No left turns were allowed from NE on Montcalm during the "before" period ad well as during the "after" period.

TABLE 35

CITY OF PONTIAC
CUMULATIVE DURATION OF LANE STOPPAGES DUE TO LEFT TURNS
Intersection of Oakland Ave. and Johnson St.
(Extent of Delay in Seconds)

15 Min. Period	From SW on Johnson		From NW on Oakland		From NE on Johnson		From SE on Oakland	
	Before	After	Before	After	Before	After	Before	After
6-6:15A	0	No left-turn delay on account of one-way operation on Johnson	0	No traffic from SW on account of one-way operation	0	No traffic from NE on account of one-way operation	0	No left-turn on account of one-way operation on Johnson
30	4		0		0		0	
45	0		0		0		0	
7A	7		0		0		29	
7-7:15A	0		2		0		11	
30	0		0		0		2	
45	6		64		4		40	
8A	0		44		0		58	
8-8:15A	5		12		0		16	
30	0		0		0		4	
45	0		16		8		12	
9A	0		0		0		87	
3-3:15P	18		5		4		34	
30	10		12		0		87	
45	20		65		16		45	
4P	31		30		7		17	
4-4:15P	52		25		8		26	
30	29		54		0		21	
45	40		39		0		27	
5P	35		44		6		41	
5-5:15P	103		68		0		74	
30	35		52		6		51	
45	19		54		0		43	
6P	15		28		5		17	
6-Hr. Total	429		614		64		742	

TABLE 36

CITY OF PONTIAC
CUMULATIVE DURATION OF LANE STOPPAGES DUE TO LEFT TURNS
Intersection of Oakland Ave., Baldwin Ave., and Allison St.
(Extent of Delay in Seconds)

15 Min. Period	From SE on Oakland		From SW on Allison		From N on Baldwin	
	Before	After	Before	After	Before	After
6-6:15A	0	0	0	0	0	
30	0	0	0	0	0	
45	0	0	0	0	0	
7A	0	0	0	0	0	
7-7:15A	0	0	0	0	0	
30	0	0	0	0	0	
45	7	0	0	0	0	
8A	14	0	0	0	0	
8-8:15A	8	0	0	0	0	
30	0	0	5	0	0	
3-3:15P	9	0	0	0	0	
30	18	0	0	0	0	
45	0	0	0	0	0	
4P	0	0	0	0	0	
4-4:15P	0	0	0	0	0	
30	10	0	0	0	0	
45	0	0	0	0	0	
5P	0	0	0	0	0	
5-5:15P	0	0	0	0	20	
30	0	0	0	0	0	
45	6	0	0	0	0	
6P	0	0	0	0	0	
5½-Hr. Total	72	0	5	0	20	

No left turn due to one-way operation

NOTE: No left turns from NW on Oakland onto Baldwin were allowed during the "before" period.

TABLE 37

CITY OF PONTIAC
CUMULATIVE DURATION OF LANE STOPPAGES DUE TO LEFT TURNS
Intersection of Cass Ave. and Johnson St.
(Extent of Delay in Seconds)

15 Min. Period	From SW on Johnson		From NW on Cass		From NE on Johnson		From SE on Cass	
	Before	After	Before	After	Before	After	Before	After
6-6:15A	0		0	0	0		0	
30	0		0	0	0		0	
45	12		0	0	0		0	
7A	39		0	0	0		0	
7-7:15A	28		0	0	0		0	
30	32		0	0	0		0	
45	47		0	0	0		0	
8A	27		0	0	0		0	
8-8:15A	22		0	0	0		0	
30	10		0	0	0		0	
45	3		0	0	0		0	
9A	27		0	0	0		0	
3-3:15P	6		0	0	0		0	
30	26		0	0	10		65	
45	52		0	0	14		12	
4P	44		2	0	10		6	
4-4:15P	*		0	0	4		4	
30	47		0	0	0		6	
45	72		0	0	0		0	
5P	50		0	0	0		12	
5-5:15P	90		0	0	7		10	
30	71		0	0	0		15	
45	58		0	0	0		3	
6P	42		0	0	15		0	
6-Hr. Total	805		2	0	60		133	

No left turn on account of one-way operation

No traffic from NE due to one-way operation of Johnson NE of the intersection

No traffic from SE on account of one-way operation

* 127 seconds of delay due to railroad train did not allow timing of delay due to left turns.

TABLE 38

CITY OF PORT HURON
CUMULATIVE DURATION OF LANE STOPPAGES DUE TO LEFT TURNS
Two-Way Operation
Intersection of Griswold St. and 24th St.
(Extent of Delay in Seconds)

15 Min. Period	On 24th St.		On Griswold St.	
	From N	From S	From E	From W
6-6:15A	0	15	8	0
30	0	5	5	5
45	26	15	37	0
7A	0	21	98	14
7-7:15A	0	29	21	0
30	16	0	8	0
45	35	27	80	16
8A	37	61	152	0
8-8:15A	18	0	21	0
30	8	10	10	0
45	26	0	6	0
9A	12	9	15	10
11-11:15A	48	10	27	20
30	33	26	15	0
45	67	32	38	8
12N	57	12	28	30
12-12:15P	124	48	15	25
30	62	10	53	28
45	19	9	85	0
1P	23	28	7	8
3-3:15P	28	15	52	15
30	37	51	58	33
45	34	13	33	54
4P	23	6	39	34
4-4:15P	28	11	126	78
30	65	42	30	16
45	112	38	19	34
5P	24	0	32	6
5-5:15P	88	0	0	15
30	22	0	0	15
45	46	19	0	0
6P	52	0	20	0
8-Hr. Total	1170	562	1138	464

TABLE 39

CITY OF PORT HURON

CUMULATIVE DURATION OF LANE STOPPAGES DUE TO LEFT TURNS

Two-Way Operation
Intersection of Griswold St. and Military St.
(Extent of Delay in Seconds)

15 Min. Period	On Military St.		On Griswold St.	
	From S	From N	From E	From W
6-6:15A	5	0	0	0
30	22	0	0	6
45	18	0	5	0
7A	0	0	4	0
7-7:15A	0	0	0	0
30	0	0	0	0
45	5	0	6	0
8A	0	25	4	0
8-8:15A	15	0	0	8
30	4	21	9	0
45	13	0	0	0
9A	0	44	5	0
11-11:15A	31	8	14	19
30	25	81	29	14
45	50	0	23	0
12N	75	16	0	10
12-12:15P	12	11	5	11
30	5	0	25	0
45	31	0	0	5
1P	47	11	8	0
3-3:15P	48	0	0	12
30	43	33	7	9
45	58	14	0	9
4P	83	19	11	0
4-4:15P	41	5	5	12
30	29	0	0	0
45	98	41	0	28
5P	81	12	13	0
5-5:15P	125	13	8	22
30	71	0	13	0
45	75	0	0	6
6P	63	18	0	0
8-Hr. Total	1173	372	194	171

Using the information from Tables 20-b, 21-b and 22-b for Lansing final phase, the "before" and "after" figures for average travel length per vehicle are 0.48 and 0.55 mile, respectively, or a change of 15 percent.

Similar calculations for Kalamasoo, using the information from Tables 23-25, result in average travel length per vehicle crossing the boundary of the study area of 0.38 mile during the "before", and 0.37 mile during the "after" period. This is a decrease rather than an increase; however, considering the limited accuracy of this calculation method, it would be safer to state that there was no difference, even if an apparent reduction may be disregarded.

In the case of Pontiac the average travel length was calculated to have changed from 0.44 to 0.45 mile.

It is conjectured that shortening of some trips in the after period due to removal of left-turn prohibitions, and choice of new and shorter routes, made possible in some cases with the elimination of congestion at bottlenecks, has offset some of the adverse distances caused by the one-way movements, with the result that trip lengths are kept shorter than might be expected.

RESULTS OF TURNING-MOVEMENT STUDIES

In all of the four study cities, turning-movement counts were taken at a few intersections as earlier described. The numbers of vehicles making turns did not, in themselves, provide information of any significance other than some auxiliary data which on occasion provided supplement to the volume counts. Survey of left-lane stoppages which were taken during the turning-movement counts, however, provided insight into vehicle delays. Tables 30 through 39 contain this information at the various intersections of the study cities.

Table 30 is for the intersection of Kalamazoo Street and Rose Street in the City of Kalamazoo, and shows the delays due to left turns in conflict during each 15-minute period of the two-way operation. These figures represent the total number of seconds during each 15-minute period when the left lane contained stopped vehicles unable to move because of vehicles waiting to turn left. They do not reflect the total time loss by all vehicles, since this would require more extensive data showing how long each vehicle waited. No delays were encountered during the one-way operation.

Table 31 for the intersection of Saginaw Street and Verlinden Avenue in Lansing indicates considerable reduction in delays during the one-way phase. Table 32 for the Saginaw and Jenison intersection in the same city shows an increase in the delays in Jenison traffic from the north. There are no delays on any of the other three approaches, of course, due to one-way operation. Table 33 for the Oakland and Logan intersection shows substantial increase in the delays from the south, which is only natural because during the "before" phase there was no northbound traffic at this intersection with destination on the westbound state trunk line.

In Table 34 for the Oakland, Cass and Montcalm intersection in Pontiac, delays have lengthened mainly during the afternoon peaks on the approach from northwest. This is due to the general increase in the traffic volumes during the intervening period. Delays on the other approaches have been entirely eliminated due to one-way operation. Left turns were not allowed from Montcalm Street even during the two-way phase, so that this approach is not shown in the table. All left-turn delays are eliminated at the Oakland and Johnson intersection as seen in Table 35. The same is true for the Oakland, Baldwin and Allison intersection as shown in Table 36. Again no left-turns were allowed from southeastbound Oakland during the before phase. The Cass and Johnson intersection delays were also entirely eliminated as indicated in Table 37.

Tables 38 and 39 for two intersections of Griswold Street in Port Huron show the left-turn delays during the two-way phase. These were all eliminated during the one-way phase.

RESULTS OF ACCIDENT STUDIES

Extensive tabulations of accident analysis for the four cities are presented in the following pages,

as well as supplementary lists, in the Appendices, for accident experience at specific locations. However, the data do not indicate, in all cases, similar trends in all cities as to improvement or worsening of traffic safety after conversion to one-way operation.

Degree of traffic safety is a parameter which does not always reflect accurately the change in any one aspect of highway transportation. Recent research into accident causes has drawn attention to the fact that every traffic accident is usually the result of a series of failures in a system comprising several interdependent elements such as the driver, the vehicle, physical conditions of the roadway, type of land use, quality of traffic flow, traffic control devices, natural and environmental conditions like weather and lighting, traffic law enforcement, general economic conditions, etc. Therefore, it is difficult to evaluate effectively the result of only the change in traffic operation from two-way to one-way. It appears that, at least in certain cases, some of the other elements or their combinations have had stronger adverse effect on safety than the favorable effect of one-way operation per se.

Table 40 compares the accident types on the eastern section of Saginaw Street in Lansing before and after this section was changed to one-way operation. It is at once apparent that substantial reduction has been achieved in rear-end and right-angle collisions. On the other hand, sideswipes have risen very sharply. Overall performance of the one-way trunk line, expressed in accidents per million vehicle-miles, has worsened.

Table 41 is a similar comparison of the western section of Saginaw Street where traffic continued to run in both directions during the interim period. A general upward trend is noted in the number and rate of accidents in this section also.

Table 42 compares accidents on Saginaw Street during the two-way and the final one-way operation. This result is the reverse of that in Table 40, and a significant reduction is indicated in the rate of accidents. Table 43 shows the accident experience of the total area studied in Lansing during the three phases. The accident total worsened between the two-way and the initial one-way phase but improved during the final one-way phase. Considering the increase in traffic volume of about 50 percent during the five and a half years, this improvement is noteworthy. This is also true for the injury accidents although the absolute number does not show a decrease between the initial and final one-way phases. Table 44 is a breakdown of the totals shown in Table 43 by day and night.

One last remark concerning the accident experience in Lansing will be about the change in the safety record of the Saginaw-Grand intersection. During the two-way operation, despite heavy left-turns from westbound Saginaw onto Grand in the presence of opposing traffic, and with considerably higher total traffic volumes on Saginaw Street, there were only three property-damage accidents in one year (See Appendix 13). During the one-way operation, with the completion of the north leg of Grand Avenue, a four-leg intersection of two one-way streets was formed, and stop-and-go signals were installed. Also, as mentioned earlier, the flow direction on Grand was reversed from southbound to northbound. During the one-year period, 12 property-damage and 5 injury-accidents were reported. This experience of rise in accidents upon signal installations is typical of numerous other intersections throughout the state.

Table 45 shows the accident experience on the section of Michigan Avenue in Kalamazoo where traffic was changed to one-way. Appreciable reduction is observed, especially in rear-end collisions and parking accidents. However, a control section of Michigan Avenue where operation remained two-way is shown in Table 46, and a similar reduction in the accident rate per million vehicle-miles has occurred which nullifies the apparent improvement due to one-way operation. Table 47 contains accidents on Kalamazoo Avenue which was a local two-way street during the before period. Accident rate has decreased on this street also. Tables 48 and 49 reflect the experience of the total study area. A reduction in total accidents from 1380 to 1291 is experienced, a decrease of 6 percent. Again, as a control figure, this should be compared with a reduction of 1 percent in the number of accidents

(Text continued on p. 133)

TABLE 40

CITY OF LANSING

Accident Types on Saginaw Street
Between Logan (Excluded) and Grand (Included)
(One-Year Periods)

Type of Accident	Two-Way Phase (Jan. 31, 1964 -Jan. 30, 1965)		One-Way Initial Phase (Apr. 30, 1965 -Apr. 29, 1966)	
Rear-end, straight	73		26	
Rear-end involving left turn	5	83	--	34
Rear-end involving right turn	5		8	
Head-on, straight	–		–	
Head-on involving left turn	9		1	
Sideswipe, same direction	19	22	58	60
Sideswipe, opposite direction	3		2	
Right angle	41		22	
Involving parking of parked vehicle	5		1	
Hitting fixed object	2		6	
Backing vehicle	9		7	
Hitting pedestrian	1		2	
Unknown	1		–	
Total	173		133	
Rate of total accidents per million vehicle-miles	24.7		26.8	

TABLE 41

CITY OF LANSING

Accident Types on Saginaw Street
Between Belt Line RR and Logan (Inclusive)
(Two-Way Operation During Both Study Periods)

Type of Accident	One-Year Before (Jan. 31, 1964 Jan. 30, 1965)		One-Year After (Apr. 30, 1965 -Apr. 29, 1966)	
Rear-end, straight	45		58	
Rear-end involving left turn	7	57	3	68
Rear-end involving right turn	5		7	
Head-on, straight	1		–	
Head-on involving left turn	6		10	
Sideswipe, same direction	14	16	19	21
Sideswipe, opposite direction	2		2	
Right angle	25		24	
Involving parking or parked vehicle	1		2	
Hitting fixed object	5		3	
Backing vehicle	7		4	
Hitting pedestrian	1		2	
Unknown	2		–	
Total	121		134	
Rate of total accidents per million vehicle-miles	19.6		21.5	

TABLE 42
CITY OF LANSING
Accident Types on Saginaw Street Between Belt Line RR and Cedar (Inclusive) (One-Year Periods)

Type of Accident	Two-Way Phase (Jan. 31, 1964-Jan. 30, 1965)		One-Way Final Phase (Aug. 14, 1969-Aug. 13, 1970)	
Rear-end, straight	131		81	
Rear-end involving left turn	12	153	9	103
Rear-end involving right turn	10		13	
Head-on, straight	1		–	
Head-on involving left turn	15		4	
Sideswipe, same direction	55	60	79	81
Sideswipe, opposite direction	5		2	
Right angle	82		65	
Involving parking or parked vehicle	6		--	
Hitting fixed object	11		21	
Backing vehicle	16		9	
Hitting pedestrian	2		2	
Other	–		1	
Unknown	3		--	
Total	349		286	
Rate of total accidents per million vehicle-miles	23.3		18.8	

TABLE 43
CITY OF LANSING
Accident Types Within Study Area (One-Year Periods)

Type of Accident	Two-Way Phase (Jan. 31, 1964-Jan. 30, 1965)		One-Way Initial Phase (Apr. 30, 1965-Ap. 29, 1966)		One-Way Final Phase (Aug. 14, 1969-Aug. 13, 1970)	
Rear-end, straight	147		163		173	
Rear-end involving left turn	16	174	13	199	19	208
Rear-end involving right turn	11		23		16	
Head-on, straight	3		–		–	
Head-on involving left turn	27		25		8	
Sideswipe, same direction	85	93	166	174	129	133
Sideswipe, opposite direction	8		8		4	
Right angle	139		138		122	
Involving parking or parked vehicle	29		28		9	
Hitting fixed object	27		27		39	
Backing vehicle	24		20		23	
Hitting pedestrian	2		12		5	
Other	–		–		2	
Unknown	2		1		2	
Total	520		624		551	
Injury accidents	114*		133		135*	

* 1 fatal

TABLE 44
CITY OF LANSING
Accidents Within Study Area by Day or Night
(One-Year Periods)

	Two-Way Phase (Jan. 31, 1964-Jan. 30, 1965)	One-Way Initial Phase (Ap. 30, 1965-Ap. 29, 1966)	One-Way Final Phase (Aug. 14, 1969-Aug. 13, 1970)
Day Time	365	463	403
Night time	123	140	148
Twilight	32	21	–
Total	520	624	551

TABLE 45
CITY OF KALAMAZOO
Accident Types on Michigan Avenue
Between Main (Excluded) and Porter (Included)

Type of Accident	One-Year Before		One-Year After	
Rear-end, straight	158	176	83	107
Rear-end involving left turn	9		19	
Rear-end involving right turn	9		5	
Head-on, straight	1		–	
Head-on involving left turn	7		2	
Sideswipe, same direction	57	57	54	58
Sideswipe, opposite direction	–		4	
Right angle	35		40	
Involving parking or parked vehicle	56		38	
Hitting fixed object	9		4	
Backing vehicle	10		11	
Hitting pedestrian	5		7	
Unknown	1		–	
Total	357		267	
Rate of total accidents per million vehicle-miles	57.5		52.3	

TABLE 46
CITY OF KALAMAZOO
Accident Types on Michigan Avenue Between Lovell and Main (Inclusive)

Type of Accident	One-Year Before		One-Year After	
Rear-end, straight	40		40	
Rear-end involving left turn	1	42	5	48
Rear-end involving right turn	1		3	
Head-on, straight	–		3	
Head-on involving left turn	1		1	
Sideswipe, same direction	15	16	13	14
Sideswipe, opposite direction	1		1	
Right angle	13		3	
Involving parking or parked vehicle	2		1	
Hitting fixed object	7		9	
Backing vehicle	–		1	
Hitting pedestrian	1		–	
Total	82		80	
Rate of total accidents per million vehicle-miles	59.5		55.6	

TABLE 47
CITY OF KALAMAZOO
Accident Types on Kalamazoo Avenue

Type of Accident	One-Year Before		One-Year After	
Rear-end, straight	36		40	
Rear-end involving left turn	2	40	11	51
Rear-end involving right turn	2		–	
Head-on, straight	–		2	
Head-on involving left turn	5		1	
Sideswipe, same direction	26	30	35	37
Sideswipe, opposite direction	4		2	
Right angle	34		30	
Involving parking or parked vehicle	11		7	
Hitting fixed object	8		4	
Backing vehicle	5		5	
Hitting pedestrian	2		4	
Total	135		141	
Rate of total accidents per million vehicle-miles	33.5		29.4	

TABLE 48
CITY OF KALAMAZOO
Accident Types Within Study Area

Type of Accident	One-Year Before		One-Year After	
Rear-end, straight	422		336	
Rear-end involving left turn	33	484	58	419
Rear-end involving right turn	29		25	
Head-on, straight	11		11	
Head-on involving left turn	33		26	
Sideswipe, same direction	263	290	269	292
Sideswipe, opposite direction	27		23	
Right angle	205		237	
Involving parking or parked vehicle	182		144	
Hitting fixed object	75		70	
Backing vehicle	73		67	
Hitting pedestrian	23		22	
Unknown	4		3	
Total	1380		1291	

TABLE 49
CITY OF KALAMAZOO
Accidents Within Study Area by Day or Night

	One-Year Before	One-Year After
Day time	950	909
Night time	375	321
Twilight	52	55
Unknown	3	6
Total	1380	1291

TABLE 50
CITY OF PONTIAC
Accident Types on Oakland Avenue Between Cass-Montcalm (Included) and Wide Track Drive (Included)

Type of Accident	One-Year Before		One-Year After	
Rear-end, straight	33		27	
Rear-end involving left turn	8	47	1	32
Rear-end involving right turn	6		4	
Head-on, straight	–		–	
Head-on involving left turn	18		7	
Sideswipe, same direction	27	31	57	58
Sideswipe, opposite direction	4		1	
Right angle	31		20	
Involving parking or parked vehicle	5		2	
Hitting fixed object	11		9	
Backing vehicle	4		1	
Hitting pedestrian	3		2	
Unknown	1		–	
Other	–		2	
Total	151		133	
Rate of total accidents per million vehicle-miles	24.9		31.9	

TABLE 51
CITY OF PONTIAC
Accident Types on Oakland Avenue Between West Boulevard (Included) and Cass-Montcalm (Excluded)

Type of Accident	One-Year Before		One-Year After	
Rear-end, straight	6		5	
Rear-end involving left turn	7	15	7	12
Rear-end involving right turn	2		–	
Head-on, straight	–		–	
Head-on involving left turn	6		3	
Sideswipe, same direction	5	5	6	6
Sideswipe, opposite direction	–		–	
Right angle	8		5	
Involving parking or parked vehicle	2		4	
Hitting fixed object	3		4	
Backing vehicle	1		–	
Hitting pedestrian	1		–	
Other	–		1	
Total	41		35	
Rate of total accidents per million vehicle-miles	5.6		4.3	

TABLE 52
CITY OF PONTIAC
Accident Types on Cass Avenue Between Oakland-Montcalm (Excluded) and Wide Track Drive (Included)

Type of Accident	One-Year Before		One-Year After	
Rear-end, straight	10	10	21	22
Rear-end involving left turn	–		–	
Rear-end involving right turn	–		1	
Head-on, straight	–		–	
Head-on involving left turn	1		1	
Sideswipes, same direction	3	4	14	14
Sideswipes, opposite direction	1		–	
Right angle	13		35	
Involving parking or parked vehicle	1		1	
Hitting fixed object	3		10	
Backing vehicle	1		4	
Hitting pedestrian	–		–	
Other	–		1	
Total	33		88	
Rate of total accidents per million vehicle-miles	12.9		19.4	

TABLE 53
CITY OF PONTIAC
Accident Types Within Study Area

Type of Accident	One-Year Before		One-Year After	
Rear-end, straight	57	80	61	75
Rear-end involving left turn	15		9	
Rear-end involving right turn	8		5	
Head-on, straight	–		–	
Head-on involving left turn	28		14	
Sideswipe, same direction	39	48	89	91
Sideswipe, opposite direction	9		2	
Right angle	63		82	
Involving parking or parked vehicle	20		17	
Hitting fixed object	21		31	
Backing vehicle	6		5	
Hitting pedestrian	7		4	
Unknown	1		–	
Other	–		4	
Total	274		323	

TABLE 54
CITY OF PONTIAC
Accidents Within Study Area by Day or Night

	One-Year Before	One-Year After
Day time	187	225
Night time	87	98
Total	274	323

TABLE 55
CITY OF PORT HURON
Accident Types on Griswold Street

Type of Accident	One-Year Before	One-Year After
Rear-end, straight	24	13
Rear-end involving left turn	1	3
Rear-end involving right turn	3	–
Head-on, straight	1	–
Head-on involving left turn	2	1
Sideswipe, same direction	10	34
Sideswipe, opposite direction	4	–
Right angle	21	36
Involving parking or parked vehicle	4	1
Hitting fixed object	6	3
Backing vehicle	4	2
Hitting pedestrian	4	–
Total	84	93
Rate of total accidents per million vehicle-miles	18.8	29.6

TABLE 56
CITY OF PORT HURON
Accident Types on Oak Street

Type of Accident	One-Year Before	One-Year After
Rear-end, straight	1	9
Rear-end involving left turn	–	1
Rear-end involving right turn	–	2
Head-on, straight	–	2
Head-on involving left turn	–	1
Sideswipe, same direction	1	24
Sideswipe, opposite direction	–	3
Right angle	6	33
Involving parking or parked vehicle	2	–
Hitting fixed object	–	3
Backing vehicle	1	2
Hitting pedestrian	–	1
Total	11	81
Rate of total accidents per million vehicle-miles	38.6	25.1

TABLE 57
CITY OF PORT HURON
Accident Types on Union & Court Streets

Type of Accident	One-Year Before	One-Year After
Rear-end, straight	23	23
Rear-end involving left turn	2	3
Rear-end involving right turn	1	2
Head-on, straight	2	3
Head-on involving left turn	–	1
Sideswipe, same direction	10	9
Sideswipe, opposite direction	3	2
Right angle	27	33
Involving parking or parked vehicle	2	1
Hitting fixed object	6	4
Backing vehicle	–	10
Hitting pedestrian	3	–
Total	79	91
Rate of total accidents per million vehicle-miles	37.0	46.1

TABLE 58
CITY OF PORT HURON
Accident Types within Oak-Griswold Corridor

Type of Accident	One-Year Before	One-Year After
Rear-end, straight	34	31
Rear-end involving left turn	1	6
Rear-end involving right turn	4	4
Head-on, straight	1	2
Head-on involving left turn	3	2
Sideswipe, same direction	13	61
Sideswipe, opposite direction	4	3
Right angle	35	83
Involving parking or parked vehicle	7	3
Hitting fixed object	6	14
Backing vehicle	5	12
Hitting pedestrian	4	3
Total	117	224

TABLE 59
CITY OF PORT HURON
Accident Types within Lapeer Avenue & Water Street Corridor

Type of Accident	One-Year Before	One-Year After
Rear-end, straight	107	77
Rear-end involving left turn	3	2
Rear-end involving right turn	12	7
Head-on, straight	–	6
Head-on involving left turn	6	18
Sideswipe, same direction	25	28
Sideswipe, opposite direction	7	8
Right angle	42	41
Involving parking or parked vehicle	3	4
Hitting fixed object	10	9
Backing vehicle	9	22
Hitting pedestrian	4	3
Overturned motorcycle	–	1
Total	228	226

TABLE 60
CITY OF PORT HURON
Accidents within Lapeer-Water & Oak-Griswold Corridors by Day or Night

	One-Year Before	One-Year After
Day time	197	290
Night time	112	139
Twilight	17	14
Unknown	19	7
	345	450

TABLE 61
CITY OF PORT HURON
Accidents on Union & Court Streets by Day or Night

	One-Year Before	One-Year After
Day time	50	59
Night time	21	30
Twilight	6	2
Unknown	2	–
	79	91

in the whole City of Kalamazoo (Table 62 – Sheet 6). Attention is called to the intersection of Michigan and Kalamazoo and the intersection of Main and Douglas in the City of Kalamazoo (See Appendix 16). These two intersections were signal-controlled during the two-way operation, and the signals were removed by virtue of the one-way operation, with the result that accidents dropped from 22 to 8 at the former intersection, and from 15 to 4 at the latter. This is a reverse of the situation at the Saginaw-Grand intersection in Lansing which experienced a rise in accidents after the installation of signals.

It is not possible to detect safety improvement in Pontiac due to the one-way project under study, except a relief in the total number of accidents on Oakland Avenue (Table 50). Accident rate, however, has increased on this street. The control section of Oakland where operation remained two-way, on the contrary, shows decrease in accident rates (Table 51). These rates, however, are very low in comparison with the one-way section because there are no signals in the control section, and the character of the traffic flow is not comparable. Cass Avenue accidents have also increased (Table 52). The study area experience is shown in Tables 53 and 54, and accidents have risen from 274 to 323. This is a rise of 18 percent which is higher than the 5 percent rise in accidents in all of the city.

As already explained, the one-way project in Port Huron, the last of the cities under study, was basically different. Accident totals and rates both increased on Griswold, one of the new one-way pair (Table 55). On Oak, the other street in this pair, accident totals increased but the rate decreased (Table 56). On Union and Court Streets, which form another one-way pair in this city and were examined for control purposes, accident totals and rates also rose (Table 57). Table 58 shows the accidents on the Oak-Griswold corridor, including a three-block portion of all cross-streets. The result is almost a doubling in the number of accidents. An unproportionate rise is seen in same-direction side-swipes and right-angle collisions. On the other hand, no relief can be observed as a trade-off on the Lapeer Avenue and Water Street corridor which is no longer on a State Trunk Line (Table 59). Table 60 is a summation of the two corridors mentioned above. A rise in accident experience from 345 to 450 is shown, which is 30 percent. Table 61 is a similar summation for the control pair of Union and Court. The rise here is from 79 to 91, or 15 percent. As a final comparison (from Table 62 – Sheet 6), city-wide rise was 38 percent.

A few casual references were made earlier to Table 62. This Comparative Accident Summary Table will now be reviewed in some detail. It is divided into six sections. Section I compares the streets in each city which changed from a two-way state trunk line to one-way trunk line operation. Section II refers to a control section of the same state trunk line as in Section I but where operation remained two-way. Section III indicates the street which changed from two-way into a one-way state trunk line operation. Section IV is an evaluation of the pair of streets, considered together, before and after they were made part of the one-way system. Section V reviews the accidents in all the streets considered in each study area. Finally, Section VI is the total experience in the whole city, and provides a general basis for comparison. In this last section the one-year periods do not coincide with the exact one-year periods of the before and after phases of the study, but they are calendar years nearest to these phases.

Table 62 will provide a multitude of information as to accident rates and types, and influence of signals, peak periods, etc. It will also make it possible to compare all the cities studied.

The last column in this table provides a total evaluation of the performance of all cities lumped together as one project. The "after" information in Lansing refers to the first "after", or the initial phase of the one-way operation. Some salient points in Table 62 are as follows:

In Section I, total accident rates (I-A.6) worsened in two cities and improved in one city. Comparing with the control streets in Section II (II-A.6), the rise in the accident rate of the one-way portion in Lansing (+8 percent) is not very much different from the two-way portion (+10 percent). A similar

observation is true for Kalamazoo, except that in this case the rates have both decreased (-9 percent vs. -7 percent). In Pontiac, however, the one-way section shows considerable deterioration (+28 percent) in comparison with the two-way section (-23 percent). This was discussed earlier. Injury accident rates (I-B.6) in Lansing showed no change in the one-way section but improved in the two-way (II-B.6) section (-12 percent). In Kalamazoo they showed improvement in the one-way portion (-38 percent) in comparison to a sharp deterioration in the two-way portion (+103 percent). Injury accident rates in Pontiac showed the same poor record as the total accident rates (+11 percent in Section I versus -36 percent in Section II). Rear-end collisions dropped on the one-way sections (I-D.3) in Lansing and Kalamazoo, whereas such collisions increased on the two-way sections (II-D.3). In Pontiac both the one-way and the two-way sections improved (-32 percent and -20 percent). Sideswipes worsened on the one-way sections (I-E.3) in all cities. A lesser degree of worsening was also experienced in the two-way sections (II-E.3) in Lansing and Pontiac, but a 12 percent improvement was observed in Kalamazoo. Because of the character of the traffic in the particular trunk lines under study, there were very few pedestrian accidents in all cities, and such small numbers are insufficient to indicate significant trends (I-G and II-G). Accidents during peak periods were reduced on the one-way section (I-L.3) in Lansing by 29 percent but increased on the control section (II-L.3) by 12 percent. Kalamazoo and Pontiac showed similar reduction trends on both sections. Accidents at signalized intersections dropped on the one-way sections of all cities (I-N.3) in contrast to some rise on the two-way portions (II-N.3). In all cities, accidents at non-signalized intersections increased on the one-way routes (I-P.3), while on the two-way routes (II-P.3) they increased only in Lansing and decreased in Pontiac. Accidents on the two-way section in Kalamazoo were too few to indicate a trend. Midblock accidents on the one-way streets (I-Q.3) showed considerable improvement in Lansing and Kalamazoo as compared with the two-way portion (II-Q.3). In Pontiac no change occurred on the one-way street but a 40 percent rise in midblock accidents took place on the two-way section.

The safety record of the streets which were not state trunk lines before and were converted into one of the one-way trunk line pair was aggravated in all cities except Kalamazoo where a slight improvement was observed (III-A.3). In most cases this aggravation was the direct result of much heavier traffic volumes on these streets during the after phase. An extreme example of such a situation occurred in Lansing. Former Oakland and Jefferson Streets were purely residential access streets with no through-traffic whatever. In fact, this route was discontinuous at two locations, and physically no through-movement was possible. Therefore, traffic volumes and speeds were in no way comparable with the "after" phase when actually a new state trunk line was built, where these streets existed before, to carry heavy traffic, and the accident experience became proportionately severe.

Section IV is a summation of Sections I and III, and serves as a balance sheet of gains and losses in accidents on the state trunk line route through the study area. This overall evaluation indicated improvement in the rate of total accidents (IV-A.6) for Kalamazoo and deterioration in Pontiac. No significant change occurred in Lansing. The rate of injury accidents (IV-B.6) decreased in Kalamazoo, increased in Pontiac and did not materially change in Lansing. Intersection accidents (IV-O.3) increased in Lansing and Pontiac, and decreased slightly in Kalamazoo. Midblock accidents (IV-Q.3) improved in Lansing and Kalamazoo but worsened in Pontiac.

From Section V it may be deduced that total accidents in the study area (V-A.3) increased in Lansing, Pontiac and Port Huron, and decreased in Kalamazoo. Similar results were seen for injury accidents (V-B.3). Pedestrian accidents remained practically the same in Kalamazoo, decreased in Pontiac and Port Huron, but increased in Lansing.

(Text continued on p. 141)

TABLE 62

COMPARATIVE ACCIDENT SUMMARY

Two-Way Vs. One-Way Trunk Line Operation
(One-Year Periods)

	City of Lansing	City of Kalamazoo	City of Pontiac	City of Port Huron	All Cities
I. STREET WHICH CHANGED FROM TWO-WAY TRUNK LINE TO ONE-WAY TRUNK LINE: (1)					
I-A Total Accidents:					
1. Before: Number	173	357	151	*	681
2. After: Number	133	267	133	*	533
3. Percent Change in Number	−23%	−25%	−18%	*	−22%
4. Before: Rate per million vehicle-miles	24.7	57.5	24.9	*	35.7**
5. After: Rate per million vehicle-miles	26.8	52.3	31.9	*	37.0**
6. Percent Change in Rate	+8%	−9%	+28%	*	+4%
I-B Injury Accidents:					
1. Before: Number	39 (F)	53	46	*	138 (F)
2. After: Number	28	27	35	*	90
3. Percent Change in Number	−28%	−49%	−24%	*	−35%
4. Before: Rate per million vehicle-miles	5.6	8.5	7.6	*	7.2**
5. After: Rate per million vehicle-miles	5.6	5.3	8.4	*	6.4**
6. Percent Change in Rate	0	−38%	+11%	*	−11%
I-C Property-damage Accidents:					
1. Before: Number	134	304	105	*	543
2. After: Number	105	240	98	*	443
3. Percent Change in Number	−22%	−21%	−7%	*	−18%
4. Before: Rate per million vehicle-miles	19.1	49.0	17.3	*	28.5**
5. After: Rate per million vehicle-miles	21.2	47.1	23.5	*	30.6**
6. Percent Change in Rate	+11%	− 4%	+36%	*	+7%
I-D Rear-end Collisions:					
1. Before	83	176	47	*	306
2. After	34	107	32	*	173
3. Percent change	−59%	−39%	−32%	*	−43%
I-E Sideswipes:					
1. Before	22	57	31	*	110
2. After	60	58	58	*	176
3. Percent change	+173%	+2%	+87%	*	+60%
I-F Right-angle Collisions:					
1. Before	41	35	31	*	107
2. After	22	40	20	*	82
3. Percent change	−46%	+14%	−35%	*	−23%

(1) In Lansing: Saginaw St. between Logan and Grand. In Kalamazoo: Michigan Ave. between Main and Porter. In Pontiac: Oakland Ave. between Montcalm-Cass and Wide Track Dr. None in Port Huron.

* No street in Port Huron was changed from two-way trunk line to one-way trunk line.

** Average

(F) Includes one fatal accident.

TABLE 62 – Sheet 2

	City of Lansing	City of Kalamazoo	City of Pontiac	City of Port Huron	All Cities
I-G Pedestrian Accidents:					
1. Before	1	5	3	*	9
2. After	2	7	2	*	11
3. Percent change	+100%	+40%	–33%	*	+22%
I-H Day Accidents:					
1. Before	123	232	103	*	458
2. After	96	193	90	*	379
3. Percent change	–22%	–17%	–13%	*	–17%
I-J Night Accidents:					
1. Before	39	111	48	*	198
2. After	31	63	43	*	137
3. Percent change	–21%	–43%	–10%	*	–31%
I-K Twilight Accidents:					
1. Before	11	14	(NL)	*	25
2. After	6	11	(NL)	*	17
3. Percent change	–45%	–21%	(NL)	*	–32%
I-L Peak-traffic Accidents					
1. Before	94	172	72	*	338
2. After	67	140	53	*	260
3. Percent change	–29%	–19%	–26%	*	–23%
I-M Off-Peak Traffic Accidents:					
1. Before	78	181	79	*	338
2. After	66	123	80	*	269
3. Percent change	–15%	–32%	+1%	*	–20%
I-N Accidents at Signalized Intersections; (2)					
1. Before	69	147	99	*	315
2. After	46	125	74	*	245
3. Percent change	–33%	–15%	–25%	*	–22%
I-P Accidents at Non-Signalized Intersections: (2)					
1. Before	36	19	34	*	89
2. After	38	21	41	*	100
3. Percent change	+6%	+11%	+21%	*	+12%
I-Q Midblock					
1. Before	65	180	18	*	263
2. After	32	111	18	*	161
3. Percent change	–51%	–38%	0	*	–39%
I-R Percent change in vehicle-miles of travel	–29%	–12%	–31%	*	–23%

* No street in Port Huron was changed from two-way trunk line to one-way trunk line.

(NL) Not listed.

(2) Not including accidents at those intersections where signals were either installed or removed during the one-way operation.

TABLE 62 – Sheet 3

II. A SECTION OF SAME TRUNK LINE AS IN SECTION I BUT WHERE OPERATION REMAINED TWO-WAY: (3)	City of Lansing	City of Kalamazoo	City of Pontiac	City of Port Huron	All Cities
II-A Total Accidents					
1. Before: Number	121	82	41	*	244
2. After: Number	134	80	35	*	249
3. Percent change in number	+11%	–2%	–15%	*	+2%
4. Before: Rate per million vehicle-miles	19.6	59.5	5.6	*	28.2**
5. After: Rate per million vehicle-miles	21.5	55.6	4.3	*	27.1**
6. Percent change in rate	+10%	–7%	–23%	*	–4%
II-B Injury Accidents:					
1. Before: Number	30	9	18	*	57
2. After: Number	26	19	13 (F)	*	58 (F)
3. Percent change in number	–13%	+111%	–28%	*	+2%
4. Before: Rate per million vehicle-miles	4.8	6.5	2.5	*	4.6**
5. After: Rate per million vehicle-miles	4.2	13.2	1.6	*	6.3**
6. Percent change in rate	–12%	+103%	–36%	*	+37%
II-C Property-damage Accidents:					
1. Before: Number	91	73	23	*	187
2. After: Number	108	61	22	*	191
3. Percent change in number	+19%	–16%	–4%	*	+2%
4. Before: Rate per million vehicle-miles	14.7	53.0	3.2	*	23.6**
5. After: Rate per million vehicle-miles	17.3	42.4	2.7	*	20.8**
6. Percent change in rate	+18%	–20%	–16%	*	–12%
II-D Rear-end Collisions:					
1. Before	57	42	15	*	114
2. After	68	48	12	*	128
3. Percent change	+19%	+14%	–20%	*	+11%
II-E Sideswipes:					
1. Before	20	16	5	*	41
2. After	29	14	6	*	49
3. Percent change	+45%	–12%	+20%	*	+20%
II-F Right-angle Collisions:					
1. Before	25	13	8	*	46
2. After	24	3	5	*	32
3. Percent change	–4%	–77%	–38%	*	–30%
II-G Pedestrian Accidents:					
1. Before	1	1	1	*	3
2. After	2	0	0	*	2
3. Percent change	+100%	–100%	–100%	*	–33%

(3) In Lansing: Saginaw St. between Beltline Railroad and Logan St. In Kalamazoo: Michigan Ave. between Lovell and Main. In Pontiac: Oakland Ave. between West Blvd. and Montcalm-Cass intersection.

* No street in Port Huron was changed from two-way trunk line to one-way trunk line.

** Average

(F) Includes one fatal accident.

TABLE 62 – Sheet 4

	City of Lansing	City of Kalamazoo	City of Pontiac	City of Port Huron	All Cities
II-H Day Accidents:					
1. Before	94	52	26	*	172
2. After	97	52	23	*	172
3. Percent change	+3%	0	–12%	*	0
II-J Night Accidents:					
1. Before	22	26	15	*	63
2. After	31	24	12	*	67
3. Percent change	+41%	–8%	–20%	*	+6%
II-K Twilight Accidents:					
1. Before	5	4	(NL)	*	9
2. After	6	4	(NL)	*	10
3. Percent change	+20%	0	(NL)	*	+11%
II-L Peak-Traffic Accidents:					
1. Before	73	44	25	*	142
2. After	82	38	17	*	137
3. Percent change	+12%	–14%	–32%	*	–4%
II-M Off-peak Traffic Accidents:					
1. Before	48	38	16	*	102
2. After	52	41	18	*	111
3. Percent change	+8%	+8%	+12%	*	+9%
II-N Accidents at Signalized Intersections:					
1. Before	55	56	(NS)	*	111
2. After	61	58	(NS)	*	119
3. Percent change	+11%	+4%	(NS)	*	+7%
II-P Accidents at Non-Signalized Intersections:					
1. Before	22	2	32	*	56
2. After	30	0	20	*	50
3. Percent change	+36%	–100%	–37%	*	–12%
II-Q Midblock Accidents:					
1. Before	44	24	9	*	77
2. After	43	22	15(F)	*	80(F)
3. Percent change	–2%	–8%	+40%	*	+4%
II-R Percent change in vehicle-miles of travel	+1%	+1%	+10%	*	+6%
III. STREET WHICH CHANGED FROM TWO-WAY NON-TRUNK LINE TO ONE-WAY TRUNK LINE: (4)					
III-A Total Accidents:					
1. Before	9	157	33	95	294
2. After	115	149	88	174	526
3. Percent change	+1180%	–5%	+175%	+83%	+79%

* No street in Port Huron was changed from two-way trunk line to one-way trunk line.

(NL) Not listed.

(NS) No Signals

(F) Includes one fatal accident.

(4) In Lansing: Oakland and Jefferson Sts. between Logan and Grand. In Kalamazoo: Kalamazoo St. between Douglas and Michigan. In Pontiac: Cass Ave. between Oakland and Wide Track. In Port Huron: Oak St. between 27th and Military, and Griswold between 32nd and 4th.

TABLE 62 – Sheet 5	City of Lansing	City of Kalamazoo	City of Pontiac	City of Port Huron	All Cities
III-B Injury Accidents:					
1. Before	2	26	10	25(F)	63(F)
2. After	26	21	29	46	122
3. Percent change	+1200%	–19%	+222%	+91%	+48%
III-C Property-damage Accidents:					
1. Before	7	131	23	70	231
2. After	89	128	59	128	404
3. Percent change	+1170%	–2%	+157%	+83%	+75%
III-N Accidents at Signalized Intersections:					
1. Before	***	94	21	37	152
2. After	58	101	28	102	289
3. Percent change	–	+7%	+33%	+176%	+90%
III-P Accidents at Non-Signalized Intersections:					
1. Before	6	26	8	48	88
2. After	31	25	39	53	148
3. Percent change	+417%	–4%	+388%	+10%	+68%
III-Q Midblock Accidents:					
1. Before	3	37	4	10	54
2. After	26	23	21	19	89
3. Percent change	+767%	–38%	+425%	+90%	+65%
III-S Number of Signalized Intersections:					
1. Before	0	7	2	3	12
2. After	6	6	2	6	20
IV. THE TWO STREETS FORMING THE ONE-WAY PAIR: (5)					
IV-A Total Accidents:					
1. Before: Number	182	514	184	NI	880
2. After: Number	248	416	221	NI	885
3. Percent change in number	+36%	–19%	+20%	NI	+1%
4. Before: Rate per million vehicle-miles	23.1	50.6	21.4	NI	31.7**
5. After: Rate per million vehicle-miles	23.3	42.0	25.4	NI	30.2**
6. Percent change in rate	+1%	–17%	+19%	NI	–5%
IV-B Injury Accidents:					
1. Before: Number	41	79	56	NI	176
2. After: Number	54	48	64	NI	166
3. Percent change in number	+32%	–39%	+14%	NI	–6%
4. Before: Rate per million vehicle-miles	5.2	7.8	6.5	NI	6.5**
5. After: Rate per million vehicle-miles	5.1	4.8	7.4	NI	5.8**
6. Percent change in rate	–2%	–38%	+14%	NI	–11%

(F) Includes one fatal accident.

*** There were no signalized intersections during the "before" period, and 6 intersections were signalized during the "after" period. (See III-S.)

(5) Total of I and III. (Port Huron data are not included in this section because the situation is not similar to the other three cities.)

NI Not included. (See above note.)

** Average

TABLE 62 – Sheet 6

	City of Lansing	City of Kalamazoo	City of Pontiac	City of Port Huron	All Cities
IV-C Property-damage Accidents:					
1. Before: Number	141	435	128	NI	704
2. After: Number	194	368	157	NI	719
3. Percent change in number	+38%	−15%	+23%	NI	+2%
4. Before: Rate per million vehicle-miles	17.9	42.8	14.9	NI	25.2**
5. After: Rate per million vehicle-miles	18.2	37.2	18.0	NI	24.5**
6. Percent change in rate	+2%	−13%	+21%	NI	−3%
IV-O Intersection Accidents:					
1. Before	111	286	162	NI	559
2. After	173	272	182	NI	627
3. Percent change	+56%	−5%	+12%	NI	+12%
IV-Q Midblock Accidents:					
1. Before	68	217	22	NI	307
2. After	58	134	39	NI	231
3. Percent change	−15%	−38%	+77%	NI	−25%
IV-R Percent change in vehicle-miles of travel	+35%	−3%	+1%	NI	+10%
V. ALL STREETS IN STUDY AREA: (6)					
V-A Total Accidents:					
1. Before: Number	520	1380	274	345	2519
2. After: Number	624	1291	323	450	2688
3. Percent change in number	+20%	−6%	+18%	+30%	+7%
V-B Injury Accidents:					
1. Before	114	188	87	76	465
2. After	133	176	96(F)	96	501(F)
3. Percent change	+17%	−6%	+10%	+26%	+8%
V-G Pedestrian Accidents:					
1. Before	2	23	7	8	40
2. After	12	22	4	6	44
3. Percent change	+500%	−4%	−43%	−25%	+10%
VI. WHOLE CITY:					
VI-A Total Accidents:					
1. Before	7000	5153	4661	1392	18206
2. After	7980	5077	4872	1914	19843
3. Percent	+14%	−1%	+5%	+38%	+9%
VI-B Injury Accidents:					
1. Before	1500	1084	1414	316	4314
2. After	1862	1020	1477	391	4750
3. Percent change	+24%	−6%	+4%	+24%	+10%
VI-G Pedestrian Accidents:					
1. Before	149	80	108	23	360
2. After	141	97	101	37	376
3. Percent change	−5%	+21%	−6%	+61%	+4%

NI Not included

** Average

(6) In Port Huron: two corridors along Lapeer-Water, Oak and Griswold Sts.

(F) Includes one fatal accident

Most of the foregoing analysis fails to indicate similarities in the safety trends which were looked for in the four study cities. Some results common to all cities were that on the two-way state trunk lines which were converted to one-way operation the total accidents, injury accidents, rear-end collisions and accidents at signalized intersections decreased; and sideswipes and collisions at non-signalized intersections increased. Considering the three cities of Lansing, Kalamazoo and Pontiac, an appraisal of the one-way pairs before and after the conversion fails to indicate a trend toward either a gain or a loss in safety of operation, based on rates per million vehicle-miles.

As was pointed out at the start of this discussion on the results of accident studies, there exist wide differences in the accident experiences of the study cities. To make a comparison of accident experiences possible, the only tool known to date is to express them in rates based on vehicle-miles of travel. However, recent studies (5, 6) suggest that accident rate is not a linear function of traffic volume but varies on a parabolic curve, decreasing as hourly volume increases and then rising again as volume further increases.

Other studies (7) find that the roadway is responsible for about 45 percent of the variation in the accident rate and that the remaining 55 percent of the variability is accountable to such factors as the driver and the vehicle. This makes it difficult to use accidents as a sensitive criterion in evaluating improvements in the highway system.

A final reminder is that some of the variation in results may also be due to the difference in the degree of traffic enforcement and the procedures used for accident reporting in different cities.

SUGGESTED DESIGN CRITERIA

This study is by no means an exhaustive examination of all types of one-way street systems. It is merely a case study of a traffic corridor in each of the four cities where the State Trunk Line was changed from two-way to one-way operation. It should also be remembered that the study was an evaluation coincidental with normal highway projects. No attempts were made to interject deliberate parameters into the individual projects for purposes of controlled research. The design criteria suggested below are somewhat limited in scope to the experience gained from these four projects.

GUIDELINES FOR CONSIDERATION OF ONE-WAY TRUNK LINE SYSTEMS

Conversion to a one-way system should be considered when the following conditions exist after optimization of signal timing has been effected and additional laneage possibilities have been ruled out:

1. Average overall travel speed during peak periods falls below 20 m.p.h. under normal daily operation.

2. Average stopped delays are in the vicinity of 30 seconds or greater per mile of trunk line.

3. Accident rates continue to be above average for comparable streets particularly after unsuccessful attempts to correct specific accident patterns.

4. Considerable desire to turn left from the trunk line is present but cannot be accommodated by special signal-phasing which requires loss of needed through-capacity.

5. Impending need for new traffic signals at some of the stop-controlled intersections, which can continue to be stop-controlled under one-way operation by virtue of creating more usable gaps in the trunk line traffic stream.

6. Traffic congestion on streets within the trunk line corridor becomes intolerable and the efficiency of a well planned one-way system is viewed as an aid to organizing traffic flow.

Each of the above items may not by itself be viewed as adequate justification for initiating a one-way street system. As more of the above guidelines are evidenced, the case for such a system becomes stronger. No specific volume warrants appear to be appropriate; rather, the ability to provide a desired level of service should be the consideration.

Implied in the consideration of a one-way street system is the existence of a suitable corridor for constructing or reconstructing the street to be paired with the trunk line.

SUGGESTIONS FOR SYSTEM DESIGN

1. Free-flow channelization should be used if feasible. This will minimize the number of stop-and-go signals which reduce capacity and may increase accidents. Such operation can be made possible by constructing channelizing islands. There are two areas of application where such channelization can be used. The first is at transitions between one-way and two-way sections. The second is at cross-streets where turning movements are accommodated. Merge and diverge operations on the trunk line will require extra pavement width near such cross-streets to allow construction of the channelizing islands and free-flow operation. This can sometimes be accomplished by eliminating parking, standing or stopping at least in the vicinity of cross streets. Decisions for free-flow channelization should be tempered by considering any factors which may introduce operation haz-

ards. The presence of driveways, alleys and streets which intersect the auxiliary lanes are such hazard factors.

2. The one-way pair of streets should normally operate to the right of the intervening block or blocks, as in the case of a divided highway with a median. This will permit normal counter-clockwise circulation around the blocks and also permit simple transition geometrics at the two extremities.

3. Wherever feasible, implementation of one-way flow on the cross-streets will further improve over-all operations.

4. Weaving conditions should be kept to a minimum to reduce sideswipe accidents which are typical of multilane one-way traffic.

5. Lane concentration in traffic flow is an important factor in ensuring full capacity of the system. It is sometimes possible to improve lane concentration by means of advance overhead signing so that unbalanced concentration of traffic on certain lanes may be avoided. Such measures will also be helpful in reducing weaving. Provision for more than one turning lane for each movement at necessary locations will also help in a better distribution of flow among the available lanes.

6. Conversion to one-way operation can be accomplished effectively by phasing it into successive sections along the traffic corridor. Ample transitions should be designed, however, into the interim schemes so as not to create bottlenecks at the temporary terminals. Furthermore, the design of roadways and signing should obviate any driver confusion which may cause wrong-way travel.

7. Elimination of parking on the streets should be considered when feasible.

8. Signals should be interconnected to synchronize them for optimum speed.

9. Signal-progression speed should approximate the legal speed limit which should be posted frequently on the streets.

10. New traffic signs needed for one-way operation can be given added emphasis by adding flashing lights for the first few months after conversion to one-way operation, until all drivers familiar with the old scheme are acclimated to the new system.

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APPENDICES

APPENDIX 1

DETAILED DESCRIPTION OF TRAFFIC SURVEYS

CITY OF KALAMAZOO

The "before" phase of the traffic surveys was conducted between October 19 and October 30, 1964. Volume counts by pneumatic counters were taken at 66 locations which are shown in Figure 5. At five of these locations, the counts were continuous for at least seven days and as long as other traffic surveys were in progress. At the remainder of the locations, 48-hour counts were taken. Actually, the total number of volume counts were much more than 66 since separate counts were taken for each direction of traffic at most locations. Thus, for the "before" surveys, 105 volume counts were taken. The taking of the 48-hour counts was spread over a period of 12 days due to their large number, which, of necessity, made such counts non-simultaneous. The machines recorded the volumes by 15-minute periods.

Time gaps in the traffic stream were measured on Kalamazoo and Michigan Avenues at their intersections with Church Street. These were taken one day only from 7 to 9 a.m. and from 3 to 6 p.m., and were totaled by 15-minute intervals. Nothing shorter than 6 seconds was recorded, and the gaps were divided into four size-groups of 6 to 10 seconds, 10 to 15 seconds, 15 to 20 seconds and over 20 seconds.

Turning-movements were counted for six hours, from 6 to 9 a.m. and from 3 to 6 p.m., at the intersections of Kalamazoo and Rose, and Michigan and Lovell. Stoppage of left lanes caused by traffic waiting to make left turns at the Kalamazoo and Rose intersection was recorded in seconds by 15-minute intervals.

Speed-and-delay study runs listed below were made by the floating car method during the "before" period, where total travel time, and points and duration of all delays were recorded in these cars using automatic recording equipment (See Figure 6):

1-A. From the intersection of Thompson Street and Main Street, eastbound via Main-Douglas-Kalamazoo-Michigan, to the intersection of Harrison Street and Michigan Avenue. Three runs were made during each of the three peak periods, morning, noon and afternoon, for three consecutive days.

2-A. From the intersection of Harrison and Michigan, westbound via Michigan-Kalamazoo-Douglas-Main, to the intersection of Thompson and Main. Same number of runs were made as in the eastbound runs mentioned above.

3-A. From the intersection of Thompson and Main, eastbound via Main-Michigan, to the intersection of Harrison and Michigan. Three runs were made during each of the three peak periods for two days.

4-A. From the intersection of Harrison and Michigan, westbound via Michigan-Main, to the intersection of Thompson and Main. Same number of runs were made as in the eastbound runs mentioned for route 3-A, above.

5-A. From the intersection of Lovell and Michigan, eastbound via Michigan, to the intersection of Harrison and Michigan. Three runs were made during each peak period of one day only.

6-A. From the intersection of Harrison and Michigan, westbound via Michigan, to the intersection of Lovell and Michigan. Same number of runs were made as in the eastbound runs mentioned for route 5-A, above.

Total travel time only was clocked by a survey car on the six cross-streets which are situated in a general north-south direction and which intersect the one-way pair. These streets and the directions of survey runs were as follows: (See Figure 6).

1. Westnedge (southbound)
2. Park (northbound)
3. Church (southbound)
4. Rose (northbound and southbound)
5. Edwards (northbound)
6. Pitcher (southbound)

The beginning and the end of all but one of these runs were Ransom Street, which is two blocks north of Kalamazoo Avenue, and South Street, which is two blocks south of Michigan Avenue. The run on Church Street was ended at Academy Street which terminates Church Street on the south.

During the "before" surveys, on each of the streets and directions indicated above, three runs were made during morning peak periods (two of these on the same day and the third on the next day), two runs during morning off-peak periods (both on the same day), three runs during noon peak (all on the same day), one run during afternoon off-peak, and three runs during afternoon peak (two of them on the same day and the third on another day).

Traffic surveys reflecting the "after" or one-way traffic conditions were taken in Kalamazoo between May 2, 1966 and May 14, 1966. Basically the same count stations and speed-and-delay routes were used during these "after" surveys, except that some modifications were made for new streets and travel routes as necessitated by the one-way operation.

Volume counts numbered 89 during the "after" surveys. The taking of the 48-hour counts were distributed within a period of 10 days.

Traffic gaps and turning movements were counted at the same stations and in the exact manner as the "before" surveys.

Four speed-and-delay study runs as listed below were made during the "after" period. (see Figure 7.)

2-B. From the intersection of Harrison and Michigan, westbound via Michigan-Kalamazoo-Douglas-Main, to the intersection of Thompson and Main.

3-B. From the intersection of Thompson and Main, eastbound via Main-Michigan, to the intersection of Harrison and Michigan.

5-B. From the intersection of Lovell and Michigan, eastbound via Michigan, to the intersection of Harrison and Michigan.

7-B. From the intersection of Harrison and Michigan, westbound, via Michigan-Kalamazoo-Michikal-Michigan, to the intersection of Lovell and Michigan.

Six runs were made on each of the above routes for each of the peak periods. The morning peaks were covered in three consecutive days, two runs being made the first day, three runs on the next and one on the third day. Noon peaks were also covered in three consecutive days, one run being made the first day, three on the second and two runs on the third day. Afternoon peaks were done in two days, three runs being completed on each day.

Travel-time surveys on the six cross-streets were repeated for the "after" phase of the study. On each of the routes, three trips were made during the morning peak period, all on the same day. One trip was made during the morning off-peak period. Three trips were made during the noon peak period, one trip being on one day and two trips on another day. Two trips were made during the afternoon off-peak on two consecutive days. Three trips were made during the afternoon peak period, one trip being on one day and two trips on another.

CITY OF LANSING

The "before" surveys were taken between July 8 and July 30, 1964. Volume counts by 15-minute totals were planned for a total of 110 stations (Figure 13). However, some stations were omitted due to construction work or narrow street widths. In the latter case instead of two stations counting directional volumes at one location, one station was used counting total traffic. The actual number of stations thus reduced to 87. At six of these stations, volume counts were continued for at least seven days and as long as other traffic surveys were in progress. At the remaining 81 stations, counts were recorded for 48 hours. The 48-hour counts took place within a total time span of 23 days.

Traffic gap surveys, similar to those in Kalamazoo, were conducted at the following seven intersections of Saginaw Street: Seymour, Chestnut, Sycamore, Clayton-Carey, Westmoreland, Cawood and Durant.

Six hours of turning-movement counts, similar to those in Kalamazoo, were also recorded at the intersections of Oakland and Logan, Saginaw and Jenison, and Saginaw and Verlinden. Delays caused by traffic waiting to turn left were also recorded.

The following speed-and-delay survey runs were made during the "before" phase of the study: (See Figure 14.)

1-A. From Beltline Railroad, eastbound via Saginaw Street, to the intersection of Cedar and Saginaw.

2-A. From Cedar and Sheridan intersection, westbound via Saginaw, to Beltline Railroad.

These runs were made during three consecutive days and within the morning, noon and afternoon peak periods of each day. For the morning peak data, five runs were made in both directions during the first day, and four runs each during the next two days. For the afternoon peak, four runs were made during each of the three days.

Cross-street travel time surveys were taken on seven streets. These runs started or terminated on Kilborn and Hyland Streets on the north, and at Genesee and Osborn Streets on the south. (See Figure 14). The names of the cross-streets and the direction of the trips were:

1. Washington (southbound)
2. Capitol (northbound)
3. Walnut (southbound)
4. Pine (northbound)
5. Logan (southbound)
6. Jenison (southbound)
7. Verlinden (northbound)

All of the above trips were made during three consecutive days, and two runs were made during each of the three daily peak periods.

Traffic surveys to reflect the initial phase of the one-way operation (for the area east of Logan Street) were taken between June 28 and July 8, 1966. Basically the same count stations and travel routes were used for this phase of surveys, with the exceptions that counts were not taken for the area west of Logan Street, that modifications were made as necessitated by the one-way system, and that the speed studies were run on the newly established streets and travel directions. Thirty-two volume counts were taken for this phase. The 48-hour counts were all taken at the same time, using as many machines.

Traffic gap studies were repeated at the three intersections that fell within the initial one-way phase study area. Turning-movement counts were repeated at the Oakland and Logan intersection.

Speed-and-delay survey routes for this phase of the study were as follows: (See Figure 15.)

1-B. From Beltline Railroad, eastbound via Saginaw Street, to the intersection of Cedar and Saginaw.

2-B. From the intersection of Cedar and Sheridan, westbound via Oakland-Logan-Saginaw, to Beltline Railroad.

On each of the above described routes, runs were made during four consecutive days. On the first day, three runs were made during the afternoon peak periods only; on each of the second and third days, three runs were made during each of the morning, noon and afternoon peaks; and on the fourth day, three runs were made during morning and noon peaks.

Cross-street travel-time runs were repeated on the first five of the seven streets listed for the before phase. However, due to the change in direction of traffic on four of the city's local streets, which went into effect on the same date as the one-way state trunk lines, the travel directions of some of the test trips were different from the "before" runs, and they were as follows: (See Figure 15.)

1. Washington (northbound and southbound)
2. Capitol (southbound)
3. Walnut (northbound)
4. Pine (southbound)
5. Logan (northbound and southbound)

The above trips were repeated twice for each of the three peak periods for three days as before,

except that they were spread to four days, afternoon peak runs only being done in the first day, and morning and noon peaks only being surveyed on the fourth day.

Traffic surveys to reflect the final phase of the one-way operation (with the area west of Logan Street also included) were taken between June 30 and August 1, 1969. These were basically a repetition of the "before" study with the adjustments necessitated by the conversion of the state trunk lines to one-way operation, and the changes in the directions of flow of some of the cross-streets as earlier mentioned. Seventy-two volume counts were taken for the final phase. The 48-hour counts were taken during a total time span of 26 days from June 30 to July 25, 1969.

Gap and turning-movement studies were repeated at the same stations as the before phase.

Speed-and-delay survey routes for the final phase were (Figure 16):

1-B. From Beltline Railroad underpass, eastbound via Saginaw Street, to the intersection of Cedar and Saginaw.

2-B. From the intersection of Cedar and Oakland, westbound via Oakland Avenue to Beltline Railroad underpass.

On each of the above routes, runs were made during three consecutive days. On the first day three runs were made during the afternoon peak only, on the second day three runs for each of the peaks were made, and on the third day three runs were made for the morning peak only.

The same seven cross-streets were driven as in the before surveys, the only difference being in the direction of travel as follows (Figure 16):

1. Washington (southbound)
2. Capitol (southbound)
3. Walnut (northbound)
4. Pine (southbound)
5. Logan (southbound)
6. Jenison (southbound)
7. Verlinden-Cleo (northbound)

All cross-street runs were completed in four consecutive days. For each of the seven routes two noon-peak runs and two afternoon-peak runs were made on the first day, two runs for each of the three peaks were made both on the second and the third day, and only two morning-peak runs were made on the fourth day.

CITY OF PONTIAC

Survey procedures were similar to Kalamazoo and Lansing, except that no cross-street travel-time runs were made. Instead, an additional speed-and-delay route making a closed loop was made through some of the cross and parallel streets near the east end of the study area.

The "before" surveys were taken between August 3 and 21, 1964. Traffic volumes were recorded at 59 stations (Figure 19). At seven of these, counts were continuous for the total duration of other traffic surveys. The remaining stations were in operation for 48 hours spread over the 18-day survey period.

Gap surveys were conducted on Oakland Avenue at its intersections with Blaine, Cadillac and Florence Streets, and on Cass Avenue at Florence intersection.

Turning-movements were recorded at the intersections of Oakland Avenue with Cass-Montcalm, Johnson, and Allison-Baldwin Streets; and at the intersection of Cass Avenue and Johnson Street. Stoppage of left lanes due to left turns were recorded as in the other cities.

Speed and delay routes for the "before" study were the following (Figure 20):

1-A. From the intersection of Oakland Avenue and Northview Street, southeastbound via Oakland, to the intersection of Oakland and Saginaw.

2-A. From the intersection of Oakland and Saginaw, northwestbound via Oakland, to the intersection of Oakland and Northview.

3-A. From the intersection of Oakland and Northview, southeastbound via Oakland-Cass, to the intersection of Cass and Wide Track Drive.

4-A. Counter-clockwise, closed loop starting and ending at the intersection of East Howard and Baldwin Streets, via Howard-Johnson-Norton-Sanderson-Oakland-Baldwin.

On each of the above routes, runs were made during four consecutive days. On the first day three runs were made during the afternoon peak only; on each of the second and third days three runs were made during the morning peak, two during the noon peak, and three during the afternoon peak; and on the fourth day three morning- and two afternoon-peak runs were made.

The first "after" surveys taken in 1967 were not analyzed, as explained in the report, and will not be discussed here.

The second "after" surveys were taken between August 5 and 15, 1968. Only 52 of the initial 59 volume stations were used due to one-way traffic. At six of these, counts were continuous for the whole survey period. The remaining were 48-hour stations which were in operation between August 5 and 8.

Gap surveys were repeated at the earlier four intersections, and turning-movement counts were also repeated at the other earlier group from four intersections.

Speed and delay routes for the "after" survey were the following (Figure 20):

1-B. From the intersection of Oakland and Northview, southeastbound via Oakland-Cass, to the intersection of Cass and Wide Track.

2-B. From the intersection of Oakland and Saginaw, northwestbound via Oakland, to the intersection of Oakland and Northview.

3-B. Clockwise, closed loop starting and ending at the intersection of East Howard and Baldwin, via Baldwin-Allison-Close-Sanderson-Norton-Johnson-Howard.

On each of the above routes, runs were made during three consecutive days, and on each day three runs were made for each of the morning, noon and afternoon peaks.

CITY OF PORT HURON

Survey procedures were similar to the other three cities. The "before" surveys were taken from August 31 to September 11, 1964. Volumes were recorded at 78 stations within three separate traffic corridors. Eight of these were key stations for continuous counts for the duration of the whole survey, the rest being 48-hour stations which recorded sometime between August 31 and September 11.

Gap surveys were conducted only on Griswold Street at its intersections with 7th, 16th, 20th and 22nd Streets. Turning-movement counts were taken at the intersections of Griswold Street with Military and 24th Streets, and included records of left-lane stoppage.

Speed and delay routes during the "before" surveys were (Figure 26):

1-A. From the intersection of Lapeer and 32nd Streets, eastbound via Lapeer and Water Streets, to the intersection of Water and Military Streets.

2-A. From the intersection of Water and Military, westbound via Water and Lapeer, to the intersection of Lapeer and 32nd.

3-A. From the intersection of Griswold and 32nd Streets, eastbound via Griswold, to the intersection of Griswold and Military.

4-A. From the intersection of Griswold and Military, westbound via Griswold, to the intersection of Griswold and 32nd.

The above routes were driven during four consecutive days. On the first day only three afternoon-peak runs were made for each of the routes. During the second and third days three runs were made for each of the three peak-periods on each route, and on the fourth day, morning and noon runs were completed by three runs for each peak.

Cross-street travel-time surveys were only done for the Griswold-Oak corridor. Vehicle runs, northbound and southbound, were made between

Chestnut and Minnie Streets on the following streets:

1. Military Street
2. 7th Street
3. 10th Street
4. 13th Street
5. 24th Street

These runs were completed during three consecutive days. During the first day two runs were accomplished in both directions on each street during each of the three peak periods. During each of the next two days, only one run in each direction on each street was completed for each peak.

The "after" surveys were completed from September 11 to 21, 1967. Volume stations were reduced to 72 in number, the key stations remaining eight as before. Gap studies were repeated at the four intersections.

Oak Street in the eastbound direction was added to the speed-and-delay survey routes (Figure 27), and conversely no eastbound runs were made on Griswold Street. Since the Lapeer-Water Streets route was abandoned as a state route, and no change in the directional operation was involved, only one survey run in each direction on this route was made for each peak period. On Griswold and Oak Streets test runs were made during three consecutive days, and each day three runs were made during each of the peak periods.

Cross-street travel-time surveys were repeated, for the "after" study, on the five routes earlier established. On Military Street these surveys were completed during a total of four days. During the first day, one morning run and two noon runs were logged in each direction. The following two days two runs were made each day for each direction during each peak. The last day's runs were made four days later, and one morning run and two afternoon runs were logged.

Travel-time runs on 7th, 10th, 13th and 24th Streets were accomplished with a similar schedule and took four days to complete, but faulty recording made the exact survey dates unavailable. Six runs were made in each direction for each peak period.

APPENDIX 2

Approximate Calculation of
NUMBER OF VEHICLES WHICH CAN UTILIZE VARIOUS GAP-SIZE GROUPS

Basic Assumptions: 1. No gap shorter than 6 seconds is acceptable.

2. Headway used by each car starting from stopped position is 4 seconds.

Gap-size Group I: 6 to 10 seconds
Assumed average gap size = 8 seconds

Headway used by 1 car = 4 seconds (deduct)
4 seconds non-usable remainder

Gap Group II: 10 to 15 seconds
Assumed average size = 12 seconds

Headway used by 2 cars = 2 × 4 = 8 seconds (deduct)
4 seconds not usable

Group III: 15 to 20 seconds
Assumed average size = 17 seconds

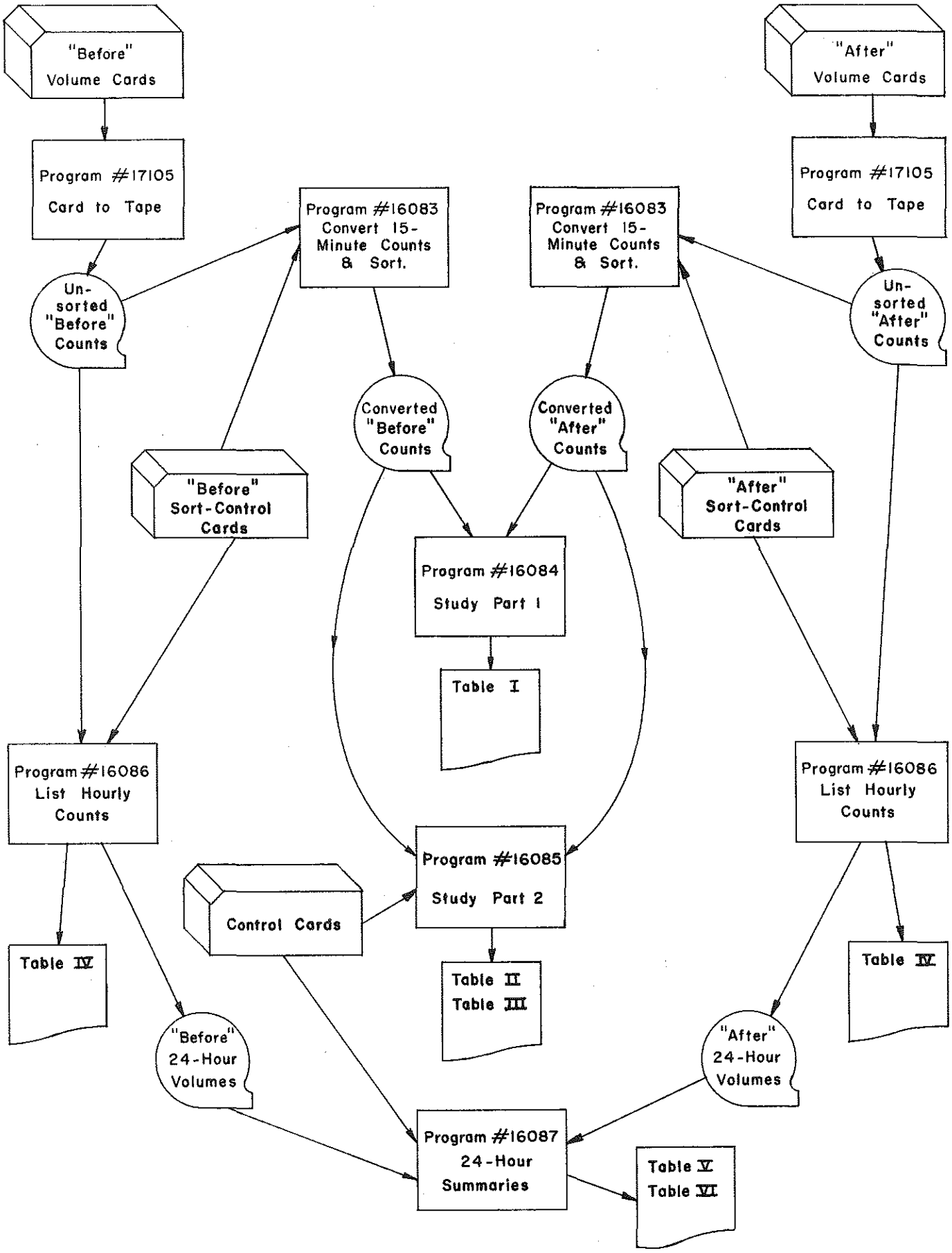
Headway used by 3 cars = 3 × 4 = 12 seconds (deduct)
5 seconds not usable

Group IV: More than 20 seconds
Minimum size = 21 seconds

Headway used by 5 cars = 5 × 4 = 20 seconds (deduct)
1 second not usable

Appendix 3

COMPUTER PROCESSING FLOW CHART



APPENDIX 4

OPERATIONAL ASPECTS OF ONE-WAY AND TWO-WAY STREETS

TABLE 1 - DETAILED ANALYSIS OF TRAFFIC VOLUME DATA

	BEFORE PERIOD									AFTER PERIOD									CHANGES			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		19	20	21	1
7	06.15A	.0825	2	64-07-23	54			4.455		.0825	5	66-07-06	64			5.280			+0010			207
7	06.30A	.0825	2	64-07-23	74			6.105		.0825	5	66-07-06	79			6.518			+0005			207
7	06.45A	.0825	2	64-07-23	97			8.003		.0825	5	66-07-06	124			10.230			+0027			207
7	07.00A	.0825	2	64-07-23	128			10.560		.0825	5	66-07-06	191			15.758			+0063			207
	6-7 AM					353	177		29.123					458	92		37.786			+0105	-0085	
7	07.15A	.0825	2	64-07-23	174			14.355		.0825	5	66-07-06	164			13.530			-0010			207
7	07.30A	.0825	2	64-07-23	242			19.965		.0825	5	66-07-06	219			18.068			-0023			207
7	07.45A	.0825	2	64-07-23	368			30.360		.0825	5	66-07-06	399			32.918			+0031			207
7	08.00A	.0825	2	64-07-23	597			49.253		.0825	5	66-07-06	503			41.498			-0094			207
	7-8 AM					187	94		15.428					1285	257		106.013			+1098	+0163	
7	08.15A	.0825	2	64-07-23	231			19.058		.0825	5	66-07-06	333			27.473			+0102			207
7	08.30A	.0825	2	64-07-23	207			17.078		.0825	5	66-07-06	256			21.120			+0049			207
7	08.45A	.0825	2	64-07-23	218			17.985		.0825	5	66-07-06	200			16.500			-0018			207
7	09.00A	.0825	2	64-07-23	201			16.583		.0825	5	66-07-06	224			18.480			+0023			207
	8-9 AM					857	429		70.703					1013	203		83.573			+0156	-0226	
7	11.15A	.0825	2	64-07-23	223			18.398		.0825	5	66-07-06	208			17.160			-0015			207
7	11.30A	.0825	2	64-07-23	214			17.655		.0825	5	66-07-06	204			16.830			-0018			207
7	11.45A	.0825	2	64-07-23	214			17.655		.0825	5	66-07-06	224			18.480			+0010			207
7	12.00P	.0825	2	64-07-23	217			17.903		.0825	5	66-07-06	241			19.883			+0024			207
	11-12 AM					868	434		71.610					877	175		72.353			+0009	-0259	
7	12.15P	.0825	2	64-07-23	282			23.265		.0825	5	66-07-06	285			23.513			+0003			207
7	12.30P	.0825	2	64-07-23	208			17.160		.0825	5	66-07-06	252			20.790			+0044			207
7	12.45P	.0825	2	64-07-23	239			19.718		.0825	5	66-07-06	261			21.533			+0022			207
7	01.00P	.0825	2	64-07-23	213			17.573		.0825	5	66-07-06	222			18.315			+0009			207
	12-1 PM					942	471		77.715					1020	204		84.150			+0078	-0267	
7	03.15P	.0825	2	64-07-23	244			20.130		.0825	5	66-07-06	224			18.480			-0020			207
7	03.30P	.0825	2	64-07-23	215			17.738		.0825	5	66-07-06	258			21.285			+0043			207
7	03.45P	.0825	2	64-07-23	303			24.998		.0825	5	66-07-06	356			29.535			+0055			207
7	04.00P	.0825	2	64-07-23	314			25.905		.0825	5	66-07-06	426			35.145			+0112			207
	3-4 PM					1076	538		88.770					1266	253		104.445			+0190	-0285	
7	04.15P	.0825	2	64-07-23	317			26.153		.0825	5	66-07-06	348			28.710			+0031			207
7	04.30P	.0825	2	64-07-23	288			23.760		.0825	5	66-07-06	297			24.503			+0009			207
7	04.45P	.0825	2	64-07-23	357			29.453		.0825	5	66-07-06	384			31.680			+0027			207
7	05.00P	.0825	2	64-07-23	373			30.773		.0825	5	66-07-06	444			36.630			+0071			207
	4-5 PM					1335	668		110.138					1473	295		121.523			+0138	-0373	
7	05.15P	.0825	2	64-07-23	519			42.818		.0825	5	66-07-06	487			40.178			-0032			207
7	05.30P	.0825	2	64-07-23	327			26.978		.0825	5	66-07-06	441			36.383			+0114			207
7	05.45P	.0825	2	64-07-23	305			25.163		.0825	5	66-07-06	337			27.803			+0032			207
7	06.00P	.0825	2	64-07-23	226			18.645		.0825	5	66-07-06	287			23.678			+0061			207
	5-6 PM					1377	689		113.603					1552	310		128.040			+0175	-0379	
	8 HR.TOTAL					06995			577.090					08944			737.882					

APPENDIX 4 – – SHEET 2

TITLES OF COLUMNS IN TABLE I

"Before" Period:

1. Count Station
2. Time
3. Travel Distance (Miles)
4. Moving Lanes
5. Date
6. 15-Minute Volume
7. Hourly Volume
8. Hourly Volume Per Lane
9. 15-Minute Vehicle-Miles
10. Hourly Vehicle-Miles

"After" Period:

11. Travel Distance (Miles)
12. Moving Lanes
13. Date
14. 15-Minute Volume
15. Hourly Volume
16. Hourly Volume Per Lane
17. 15-Minute Vehicle-Miles
18. Hourly Vehicle-Miles

Changes:

19. 15-Minute Volume
20. Hourly Volume
21. Hourly Volume Per Lane
1. Count Station

APPENDIX 5

OPERATIONAL ASPECTS OF ONE-WAY AND TWO-WAY STREETS

TABLE II - SUMMARY OF VEHICLE-MILES OF TRAVEL

GROUP 2

TIME	15-MINUTE VEHICLE-MILES BEFORE PERIOD	AFTER PERIOD	CHANGE
06.00 - 06.15 AM	83.0602	100.5717	+17.5115
06.15 - 06.30 AM	145.8342	182.9280	+37.0938
06.30 - 06.45 AM	278.9123	284.8384	+5.9261
06.45 - 07.00 AM	324.8732	272.7741	-52.0991
07.00 - 07.15 AM	246.9527	233.9110	-13.0417
07.15 - 07.30 AM	268.3260	324.2304	+55.9044
07.30 - 07.45 AM	493.2373	512.4063	+19.1690
07.45 - 08.00 AM	661.0223	599.4144	-61.6079
08.00 - 08.15 AM	510.2288	464.5305	-45.6983
08.15 - 08.30 AM	446.5250	403.4416	-43.0834
08.30 - 08.45 AM	461.9214	355.6293	-106.2921
08.45 - 09.00 AM	454.8626	352.1806	-102.6820
11.00 - 11.15 AM	511.4322	357.8741	-153.5581
11.15 - 11.30 AM	511.8417	364.9342	-146.9075
11.30 - 11.45 AM	580.1077	402.7542	-177.3535
11.45 - 12.00 PM	561.3297	550.7291	-10.6006
12.00 - 12.15 PM	541.5834	506.1947	-35.3887
12.15 - 12.30 PM	484.4245	384.8488	-99.5757
12.30 - 12.45 PM	490.1481	424.6552	-65.4929
12.45 - 01.00 PM	490.6310	442.2656	-48.3654
03.00 - 03.15 PM	489.3273	516.1893	+26.8620
03.15 - 03.30 PM	553.0450	509.5518	-43.4932
03.30 - 03.45 PM	642.0040	566.6232	-75.3808
03.45 - 04.00 PM	635.2881	530.3440	-104.9441
04.00 - 04.15 PM	601.6892	539.8008	-61.8884
04.15 - 04.30 PM	573.1616	582.7337	+9.5721
04.30 - 04.45 PM	640.5422	599.0810	-41.4612
04.45 - 05.00 PM	656.1143	611.2223	-44.8920
05.00 - 05.15 PM	710.0013	662.1968	-47.8045
05.15 - 05.30 PM	618.7114	534.5443	-84.1671
05.30 - 05.45 PM	494.3514	471.2143	-23.1371
05.45 - 06.00 PM	428.1646	363.1782	-64.9864
COMPOSITE 8 HR TOTAL	15589.6547	14007.7919	-1581.8628

APPENDIX 6

OPERATIONAL ASPECTS OF ONE-WAY AND TWO-WAY STREETS

TABLE III - SUMMARY OF TRAFFIC VOLUMES LEAVING THE STUDY AREA

GROUP 2B

TIME	15-MINUTE VOLUMES BEFORE PERIOD	AFTER PERIOD	CHANGE
06.00 - 06.15 AM	227	276	+49
06.15 - 06.30 AM	369	472	+103
06.30 - 06.45 AM	698	761	+63
06.45 - 07.00 AM	786	734	-52
07.00 - 07.15 AM	629	599	-30
07.15 - 07.30 AM	721	756	+35
07.30 - 07.45 AM	1203	1328	+125
07.45 - 08.00 AM	1553	1591	+38
08.00 - 08.15 AM	1156	1173	+17
08.15 - 08.30 AM	851	963	+112
08.30 - 08.45 AM	763	990	+227
08.45 - 09.00 AM	871	881	+10
11.00 - 11.15 AM	856	898	+42
11.15 - 11.30 AM	943	920	-23
11.30 - 11.45 AM	1134	962	-172
11.45 - 12.00 PM	1124	1090	-34
12.00 - 12.15 PM	1205	1279	+74
12.15 - 12.30 PM	1129	1039	-90
12.30 - 12.45 PM	1122	1061	-61
12.45 - 01.00 PM	1236	1195	-41
03.00 - 03.15 PM	1148	1382	+234
03.15 - 03.30 PM	1263	1212	-51
03.30 - 03.45 PM	1422	1448	+26
03.45 - 04.00 PM	1384	1390	+6
04.00 - 04.15 PM	1325	1331	+6
04.15 - 04.30 PM	1268	1293	+25
04.30 - 04.45 PM	1426	1451	+25
04.45 - 05.00 PM	1529	1461	-68
05.00 - 05.15 PM	1664	1812	+148
05.15 - 05.30 PM	1593	1399	-194
05.30 - 05.45 PM	1154	1245	+91
05.45 - 06.00 PM	961	872	-89
COMPOSITE 6 HR TOTAL	34713	35264	+551

APPENDIX 7

TABLE IV - HOURLY VOLUMES - LANSING

229 07-06-66

1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM	12AM	TOTAL
0003	0002	0004	0002	0000	0000	0009	0017	0017	0016	0013	0029	0030	0022	0055	0023	0033	0060	0026	0026	0027	0020	0014	0010	000458
0008	0001	0003	0001	0000	0000	0009	0015	0007	0008	0030	0026	0043	0029	0026										000206

230 07-05-66

1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM	12AM	TOTAL
															0027	0024	0017	0020	0023	0063	0022	0014	0009	000219
0003	0003	0005	0001	0002	0004	0006	0031	0023	0024	0018	0009	0022	0022	0022	0020	0021	0020	0018	0029	0026	0011	0015	0003	000358
0003	0002	0001	0003	0001	0003	0010	0043	0020	0021	0035	0022	0021	0038	0023										000246

235 07-05-66

1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM	12AM	TOTAL
												0191	0203	0183	0243	0284	0213	0165	0147	0116	0085	0055	0044	001929
0020	0014	0006	0003	0006	0027	0129	0330	0162	0127	0145	0139	0195	0131	0160	0271	0236	0215	0137	0166	0118	0088	0055	0045	002925
0031	0015	0007	0006	0009	0035	0118	0351	0165	0126	0137	0184													001184

236 07-05-66

1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM	12AM	TOTAL
												0288	0253	0224	0332	0380	0301	0177	0187	0152	0133	0108	0060	002595
0039	0022	0010	0005	0012	0044	0255	0620	0221	0181	0153	0178	0262	0212	0219	0341	0363	0327	0189	0196	0139	0152	0126	0060	004326
0041	0015	0016	0010	0011	0037	0238	0627	0273	0187	0168	0193	0241	0211	0204										002472

253 07-05-66

1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM	12AM	TOTAL
												0079	0085	0086	0118	0115	0118	0083	0083	0082	0084	0065	0049	001047
0069	0029	0059	0021	0009	0015	0032	0087	0076	0060	0061	0054	0078	0070	0081	0104	0134	0116	0092	0073	0100	0079	0046	0055	001608
0030	0029	0047	0023	0010	0019	0029	0094	0078	0042	0067	0077	0096												000635

258 07-05-66

1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM	12AM	TOTAL
												0600	0517	0571	0666	0673	0581	0496	0484	0407	0411	0256	0198	005860
0123	0074	0052	0023	0016	0100	0352	0472	0431	0445	0454	0441	0541	0475	0495	0645	0654	0611	0456	0471	0472	0347	0295	0206	006651
0126	0079	0060	0038	0016	0091	0374	0519	0428	0374	0409	0456													002968

259 07-05-66

1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM	12AM	TOTAL
												0529	0440	0525	0707	0744	0646	0451	0448	0399	0359	0213	0184	005645
0148	0191	0051	0022	0017	0064	0210	0538	0388	0396	0415	0449	0524	0495	0509	0768	0735	0692	0454	0502	0398	0313	0237	0183	008699
0144	0220	0062	0039	0027	0056	0205	0540	0372	0360	0341	0425	0485												003276

260 07-05-66

1AM	2AM	3AM	4AM	5AM	6AM	7AM	8AM	9AM	10AM	11AM	12PM	1PM	2PM	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM	12AM	TOTAL
												0396	0352	0391	0412	0432	0375	0329	0322	0270	0234	0176	0116	003805

APPENDIX 8

OPERATIONAL ASPECTS OF ONE-WAY AND TWO-WAY STREETS

TABLE V - 24-HOUR SUMMARY OF VEHICLE-MILES OF TRAVEL - KALAMAZOO

GROUP 2

TIME	24-HOUR VEHICLE-MILES BEFORE PERIOD	AFTER PERIOD	CHANGE
12 - 01 AM	463.5770	223.4755	-240.1015
01 - 02 AM	349.3359	150.8961	-198.4398
02 - 03 AM	224.0647	102.5568	-121.5079
03 - 04 AM	123.9435	59.9038	-64.0397
04 - 05 AM	92.8916	67.4355	-25.4561
05 - 06 AM	151.6944	152.4627	+.7683
06 - 07 AM	776.5092	812.1930	+35.6838
07 - 08 AM	1552.7424	1587.6681	+34.9257
08 - 09 AM	1673.0802	1507.1051	-165.9751
09 - 10 AM	1570.0221	1284.4770	-285.5451
10 - 11 AM	1717.9734	1310.0386	-407.9348
11 - 12 PM	2004.0629	1510.7553	-493.3076
12 - 01 PM	1939.1642	1670.1718	-268.9924
01 - 02 PM	1681.1243	1555.2982	-125.8261
02 - 03 PM	1640.1855	1588.3226	-51.8629
03 - 04 PM	2237.1746	2051.4373	-185.7373
04 - 05 PM	2378.6430	2258.0250	-120.6180
05 - 06 PM	2144.7125	1981.7379	-162.9746
06 - 07 PM	1574.2430	1260.1297	-314.1133
07 - 08 PM	1450.7132	1362.9290	-87.7842
08 - 09 PM	1157.8755	1083.2666	-74.6089
09 - 10 PM	1004.2635	852.3830	-151.8805
10 - 11 PM	687.0970	584.5454	-102.5516
11 - 12 AM	638.2067	417.3377	-220.8690
COMPOSITE 24 HR TOTAL	29233.3003	25434.5717	-3798.7286

APPENDIX 9

OPERATIONAL ASPECTS OF ONE-WAY AND TWO-WAY STREETS

TABLE VI - 24-HOUR SUMMARY OF TRAFFIC VOLUMES LEAVING THE STUDY AREA - KALAMAZOO

GROUP 2B

TIME	24-HOUR VOLUMES BEFORE PERIOD	AFTER PERIOD	CHANGE
12 - 01 AM	1071	539	-532
01 - 02 AM	677	310	-367
02 - 03 AM	489	256	-233
03 - 04 AM	344	140	-204
04 - 05 AM	249	193	-56
05 - 06 AM	434	440	+6
06 - 07 AM	1968	2170	+202
07 - 08 AM	3791	4079	+288
08 - 09 AM	3491	3756	+265
09 - 10 AM	3153	3300	+147
10 - 11 AM	3567	3494	-73
11 - 12 PM	3634	3776	+142
12 - 01 PM	4592	4404	-188
01 - 02 PM	4061	4044	-17
02 - 03 PM	3884	4159	+275
03 - 04 PM	5068	5262	+194
04 - 05 PM	5270	5308	+38
05 - 06 PM	4940	5209	+269
06 - 07 PM	3807	3045	-762
07 - 08 PM	3630	3506	-124
08 - 09 PM	2826	2798	-28
09 - 10 PM	2077	2136	+59
10 - 11 PM	1586	1461	-125
11 - 12 AM	1458	1067	-391
COMPOSITE 24 HR TOTAL	66067	64852	-1215

APPENDIX 10: ACCIDENT RECORD FORM

Study on Operational Aspects of One-Way and Two-Way Streets

ONE-YEAR ACCIDENT RECORD

$\frac{\text{Two}}{\text{One}}$ Way Operation Phase

Period:_____ Thru _____ Street:_____ City:_____

Accident Report No.	Severity	Intersection or Midblock	Type (*)	Date	Day of Week	Time	Weather	Pav't. Cond.	Daylight or Dark

(*) See coding sheet

APPENDIX 11

Study on Operational Aspects of One-Way and Two-Way Streets

ACCIDENT-TYPE CODES

1 — Rear-end, straight

2 — Rear-end involving left-turn

3 — Rear-end involving right-turn

4 — Head-on, straight

5 — Head-on involving left-turn

6 — Sideswipe, same direction

7 — Sideswipe, opposite direction

8 — Right angle

9 — Involving parking or parked vehicle

10 — Hitting fixed object

11 — Backing vehicle

12 — Hitting pedestrian

APPENDIX 12

LANSING ACCIDENT STUDY

Time period before conversion to one-way operation: January 31, 1964 thru January 30, 1965

Time period after conversion to one-way operation (excluding a period of three months for driver acclimatization and readjustment of traffic devices): April 30, 1965 thru April 29, 1966

"Before" period accidents were studied on following streets:

Street	From (Inclusive)	To (Inclusive)
1. Oakland	Stanley Intersection	Wisconsin Intersection
2. Jefferson	Pine "	Grand "
3. Sheridan	Center St. "	Cedar "
4. Saginaw	Belt Line R.R.	Cedar "
5. Stanley	Genesee Intersection	Hyland "
6. Durant	Genesee "	Hyland "
7. Verlinden	Genesee "	Hyland "
8. Cleo	Verlinden "	Hyland "
9. Cawood	Genesee "	Hyland "
10. Comfort	Saginaw "	Hyland "
11. Drexel	Genesee "	Jenison "
12. Jenison	Genesee "	Hyland "
13. Westmoreland	Genesee "	Hyland "
14. Carey	Genesee "	Saginaw "
15. Clayton	Saginaw "	Hyland "
16. Bartlet	Genesee "	Saginaw "
17. Holten	Oakland "	Hyland "
18. Clyde	Oakland "	Hyland "
19. Logan	Lapeer "	Daleford "
20. Princeton	Saginaw "	Daleford "
21. Summerville	Oakland "	Daleford "
22. Butler	Lapeer "	Saginaw "
23. Chicago	Saginaw "	Daleford "
24. Edgewood	Oakland "	Daleford "
25. Wisconsin	Saginaw "	Daleford "
26. Sycamore	Lapeer "	Bluff "
27. Leonard	Madison "	Jefferson "
28. Pine	Lapeer "	Bluff "
29. Chestnut	Lapeer "	Lawler "
30. Walnut	Lapeer "	Kilborn "
31. Seymour	Lapeer "	Kilborn "
32. Capitol	Lapeer "	Kilborn "
33. Washington	Lapeer "	Kilborn "
34. Grand	Lapeer "	Saginaw "
35. Center	Saginaw "	Sheridan "
36. Cedar	Saginaw "	Sheridan "

"After" period accidents were studied on following streets:

Street	From (Inclusive)	To (Inclusive)
1. Oakland	Stanley Intersection	Cedar Intersection
2. Saginaw	Belt Line R.R.	Cedar "
3. Stanley	Genesee Intersection	Hyland "
4. Durant	Genesee "	Hyland "
5. Verlinden	Genesee "	Hyland "
6. Cleo	Verlinden "	Hyland "
7. Cawood	Genesee "	Hyland "
8. Comfort	Genesee "	Hyland "
9. Drexel	Genesee "	Jenison "
10. Jenison	Genesee "	Hyland "
11. Westmoreland	Genesee "	Hyland "
12. Carey	Genesee "	Saginaw "
13. Clayton	Saginaw "	Hyland "
14. Bartlet	Genesee "	Saginaw "
15. Holten	Oakland "	Hyland "
16. Clyde	Oakland "	Hyland "
17. Logan	Lapeer "	Daleford "
18. Princeton	Saginaw "	Daleford "
19. Summerville	Oakland "	Daleford "
20. Butler	Lapeer "	Saginaw "
21. Chicago	Saginaw "	Daleford "
22. Edgewood	Oakland "	Daleford "
23. Wisconsin	Saginaw "	Daleford "
24. Sycamore	Lapeer "	Bluff "
25. Leonard	Madison "	Oakland "
26. Pine	Lapeer "	Bluff "
27. Chestnut	Lapeer "	Kilborn "
28. Walnut	Lapeer "	Kilborn "
29. Seymour	Lapeer "	Kilborn "
30. Capitol	Lapeer "	Kilborn "
31. Washington	Lapeer "	Kilborn "
32. Grand	Lapeer "	Dead end N. of Oakland
33. Center Street	Saginaw "	Oakland Intersection
34. Cedar	Saginaw "	Oakland "

APPENDIX 13

CITY OF LANSING

Intersection Accidents in the Study Area
(One-Year Periods)

Intersection	Two-Way Phase (Jan. 31, 1964 – Jan. 30, 1965)		One-Way Initial Phase (Ap. 30, 1965 – Ap. 29, 1966)		One-Way Final Phase (Aug. 14, 1969 – Aug. 13, 1970)	
	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Saginaw @ Belt Line RR	3	2	4	4	–	–
" " Stanley	4	–	2	5	9	2
" " Durant	4	1	5	–	3	1
" " Verlinden (S)	11	2	20	3	5	1
" " Cawood	–	1	1	–	–	–
" " Comfort	4	–	–	–	2	2
" " Jenison (S)	12	7	12	5	6	2
" " Westmoreland	1	–	2	–	1	1
" " Clayton	–	2	3	–	3	1
" " Carey	–	–	2	–	–	–
" " Bartlett	–	–	2	–	–	–
" " Logan (S)	18	5	18	3	17	7
" " Princeton	5	1	14	3	7	1
" " Butler-Chicago (S)	11	2	7	–	3	1
" " Wisconsin	1	–	3	–	–	–
" " Sycamore	3	2	4	–	–	–
" " Pine (S)	7	2	9	3	7	
" " Chestnut	3	1	2	–	3	2
" " Walnut (S)	6	3	11	2	7	–
" " Seymour	14	6	7	4	9	–
" " Capitol (S)	13	5	4	2	9	–
" " Washington (S)	14	6	6	3	7	1
" " Grand (S-A)	3	–	12	5	21	9
" " Spur RR	1	–	–	–	–	–
" " Center	3	–	6	–	–	–
" " Cedar (S)	34	9	23	10	42	10
Oakland @ Stanley	1	1	–	–	–	–
" " Cleo	–	–	–	1	1	2
" " Cawood	1	–	–	1	1	–
" " Comfort	1	–	–	1	2	–
" " Jenison	1	–	2	1	3	1
" " Westmoreland	3	2	1	–	1	1
" " Clayton	–	–	–	–	–	1
" " Logan (S-A)	–	1	14	3	20	8
" " Princeton	1	–	3	2	3	1
" " Summerville	–	–	2	–	–	–
" " Chicago	1	–	5	–	3	–
" " Edgewood	–	–	1	–	1	–
" " Wisconsin	–	–	–	–	1	1
" " Leonard	–	–	–	1	–	1
" " Pine (S-A)	–	–	5	2	5	4
" " Chestnut	–	–	3	2	4	1
" " Walnut (S-A)	–	–	3	2	3	1
" " Seymour	–	–	6	6	5	8
" " Capitol (S-A)	–	–	5	3	3	5
" " Washington (S-A)	2	1	14	1	7	4
" " Grand (S-A)	–	–	5	1	5	–

APPENDIX 13 – Sheet 2

Intersection	Two-Way Phase (Jan. 31, 1964 – Jan. 30, 1965)		One-Way Initial Phase (Ap. 30, 1965 – Ap. 29, 1966)		One-Way Final Phase (Aug. 14, 1969 – Aug. 13, 1970)	
	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
" " Center	5	1	8	4	4	6
" " Cedar (S)	20	2	27	6	15	2
Durant @ Genesee	1	1	1	1	–	–
Cleo @ Hyland	1	–	–	–	–	–
Cawood @ Hyland	1	–	–	–	–	–
Bartlett @ Genesee	1	–	–	–	–	–
Church Court @ Logan	–	–	2	–	–	–
Logan @ Rose Ct. & Englewood	4	–	12	3	–	1
Logan @ Kirby	–	–	–	–	1	–
Englewood @ Princeton	–	–	2	–	–	–
Englewood @ Chicago	–	–	–	–	1	–
Butler @ Lapeer	1	–	2	–	–	–
Chestnut @ Lapeer	3	1	–	–	–	–
Capitol @ Kilborn	–	–	1	–	–	–
Capitol @ Madison	–	1	–	1	–	–
Capitol @ Lapeer	–	–	4	1	–	–
Genesee @ Verlinden	1	–	–	–	–	–
Genesee @ Westmoreland	–	1	–	–	–	–
Hyland @ Jenison	–	1	1	–	–	–
Hyland @ Westmoreland	–	–	1	–	–	–
Genesee @ Jenison	2	–	6	3	–	–
Drexel @ Genesee	1	1	1	1	–	–
Drexel @ Jenison	2	–	–	–	–	–
Lapeer @ Logan	1	1	2	1	–	–
Lapeer @ Seymour	1	–	2	1	–	–
Lapeer @ Pine	–	–	–	1	–	–
Lapeer @ Sycamore	2	–	–	–	–	–
Lapeer @ Walnut	3	–	–	–	–	–
Lapeer @ Washington	7	1	10	1	–	–
Chicago @ Daleford	–	–	1	–	–	–
Daleford @ Logan	1	2	1	–	–	–
Daleford @ Princeton	–	–	–	1	–	–
Kilborn @ Walnut	3	1	–	–	–	–
Kilborn @ Seymour	–	2	1	–	–	–
Kilbom @ Washington	4	–	3	–	–	–
Madison @ Washington	2	1	–	–	2	–
Walnut @ Madison	–	1	–	–	–	–
Madison @ Seymour	–	–	2	–	2	–
Pine @ Madison	2	–	–	–	–	1
Grand @ Lapeer	1	–	2	–	–	–
Grand @ Madison	–	–	1	–	–	–
Center @ Monroe	–	–	–	–	–	–
Cedar @ Monroe	1	1	–	–	5	–
Total intersection accidents	258	81	341	105	259	92

(S) Signal-controlled intersection
(S-A) Intersection was signal-controlled during the one-way phases only.

APPENDIX 14

CITY OF LANSING

Midblock Accidents in the Study Area

Street	Two-Way Phase (Jan. 31, 1964 – Jan. 30, 1965)		One-Way Initial Phase (Ap. 30, 1965 – Ap. 29, 1966)		One-Way Final Phase (Aug. 14, 1969 – Aug. 13, 1970)	
	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Saginaw west of Logan	34	10	37	6	)	)
Saginaw east of Logan	59	14*	34	6	) 66	) 14
Oakland	6	2	27	5	41	17
Durant	1	–	–	1	–	–
Verlinden	–	–	1	–	2	–
Cleo	–	–	2	–	3	3
Cawood	–	–	–	–	5	–
Comfort	1	–	–	–	1	–
Jenison	2	2	5	–	4	1
Westmoreland	3	–	1	–	2	–
Clayton	–	–	–	–	4	–
Holton	1	–	–	–	–	–
Logan	4	1	9	4	5	1
Princeton	2	–	5	–	1	–
Butler	5	–	2	–	–	–
Chicago	–	–	1	1	2	1
Wisconsin	1	–	–	–	–	–
Sycamore	–	1	–	–	2	–
Pine	1	–	–	–	1	–
Chestnut	1	–	3	–	–	–
Walnut	1	–	2	1	1	–
Seymour	5	–	–	1	–	–
Capitol	4	1	3	1	2	1
Washington	9	2	14	–	6	–
Grand	–	–	–	–	–	3*
Center	2	–	–	–	–	–
Cedar	6	–	4	2	9	2
Total midblock accidents	148	33*	150	28	157	43*

* Includes one fatality

APPENDIX 15

KALAMAZOO ACCIDENT STUDY

Time period before conversion to one-way operation: October 10, 1964 thru October 9, 1965

Time period after conversion to one-way operation (considering a period of three months for driver acclimatization and readjustment of traffic devices): January 10, 1966 thru Januray 9, 1967

"Before" period accidents were studied on the following streets:

Street	From (Inclusive)	To (Inclusive)
1. North St.	Summer Intersection	Gull Rd. Intersection
2. Kalamazoo	Douglas "	Michigan "
3. Water	Westnedge "	Kalamazoo "
4. Main	Thompson "	Michigan "
5. Michigan	Lovell "	King Hwy. "
6. South St.	Michigan "	Pitcher "
7. Lovell	Michigan "	Pitcher "
8. Douglas	Main "	North "
9. Carmel	Academy "	Main "
10. Stuart	Main "	North "
11. Catherine	Academy "	Main "
12. Main Ct.	South end "	Main "
13. Woodward	Main Intersection	North "
14. Elm	Main "	North "
15. Elm Pl.	Elm "	Eleanor "
16. Allen	Michigan "	Eleanor "
17. Old Orchard Pl.	South end	Eleanor "
18. Arcadia Ct.	North end	Westnedge "
19. Eleanor	Eleanor St. "	Kalamazoo "
20. Westnedge	Lovell	North St. "
21. Cooley	Water "	Willard "
22. Park	Lovell "	North St. "
23. Church	Academy "	North St. "
24. Rose	Lovell "	North St. "
25. Burdick	Water "	North St. "
26. Portage	Michigan "	Lovell "
27. Edwards	North St. "	South St. "
28. Pitcher	North St. "	Lovell "
29. Porter	North St. "	Michigan "
30. Walbridge	North St. "	Michigan "
31. Harrison	Kalamazoo "	North St. "
32. Mitchell	Kalamazoo "	Willard "
33. Greenwich	Kalamazoo "	Willard "
34. Eleanor	Elm "	Burdick "

"After" period accidents were studied on the following streets:

Items 1 thru 14 same as for the "before" period.

Items 17 and 18 same as for the "before" period.

Items 20 thru 33 same as for the "before" period.

Street	From (Inclusive)	To (Inclusive)
15. Elm Pl.	Elm Intersection	East End
16. Allen	Michigan "	North End
19. Eleanor Pl.	South End	Kalamazoo Intersection
34. Eleanor	Elm Intersection	East End West of Michikal
35. Eleanor	West End East of Michikal	Burdick Intersection
36. Michikal	Main and Michigan Intersection	Kalamazoo and Westnedge Intersection
37. New Connector	Elm Intersection	Michigan Intersection

APPENDIX 16

CITY OF KALAMAZOO

Intersection Accidents in the Study Area

Intersection		One-Year "Before" Period		One-Year "After" Period	
		Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Michigan @ Lovell	(S)	34	4	24	7
" " South	(S)	2	–	–	–
" " Main	(S)	15	3	21	6
" " Allen		6	2	–	–
" " Westnedge	(S)	44	8	29	2
" " Park	(S)	32	8	42	2
" " Church		5	2	11	1
" " Rose	(S)	6	–	19	3
" " Burdick	(S)	20	–	5	–
" " Portage	(S-B)	11	2	10	–
" " Edwards	(S)	11	4	11	1
" " Pitcher	(S)	11	2	7	3
" " Porter		3	–	6	3
" " Walbridge		2	–	1	1
" " Kalamazoo	(S-B)	19	3	7	1
" " Harrison		9	1	11	5
" " King	(S)	5	2	2	1
Kalamazoo @ Douglas		8	–	5	–
" " Stuart		3	–	2	–
" " Woodward		2	2	2	–
" " Elm		3	–	2	1
" " Westnedge	(S)	10	4	1	–
" " Park	(S)	6	4	25	5
" " Church		3	1	2	–
" " Rose	(S)	11	2	21	7
" " Burdick	(S)	10	–	18	–
" " Edwards	(S)	11	1	9	2
" " Pitcher	(S)	8	5	11	2
" " Porter & Water		4	–	2	–
" " Walbridge		–	–	1	–
North @ Douglas	(S)	3	–	3	1
" " Stuart		2	–	1	–
" " Woodward		3	–	3	–
" " Elm		1	–	1	1
" " Westnedge	(S)	10	2	–	–
" " Park	(S)	3	2	6	7
" " Church		–	1	2	2
" " Rose	(S)	5	2	8	–
" " Burdick	(S)	8	2	7	2
" " Edwards		5	3	2	3
" " Pitcher		4	1	4	1
" " Porter		1	2	3	–
" " Harrison		–	2	1	2
" " Gull		3	1	4	2
" " Summer		–	–	1	–
Eleanor @ Elm		1	–	–	–
Eleanor @ Church		2	1	3	–
Eleanor @ Cooley		–	–	–	1
Water @ Church		3	2	12	–
South @ Burdick	(S)	4	–	–	–
South @ Henriett		1	1	1	–
Lovell @ Burdick	(S)	4	–	8	–
Lovell @ John		2	–	–	–

APPENDIX 16 – Sheet 2

Intersection		One-Year "Before" Period		One-Year "After" Period	
		Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Lovell @ Henriett		1	–	1	–
Lovell @ Jasper		2	1	1	1
Main @ Douglas	(S-B)	15	–	4	–
Main @ Stuart		3	–	6	–
Main @ Catherine		2	–	2	–
Main @ Woodward		4	–	6	–
Main @ Elm		5	1	7	–
Douglas @ Forbes		–	1	1	–
Douglas @ Jefferson		2	–	–	1
Catherine @ Academy		–	1	–	–
Westnedge @ Lovell	(S)	7	1	9	1
" " South	(S)	5	1	21	1
" " Academy		7	–	9	–
" " Water		5	1	6	–
" " Willard		2	1	–	–
" " Ransom		5	–	–	2
Park @ Lovell	(S)	15	2	14	2
" " South	(S)	12	1	8	2
" " Academy		11	–	4	1
" " Water		8	–	19	1
" " Eleanor		5	–	3	4
" " Willard		3	–	1	–
" " Ransom		3	2	3	–
Rose @ Lovell	(S)	11	3	13	1
" " South	(S)	10	3	14	1
" " Water	(S)	10	1	8	1
" " Eleanor		6	–	5	1
" " Ransom		1	1	2	–
Burdick @ Water	(S)	5	1	2	–
" " Ransom		3	–	3	–
" " Eleanor		–	–	3	–
Edwards @ South		4	–	4	2
" " Water	(S)	3	2	5	1
" " Ransom		4	1	1	1
Pitcher @ Lovell		1	1	–	–
" " Spring		4	–	1	–
" " South		8	1	2	–
" " Water	(S)	5	1	5	1
" " Ransom		1	–	6	2
Porter @ Ransom		–	–	3	1
Walbridge @ Ransom		2	1	6	1
Church @ Ransom		–	–	–	3
Harrison @ Ransom		1	–	–	–
" " Gull		4	–	3	1
Portage @ Lovell	(S)	6	–	9	1
" " Spring		1	–	2	1
" " South	(S)	13	1	6	1
Total intersection accidents		604	112	605	111

(S) Signal-controlled intersection
(S-B) Intersection was signal-controlled during the "before" period only.

APPENDIX 17

CITY OF KALAMAZOO

Midblock Accidents in the Study Area

Street	One-Year "Before" Period		One-Year "After" Period	
	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Michigan south of Main	22	2	16	6
Michigan east of Main	170	28	114	18
Kalamazoo	33	4	21	2
North	41	12	44	7
Eleanor	3	1	6	–
Water	24	2	30	1
South	51	2	38	1
Lovell	34	6	76	9
Main	28	1	14	–
Douglas	14	3	6	–
Carmel	2	2	7	1
Stuart	3	–	1	–
Catherine	4	–	1	–
Woodward	5	–	3	1
Westnedge	19	1	18	3
Park	28	3	19	1
Rose	44	2	26	2
Burdick	8	–	15	–
Edwards	4	2	9	3
Pitcher	10	–	21	2
Church	11	–	5	2
Porter	1	–	–	1
Walbridge	4	–	3	–
Harrison	1	–	5	4
Portage	23	5	12	1
Cooley	1	–	–	–
Total midblock accidents	588	76	510	65

APPENDIX 18

PONTIAC ACCIDENT STUDY

Time period before conversion to one-way operation: May 18, 1966 thru May 17, 1967

Time period after conversion to one-way operation (considering a period of three months for driver acclimatization and readjustment of traffic devices): July 5, 1968 thru July 4, 1969

"Before" and "After" period accidents were studied on following streets:

Street	From (Inclusive)	To (Inclusive)
1. Oakland	Northwest City Limits	Wide Track Blvd. Intersection
2. Cass	Oakland-Montcalm Intersection	Wide Track Blvd. Intersection
3. Montcalm	Oakland-Cass Intersection	Corwin Intersection
4. Gerdon	Oakland Intersection	Corwin "
5. Blaine	Oakland "	Jefferson "
6. Euclid	Oakland "	Jefferson "
7. Summit	Oakland "	Jefferson "
8. Cadillac	Oakland "	Putnam "
9. Adelaide	Oakland "	Howard "
10. Wisner	Cass "	Oakland "
11. Johnson	Norton "	Howard "
12. Florence	Norton "	Oakland "
13. Baldwin	Howard "	Oakland "
14. Allison	Close "	Oakland "
15. Sanderson	Norton "	Oakland "
16. Clark	Oakland "	Stockwell "
17. Wide Track	Oakland "	Cass "
18. Lafayette	Cass "	Jacokes "

APPENDIX 19

CITY OF PONTIAC

Intersection Accidents in the Study Area

Intersection	One-Year "Before" Period		One-Year "After" Period	
	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Oakland @ West Blvd.	5	1	1	–
" " Pershing	–	2	1	2
" " Sarasota	2	1	2	1
" " Inglewood	–	3	1	4
" " Orlando	1	2	–	1
" " Pensecola	5	–	3	–
" " Monticello	–	2	1	1
" " Ojista	1	1	1	–
" " Kinney	–	–	1	–
" " Northview	–	1	–	–
" " Lounsbury	4	1	–	–
" " Cass-Montcalm (S)	24	10	19	4
" " Gerdon	1	2	1	–
" " Blaine	1	3	1	–
" " Euclid	–	1	–	–
" " Summit (S)	2	3	2	–
" " Cadillac	2	–	3	–
" " Adelaide	1	–	–	1
" " Wisner	–	–	4	–
" " Johnson (S)	7	8	4	2
" " Florence	3	1	3	2
" " Allison-Baldwin (S)	12	2	13	6
" " Sanderson	6	3	12	7
" " RR Grade Crossing	2	–	3	3
" " Clark	6	2	1	–
" " Wide Track Drive (S)	25	6	19	5
Cass @ Wisner	1	2	3	–
" " Johnson (S)	15	4	10	5
" " Florence	1	–	3	1
" " Sanderson	2	2	22	10
" " Wide Track Drive (S)	1	1	6	7
Montcalm @ Corwin	4	1	3	2
Blaine @ Jefferson	1	–	–	–
Euclid @ Jefferson	–	1	–	1
Summit @ Jefferson	1	–	1	–
Cadillac @ Putnam	1	–	–	–
Cadillac @ Pingree	1	–	–	–
Johnson @ Norton	3	–	7	2
Johnson @ Howard	3	2	1	–
Johnson @ Pine Grove	–	–	1	1
Florence @ Norton	–	–	2	1
Florence @ Pine Grove	–	–	1	–
Allison-Baldwin @ Howard	5	5	8	1
Allison-Baldwin @ Close	–	1	1	1
Sanderson @ Norton	1	1	–	1
Sanderson @ Close	–	–	2	–
Clark @ Stockwell	1	–	–	–
Wide Track Dr. @ Lafayette	–	–	5	3
Total intersection accidents	151	75	172	75

(S) Signal-controlled intersection.

APPENDIX 20

CITY OF PONTIAC

Midblock Accidents in the Study Area

Street	One-Year "Before" Period		One-Year "After" Period	
	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Oakland NW of Cass-Montcalm	5	4	11	4*
Oakland SE of Cass-Montcalm	13	5	13	5
Cass	3	1	15	6
Montcalm	1	–	2	–
Gerdon	–	–	1	–
Jefferson	–	–	–	1
Euclid	1	–	2	–
Summit	3	–	3	1
Cadillac	1	–	–	–
Wisner	1	–	1	–
Johnson	3	–	2	–
Florence	2	–	2	–
Allison-Baldwin	–	1	2	1
Sanderson	–	–	–	1
Clark	2	–	2	–
Wide Track Drive	1	1	–	1
Total Midblock Accidents	36	12	56	20*

* Includes one fatality

APPENDIX 21

PORT HURON ACCIDENT STUDY

Time period before conversion to one-way operation (before start of construction period):
January 19, 1964 thru January 18, 1965

Time period after conversion to one-way operation (considering a period of three months for driver acclimatization and readjustment of traffic devices):
January 19, 1967 thru January 18, 1968

"Before" and "after" period accidents were studied on following streets:

Street	From (Inclusive)	To (Inclusive)
1. Lapeer	32nd Street Intersection	Water Street Intersection
2. Water	Lapeer Street "	4th Street "
3. Botsford	Lapeer Street "	John L. Street "
4. 24th	Farrand Street "	Lapeer Street "
5. Rural	Lapeer Street "	G.T.W. RR crossing
6. 20th	Martin Street "	Lapeer Street "
7. 18th	Martin Street "	Lapeer Street "
8. 17th	Martin Street "	Miller Street "
9. 16th	Jenks Street "	Miller Street "
10. 15th	Jenks Street "	Miller Street "
11. 14th	Jenks Street "	Miller Street "
12. 13th	Jenks Street "	Pearl Street "
13. 12th	Jenks Street "	Pearl Street "
14. 11th	Gillett Street "	Pearl Street "
15. 10th	Gillett Street "	Pearl Street "
16. Lapeer Ct.	Lapeer Street "	Ernst Street "
17. 9th	Howard Street "	Lapeer Street "
18. 8th	Howard Street "	Lapeer Street "
19. 7th	Howard Street "	Quay Street "
20. 6th	Pine Street "	Water Street "
21. Military	Pine Street "	Quar Street "
22. Mitchell	7th Street "	6th (Before-Period)
23. Mitchell	8th Street "	Military (After-period)
24. Court	20th Street "	4th Street Intersection
25. Union	24th Street "	Military Street "
26. Griswold	32nd Street "	4th Street "
27. Oak	27th Street "	8th Street "
28. 27th	Oak Street "	Griswold Street "
29. 26th	Oak Street "	Griswold Street "

APPENDIX 21 – Sheet 2

Street	From (Inclusive)	To (Inclusive)
30. 25th	Oak Street Intersection	Griswold Street Intersection
31. 24th	Division Street "	White Street "
32. 23rd	Division Street "	White Street "
33. 22nd	Division Street "	White Street "
34. 21st	Division Street "	White Street "
35. 20th	Division Street "	White Street "
36. 19th	Division Street "	White Street "
37. 18th	Division Street "	White Street "
38. 17th	Division Street "	White Street "
39. 16th	Division Street "	White Street "
40. 15th	Division Street "	White Street "
41. 14th	Division Street "	White Street "
42. 13th	Division Street "	White Street "
43. 12th	Division Street "	White Street "
44. 11th	Division Street "	White Street "
45. 10th	Division Street "	White Street "
46. 9th	Division Street "	White Street "
47. 8th	Division Street "	White Street "
48. 7th	Division Street "	White Street "
49. Jay	Division Street "	Griswold Street "
50. 6th	Division Street "	White Street "
51. Military	Division Street "	White Street "

APPENDIX 22

CITY OF PORT HURON

Accidents Along Lapeer Avenue & Water Street Corridor

INTERSECTION ACCIDENTS:	One-Year "Before" Period		One-Year "After" Period	
Intersection	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Lapeer @ 32nd	5	5	1	9
" " By Pass (S)	10	7	4	4
" " Botsford	3	1	–	1
" " 24th (S)	14	4	11	–
" " Rural	5	1	8	–
" " 20th (S)	3	3	6	–
" " 18th	2	–	3	1
" " 17th	1	–	2	–
" " 16th	3	–	1	–
" " 15th	4	–	1	–
" " 14th	2	1	–	2
" " 13th (S)	11	2	9	–
" " 12th	–	2	1	–
" " 11th	–	3	1	–
" " 10th (S)	16	4	14	7
" " 9th	4	1*	1	–
" " 8th	5	–	1	–
" " Water & 7th (S)	11	–	10	–
Water @ 6th	2	–	5	–
" " Military (S)	10	3	18	5
" " 4th	–	1	1	–
24th @ Farrand	4	1	6	–
22nd @ Farrand	–	–	2	–
20th @ Farrand	–	–	1	–
18th @ Martin	–	–	1	–
17th @ Miller	–	1	–	–
14th @ Jenks	1	–	–	–
13th @ Pearl	1	–	1	–
10th @ Gillett	–	–	–	1
10th @ Pearl	–	–	1	–
8th @ Howard	1	–	1	–
7th @ Howard	1	–	–	–
7th @ Quay	–	–	1	–
Military @ Pine	24	1	20	4
Military @ Quay	–	–	–	1
Total Intersection Accidents	143	41	132	36
Street				
Lapeer	17	6	20	2
Water	3	1	11	2
24th	3	–	–	–
20th	–	–	1	–
10th	–	–	1	–
8th	–	–	1	–
7th	4	–	1	–
6th	–	–	3	–
Military	9	1	14	2
Total Midblock Accidents	36	8	52	6

(S) Signal-controlled intersection

* Fatal

APPENDIX 23

CITY OF PORT HURON

Accidents on Union & Court Streets

INTERSECTION ACCIDENTS:	One-Year "Before" Period		One-Year "After" Period	
Intersection	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Union @ 24th	6	4	2	1
" " 22nd	–	–	1	–
" " 21st	–	1	–	–
" " 20th	2	–	3	1
" " 19th	–	–	2	–
" " 18th	–	–	1	–
" " 17th	1	–	1	–
" " 16th	1	–	2	1
" " 15th	1	–	–	–
" " 14th	–	1	1	–
" " 13th	3	1	6	1
" " 12th	1	–	1	–
" " 11th	2	1	–	–
" " 10th (S)	6	2	5	–
" " 9th	–	–	2	–
" " 8th	–	–	1	–
" " 7th (S)	2	–	2	2
" " 6th	–	–	1	–
" " Military	4	–	3	1
Court @ 20th	1	–	3	1
" " 19th	1	1	–	–
" " 18th	1	–	–	–
" " 16th	1	–	–	1
" " 15th	1	–	–	–
" " 13th	5	1	3	–
" " 11th	1	–	–	–
" " 10th (S)	2	1	6	2
" " 9th	–	1	–	–
" " 8th	–	1	2	–
" " 7th (S)	2	1	4	2
" " 6th	2	–	4	–
" " Military	5	3	3	1
" " 4th	–	–	1	–
Total Intersection Accidents	51	19	60	14
MIDBLOCK ACCIDENTS:				
Street				
Union	5	1	7	1
Court	3	–	8	1
Total Midblock Accidents	8	1	15	2

(S) Signal-controlled intersection

APPENDIX 24

CITY OF PORT HURON

Accidents on Oak Street

INTERSECTION ACCIDENTS:	One-Year "Before" Period		One-Year "After" Period	
Intersection	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Oak @ 27th	–	–	1	–
" " 26th	–	–	2	–
" " 25th	1	–	–	–
" " 24th (SA)	–	–	19	11
" " 23rd	–	–	3	2
" " 22nd	1	–	1	–
" " 20th	–	1	2	–
" " 19th	–	–	1	–
" " 15th	2	–	–	–
" " 13th	2	–	3	–
" " 12th	1	–	1	–
" " 10th (SA)	1	–	14	5
" " 8th	1	–	1	–
" " Jay	–	–	1	–
" " 7th	–	–	1	–
" " 6th	1	–	–	–
" " Military (SA)	–	–	7	3
Total Intersection Accidents	10	1	57	21
MIDBLOCK ACCIDENTS	–	–	2	1

(SA) Intersection was signal-controlled during the "after" period only.

APPENDIX 25

CITY OF PORT HURON

Accidents on Griswold Street

INTERSECTION ACCIDENTS:	One-Year "Before" Period		One-Year "After" Period	
Intersection	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Griswold @ 32nd	1	2	–	–
" " Eastbound M-21	–	–	1	–
" " 28th	1	–	–	–
" " 26th	3	–	–	–
" " 24th (S)	15	5	10	7
" " 23rd	–	–	4	1
" " 22nd	1	–	–	–
" " 21st	1	–	–	1
" " 20th	2	–	4	1
" " 19th	–	1	–	–
" " 17th	–	–	2	–
" " 16th	–	2	3	1
" " 15th	1	–	–	–
" " 13th	1	–	–	1
" " 12th	–	–	2	–
" " 11th	5	1	4	–
" " 10th (S)	5	3	11	7
" " 9th	2	–	3	1
" " 8th	2	2*	–	–
" " 7th	3	4	2	2
" " 6th	–	–	–	1
" " Military (S)	7	2	8	–
" " 4th	2	–	–	–
Total Intersection Accidents	52	22	54	23
MIDBLOCK ACCIDENTS:	8	2*	15	1

* Includes one fatal accident
(S) Signal-controlled intersection

APPENDIX 26

CITY OF PORT HURON

Accidents on Streets Crossing Oak-Griswold Corridor

INTERSECTION ACCIDENTS:

Intersection	One-Year "Before" Period		One-Year "After" Period	
	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
24th @ Division	1	1	2	1
24th @ White	1	1	1	–
23rd @ White	–	–	1	1
22nd @ White	1	–	–	–
20th @ Division	–	–	1	–
18th @ White	–	–	2	–
17th @ White	2	1	–	–
16th @ Division	–	–	1	–
15th @ Division	–	–	–	1
13th @ White	–	1	–	1
12th @ Division	–	–	1	–
11th @ Division	1	–	–	–
11th @ White	1	–	3	1
10th @ White	–	–	1	1
9th @ Division	–	–	1	–
8th @ Division	–	–	2	–
8th @ White	1	–	–	–
7th @ Division	–	–	1	–
6th @ White	1	–	–	–
Military @ Division	–	–	1	–
Military @ White	4	–	1	1*
Total Intersection Accidents	13	4	19	7

MIDBLOCK ACCIDENTS:

Streets				
24th	2	–	4	1
22nd	–	–	1	–
16th	–	–	1	–
14th	–	–	1	–
13th	–	–	2	–
11th	–	–	6	–
10th	1	1	3	1
9th	–	–	1	–
8th	–	–	1	–
Military	1	–	2	–
Total Midblock Accidents	4	1	22	2

* Fatal

APPENDIX 27

STATISTICAL ANALYSIS
(by Arthur Yang)

The results of speed-and-delay studies on the trunk line routes and of travel-time surveys on cross-streets were analyzed statistically to determine the significance of the changes between the conditions during the two-way and the one-way operations.

ONE-WAY ANALYSIS OF VARIANCE

This method was used for analyzing the changes in the average overall speeds during each peak period. The results are indicated on the individual tabulations for the study cities. The letter (S) is used to indicate that the change was significant.

The following is a brief explanation of the method:

> It is desired to test the hypothesis that the means of k normal populations are equal, given independent samples of size N_i (i = 1, 2, . . ,k) from the k populations and assuming that the populations have equal variances.

Hypotheses are defined

Null Hypothesis: $\mu_1 = \mu_2 = \ldots = \mu_k$

Alternative Hypothesis: at least two of the means are unequal.

With mathematical model

$$X_{ij} = \mu_i + \varepsilon_{ij} \quad \text{where} \quad \begin{matrix} i = 1,2,\ldots k \\ j = 1,2,\ldots N_i \end{matrix}$$

ε_{ij} are independent chance components with identical normal distribution $N(O, \sigma)$

F – statistics is used to test the hypothesis.

T-TEST

This method was used for analyzing the average number of stops during each peak period of the speed-and-delay runs, and the average travel time during each period of the cross-street travel-time runs. Statistical significance in the changes is again indicated by an (S) with the individually tabulated results.

The method is as follows:

It is desired to test the hypothesis that the means of two normal populations are equal, given independent samples from the two populations and assuming that the population variances are equal.

Hypotheses are defined

(1) One-tail test:

Null Hypothesis: $\mu_1 = \mu_2$

Alternative Hypothesis: $\mu_1 > \mu_2$

or

Null Hypothesis: $\mu_1 = \mu_2$

Alternative Hypothesis: $\mu_1 < \mu_2$

(2) Two-tail test:

Null Hypothesis: $\mu_1 = \mu_2$

Alternative Hypothesis: $\mu_1 \neq \mu_2$

with mathematival model

$$X_{ij} = \mu_i + \varepsilon_{ij} \quad \text{where } i = 1,2, \quad j = 1,2,\ldots N_i$$

ε_{ij} are independent change components with identical normal distribution $N(O,\sigma)$

t-statistics is used to test the hypothesis.