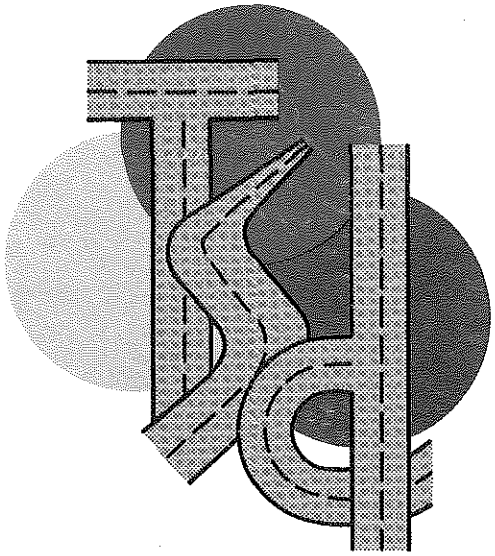
STUDY OF THE OPERATIONAL ASPECTS OF ONE-WAY AND TWO-WAY STREETS

Report TSD-TR-101 (I)-69



TRAFFIC and SAFETY DIVISION

DEPARTMENT OF STATE HIGHWAYS
STATE OF MICHIGAN

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

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

Report TSD-TR-101 (I)-69

INTERIM REPORT

By

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Conducted By

Traffic Research Section
Traffic & Safety Division

in cooperation with

U. S. Department of Transportation
Federal Highway Administration
Bureau of Public Roads

January, 1969

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ABSTRACT

By taking advantage of the Michigan Department of State Highways' scheduled plans of conversion of some state trunklines through cities from two-way to one-way traffic operation, a research study was set up to determine in a quantitative way the improvements in traffic operation obtained by the conversion. One-way trunkline systems in the cities of Lansing, Kalamazoo, Pontiac and Port Huron have been under study. Analyses of before-and-after data for Lansing and Kalamazoo are now completed. Studies for Pontiac and Port Huron are progressing according to schedule. This interim report is confined to the studies and the results obtained in Lansing and Kalamazoo.

Parameters of time, convenience and safety have been used in this study to evaluate the quality of the traffic service. Field surveys have been conducted for speed and delay of traffic on selected routes, for gaps in the traffic stream, for volumes at several locations on state trunklines and local streets, and accident analyses have been made based on reports compiled by city police.

Analyses of speed surveys indicated that, on an over-all average basis, travel speed on the trunkline increased from 18.1 to 23.5 miles per hour in Kalamazoo and from 25.3 to 28.2 miles per hour in Lansing. Average delay, calculated by dividing the total stopped time by the trip distance, was reduced by more than 50 percent in Kalamazoo and almost 30 percent in Lansing.

Gaps in the traffic stream on the arterial streets at stop-controlled intersections increased considerably during the one-way operation. In some instances, the total number of gaps showed slight increase, but the increase in the number of gaps of larger sizes was always substantial.

In analyzing the traffic volume data, 15-minute volumes entering and leaving the study area and 15-minute totals of travel in vehicle-miles in the area were examined and compared. In Lansing, traffic volumes entering the area in 24 hours showed a rise of 8.5 percent between the two-way and one-way operation. During the morning peak periods, however, 15-minute volumes entering the area showed a rise of 16.1 percent, which was an indication of the improvement in the capacity of the street network in the area to receive and distribute the traffic.

Similarly, the volumes leaving the area in Lansing in 24 hours showed an increase of 17.4 percent whereas the 15-minute peak volumes in the afternoon rush period increased by 74 percent.

The capacity of the street system to move traffic within the area itself was examined by analyzing the vehicle-miles of travel. In the Lansing area, the peak-period increases in travel between the "before" and the "after" phases of the study were of the order of 13 to 19 percent.

The "after" surveys in Kalamazoo were not taken in the month of October like the "before" surveys, but were taken in May. The

seasonal variations in the peaking characteristics of the various streets made it impossible to compare the peak traffic volumes.

Study results indicated that both in Lansing and Kalamazoo the one-way arterials attracted additional traffic, especially during rush hours, from the rest of the streets in the system, thus helping to alleviate congestion on the local streets.

Analysis of volumes and travel indicated that travel distances within the study corridors have not increased to any appreciable degree, contrary to the general belief that one-way street operation causes excessive trip lengths.

The two cities so far studied have not indicated similar conclusive trends in the safety aspects of the one-way systems. In general, the accident situation in Kalamazoo has improved, but in Lansing, it has not. Some observations of accident analysis common to both cities were that on the trunkline section which changed from two-way to one-way operation there was considerable reduction in rear-end collisions, substantial decrease in all types of midblock accidents, but some indication of rise in pedestrian accidents.

INTRODUCTION AND OBJECTIVES

Michigan Department of State Highways, being the state agency in charge of the construction and administration of the state trunkline system including urban extensions often is faced with the problem of selecting new routes through urban areas. This has to be accomplished in cooperation and agreement with the local governments concerned. In recent years, in order to keep up with the increasing traffic needs, resort has often been made to establishing one-way street pairs to carry the state trunkline traffic through such areas. Some local resistance is at times met against converting an existing thoroughfare from the usual two-way traffic to one-way operation. The leaders of such opposition have to be convinced about the benefits to the whole community of these traffic changes before the Department can proceed with the one-way plan.

Even though there seems to exist general knowledge about the benefit of one-way streets, specific cases where these benefits were described in a quantitative way are very scarce. It was believed that much aid could be had, in negotiating proposed one-way systems with local authorities and civic leaders, from a documentation of the advantages obtained when actual two-way state trunklines 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 trunkline 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. The Transportation

Planning Division of the Department is conducting a parallel study of the influence of one-way highways on land use, housing and property values. These two studies will complement each other and provide factual information on the experiences in a few areas which are representative of similar future trunkline changes.

When the study on the operational aspects was first being considered, eight cities were mentioned for possible areas of research. Actual experience in conducting field surveys on a before-and-after basis, compiling accident data and analyzing and evaluating information for the cities of Kalamazoo and Lansing made it necessary to reconsider the magnitude of the project with due consideration for manpower and funds available. Also, some of the systems which were earlier considered had to be dropped for such reasons as not being a conversion from a two-way to one-way operation, but rather a replacement of an existing one-way pair by a new one; the nature of the project not being a representative sample as far as the objectives of the study are concerned; and postponement of the conversion plans. These circumstances led to the decision to confine the study to four cities, which are Kalamazoo, Lansing, Pontiac and Port Huron.

At this stage of the study, analyses of the data from Kalamazoo and Lansing are completed. However, the one-way system now operating in Lansing is a limited section of the ultimate plan,

and a subsequent evaluation can be made when the construction of the rest of the street system is accomplished.

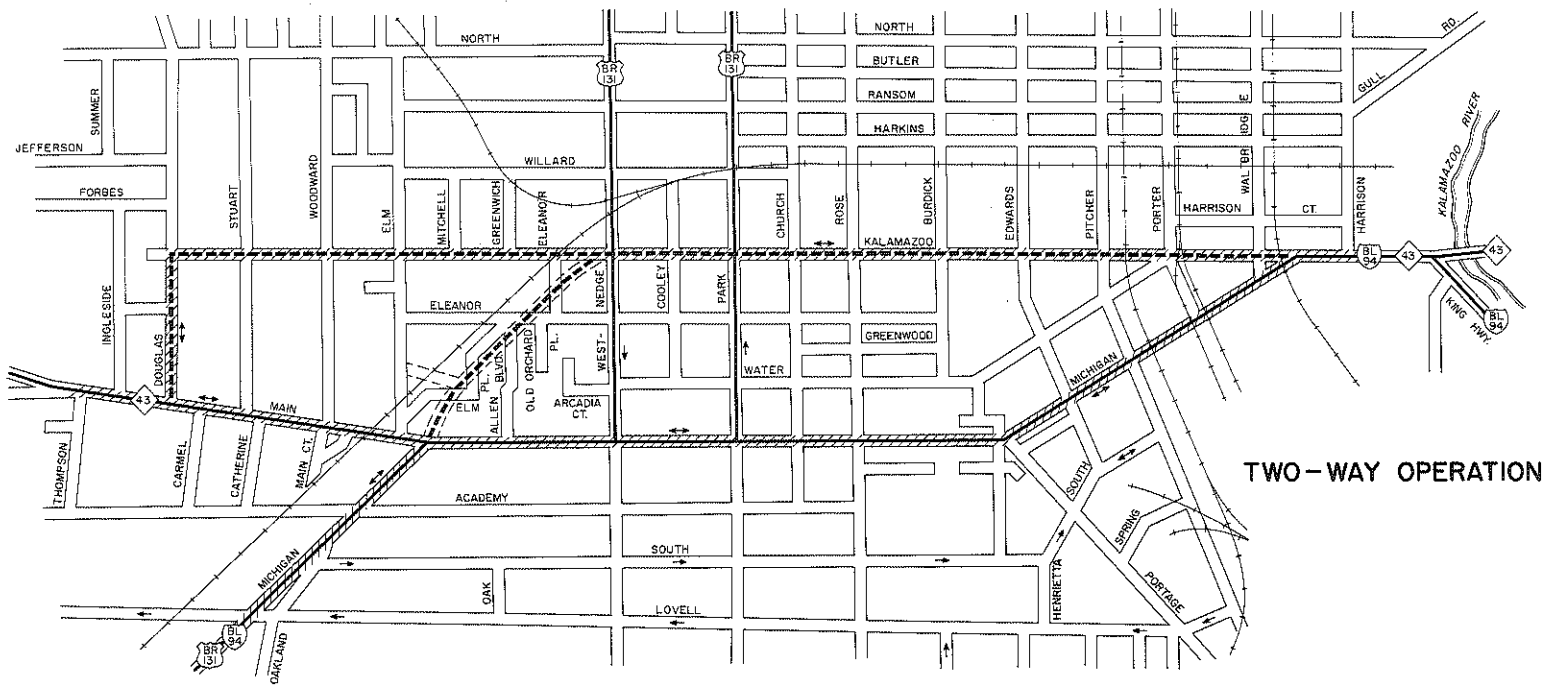
Since this study will take about two more years to complete, it was decided to prepare this interim report on the results so far obtained in Kalamazoo and Lansing. It is expected that when study data from Pontiac and Port Huron are complete, a reevaluation of all the data will be made and, hopefully, more pronounced trends in the indicated results of one-way traffic operation will be derived from the larger number of sample cities.

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 1. The area includes a substantial portion of the central business district. During the "before" phase of the study (upper half of Figure 1), 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 trunkline 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



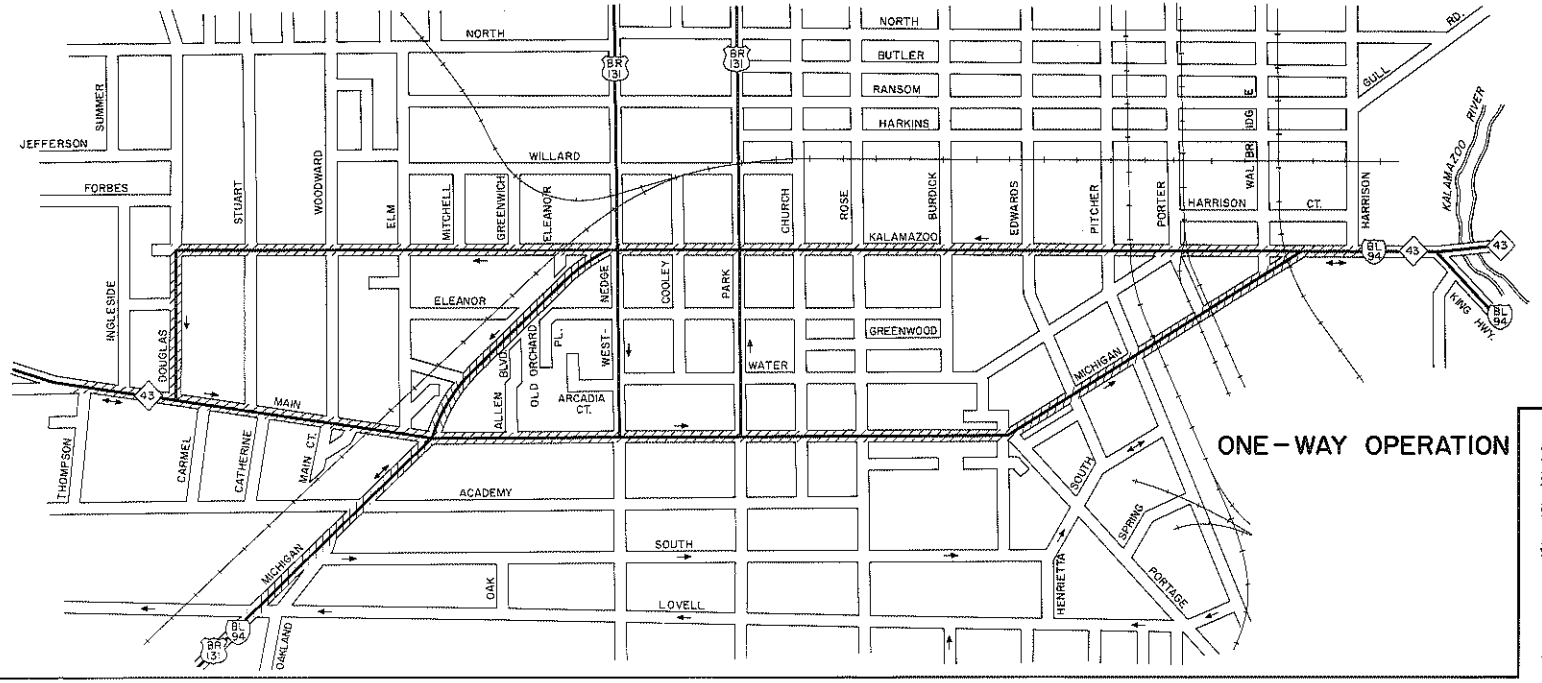


FIGURE 1 - CITY OF KALAMAZOO: STUDY AREA & SURVEY ROUTES

to handle left-turns from northeastbound Michigan to Elm Street. (Shown in Figure 3.) 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 trunkline scheme according to the one-way plan is seen in the lower half of Figure 1. The new scheme started operating on October 10, 1965. Figure 2 shows the laneage of the principal streets, and parking and other traffic controls during two-way operation in the study area. Figure 3 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 sample sizes for the various surveys were based on established methods normally used for similar work by Michigan Department of State Highways.

Volume counts by pneumatic counters were taken at 66 locations. These were shown in Figure 4. The machines recorded the volumes by 15-minute periods.

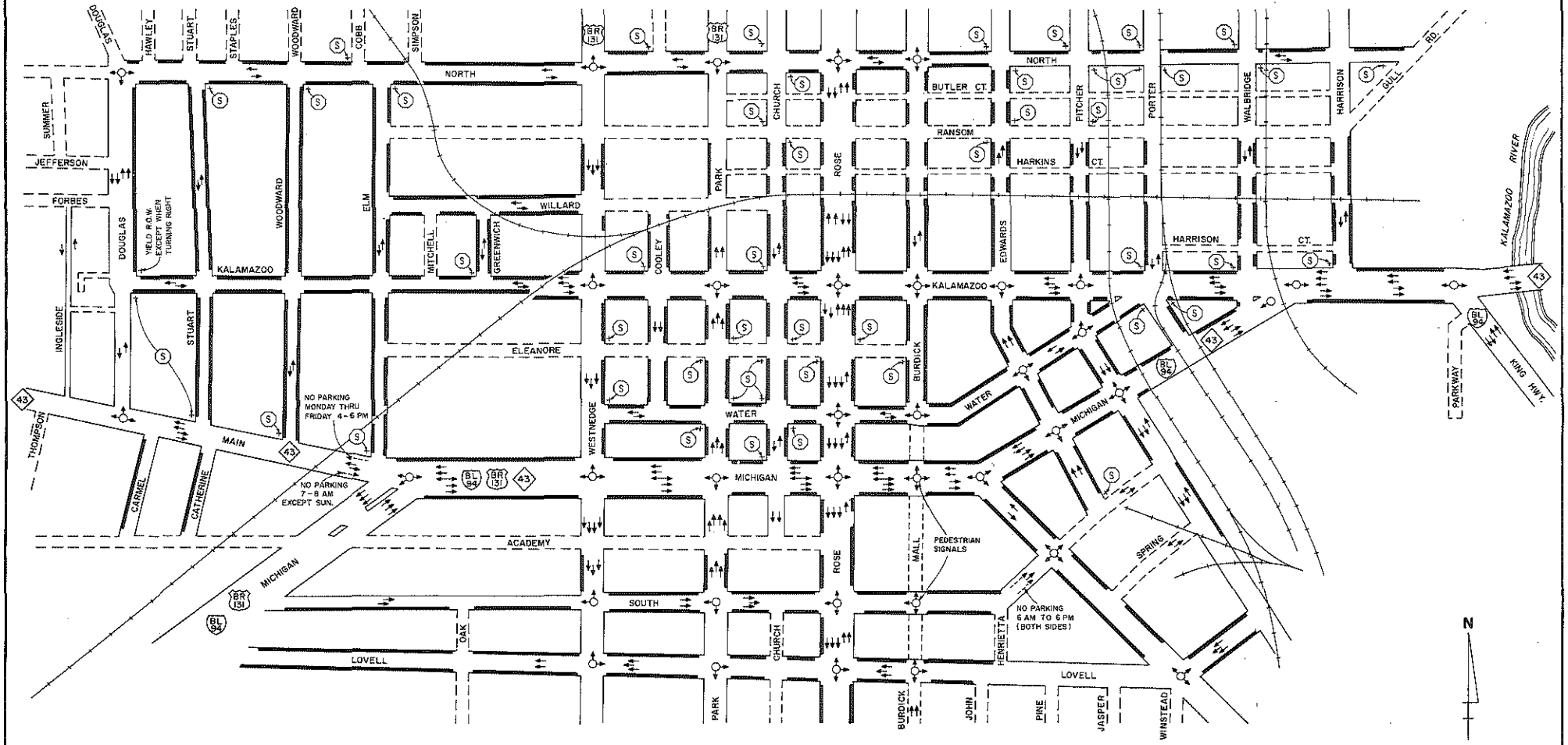


FIGURE 2 - CITY OF KALAMAZOO: INVENTORY OF STREETS AND TRAFFIC CONTROL
TWO-WAY OPERATION

Time gaps in the traffic stream were measured on Kalamazoo and Michigan Avenues at their intersections with Church Street. 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 6 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.

The speed-and-delay study runs listed below were made by the so-called floating car method during the "before" period. Total running time and points and durations of all delays were recorded in these runs using automatic recording equipment. (See Figure 5.)

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.

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

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

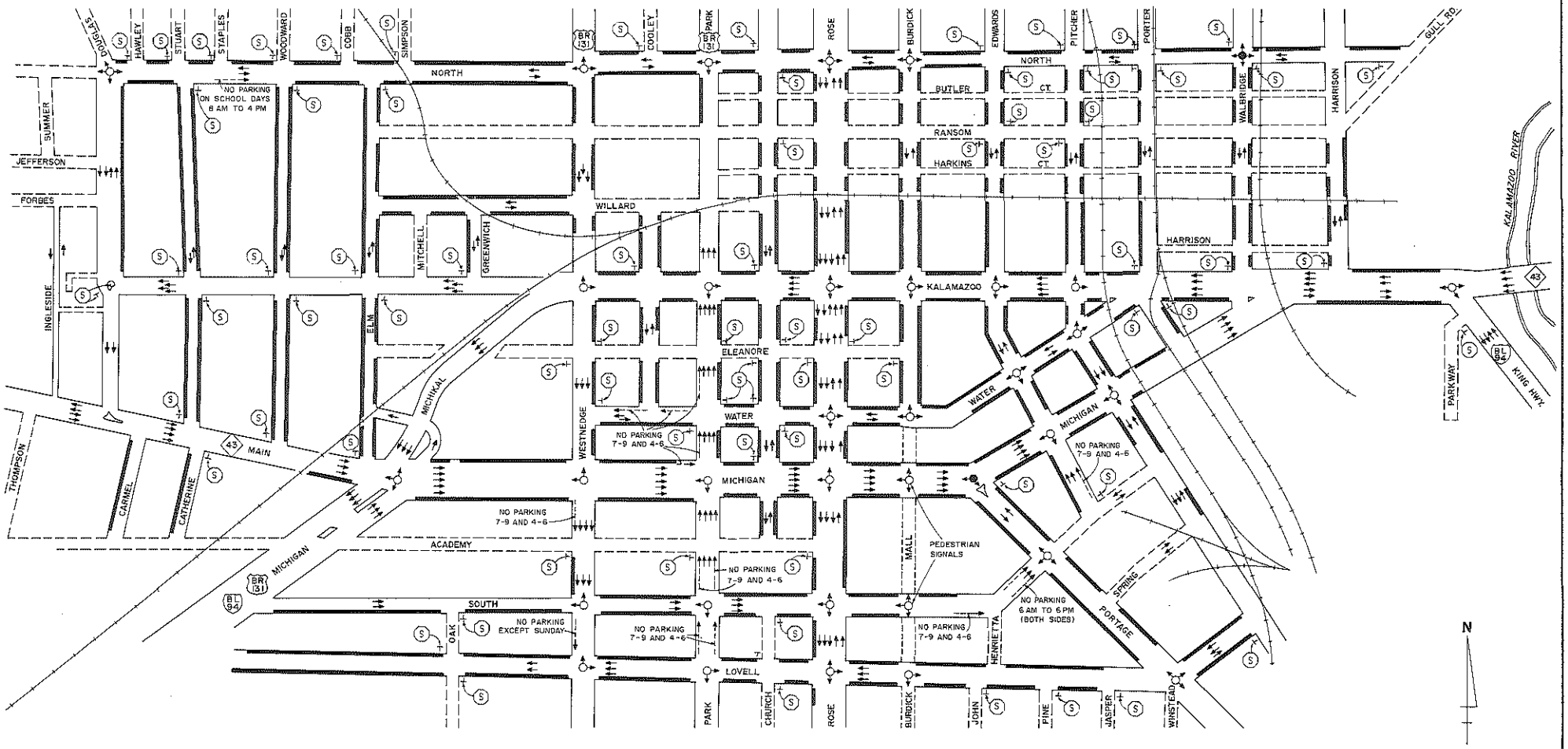


FIGURE 3 – CITY OF KALAMAZOO: INVENTORY OF STREETS AND TRAFFIC CONTROL
ONE-WAY OPERATION

4-A. From the intersection of Harrison and Michigan, westbound via Michigan-Main, to the intersection of Thompson and Main.

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

6-A. From the intersection of Harrison and Michigan, westbound via Michigan, to the intersection of Lovell and Michigan.

Total running 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 5.)

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

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 survey 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

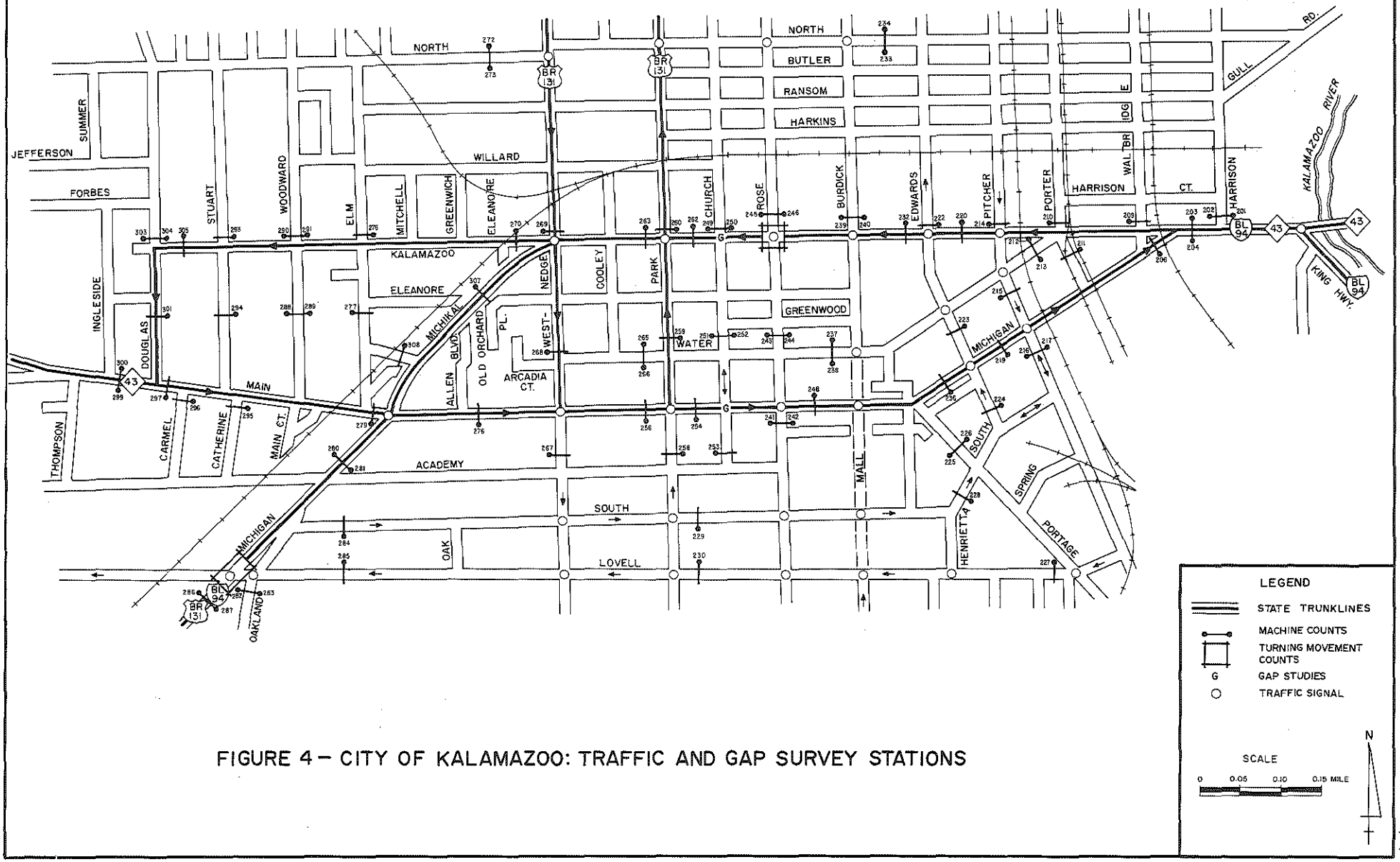


FIGURE 4 – CITY OF KALAMAZOO: TRAFFIC AND GAP SURVEY STATIONS

LEGEND

- STATE TRUNKLINES
- MACHINE COUNTS
- TURNING MOVEMENT COUNTS
- G GAP STUDIES
- TRAFFIC SIGNAL

SCALE

0 0.05 0.10 0.15 MILE

N

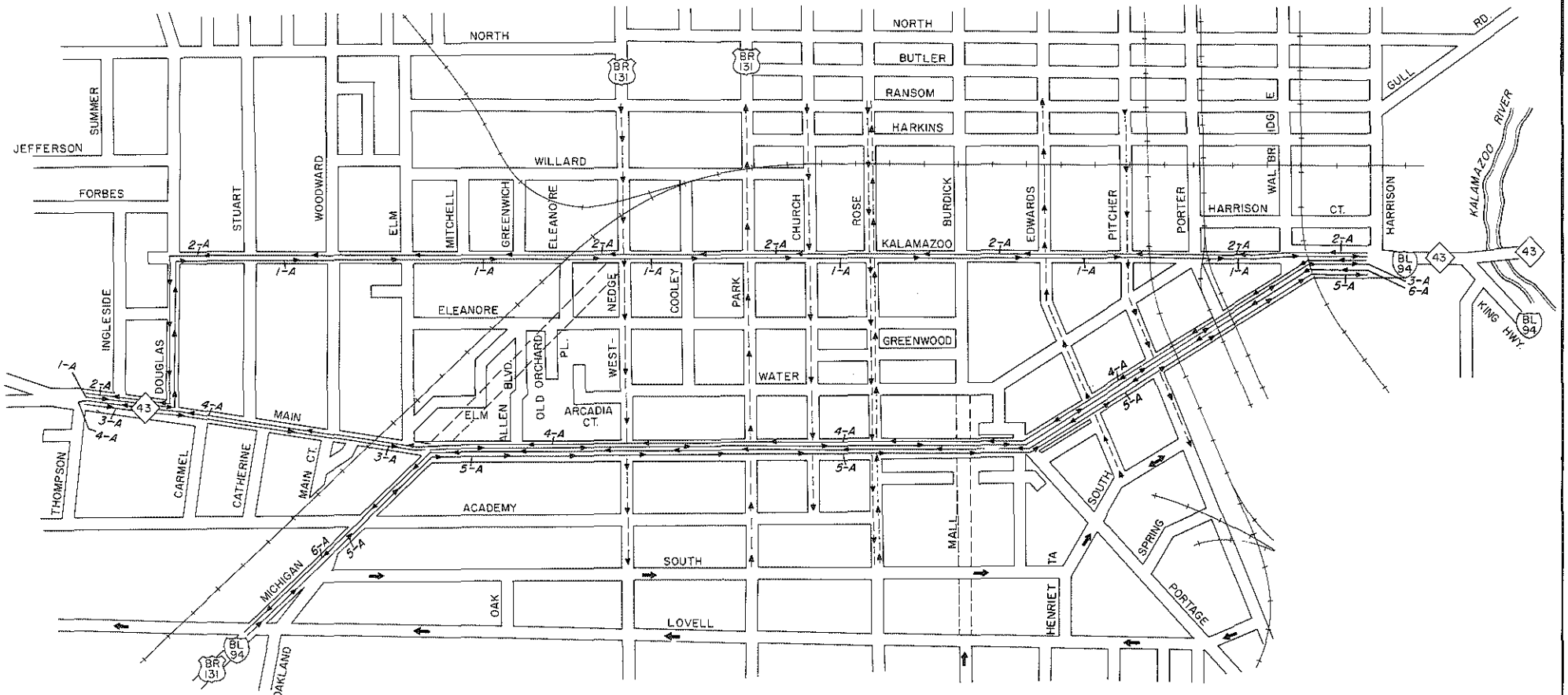
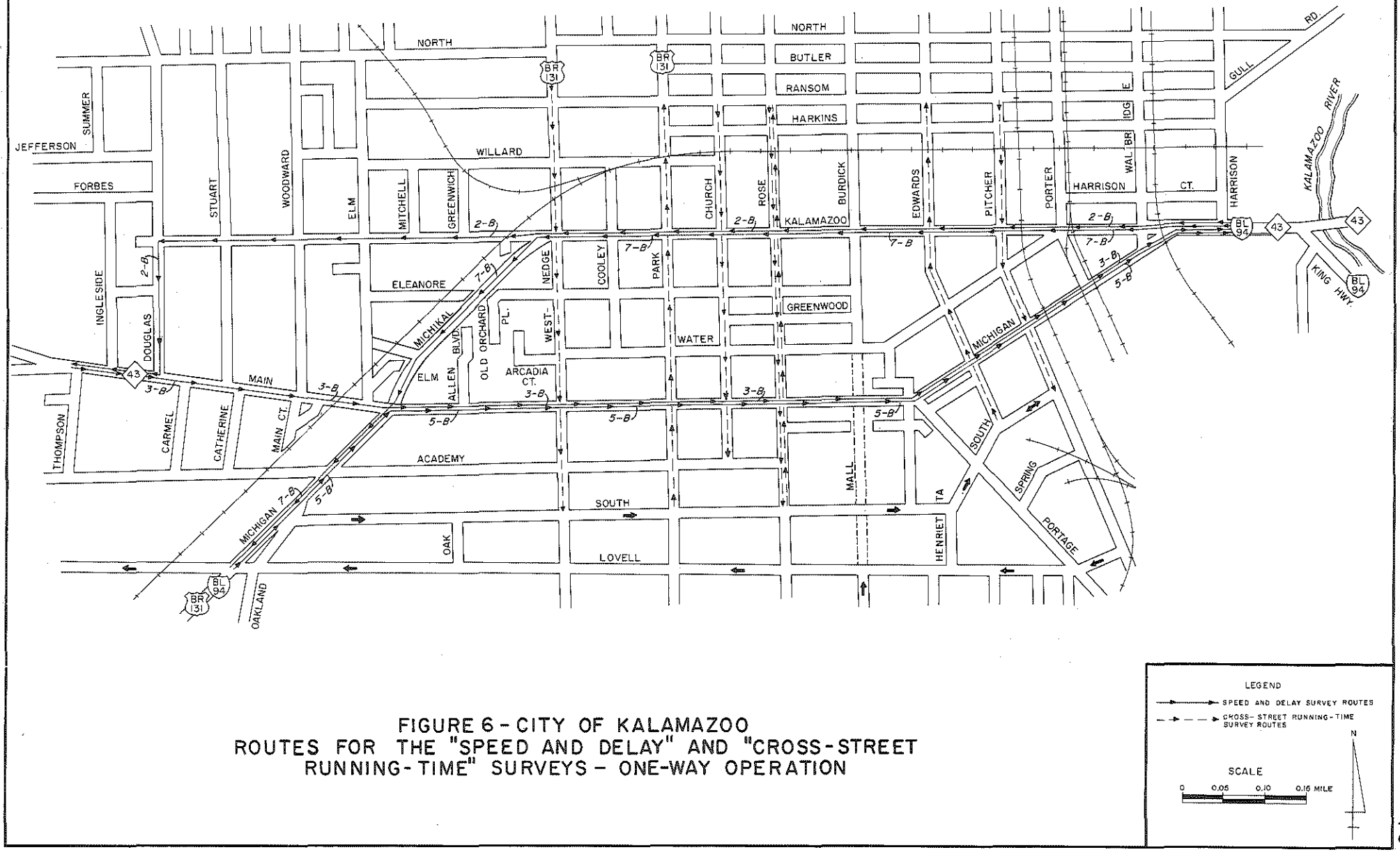


FIGURE 5 - CITY OF KALAMAZOO
ROUTES FOR THE "SPEED AND DELAY" AND "CROSS-STREET RUNNING-TIME" SURVEYS - TWO-WAY OPERATION

LEGEND
SPEED AND DELAY SURVEY ROUTES
CROSS-STREET RUNNING-TIME SURVEY ROUTES
N
SCALE
0 0.05 0.10 0.15 MILE



LEGEND

SPEED AND DELAY SURVEY ROUTES

CROSS-STREET RUNNING-TIME SURVEY ROUTES

N

SCALE

0 0.05 0.10 0.16 MILE

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

numbered 89 during the "after" surveys. 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 6.)

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.

Running-time surveys on the six cross-streets were repeated for the "after" phase of the study. Additional information describing the traffic surveys in Kalamazoo and Lansing will be found in Appendix 17.

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

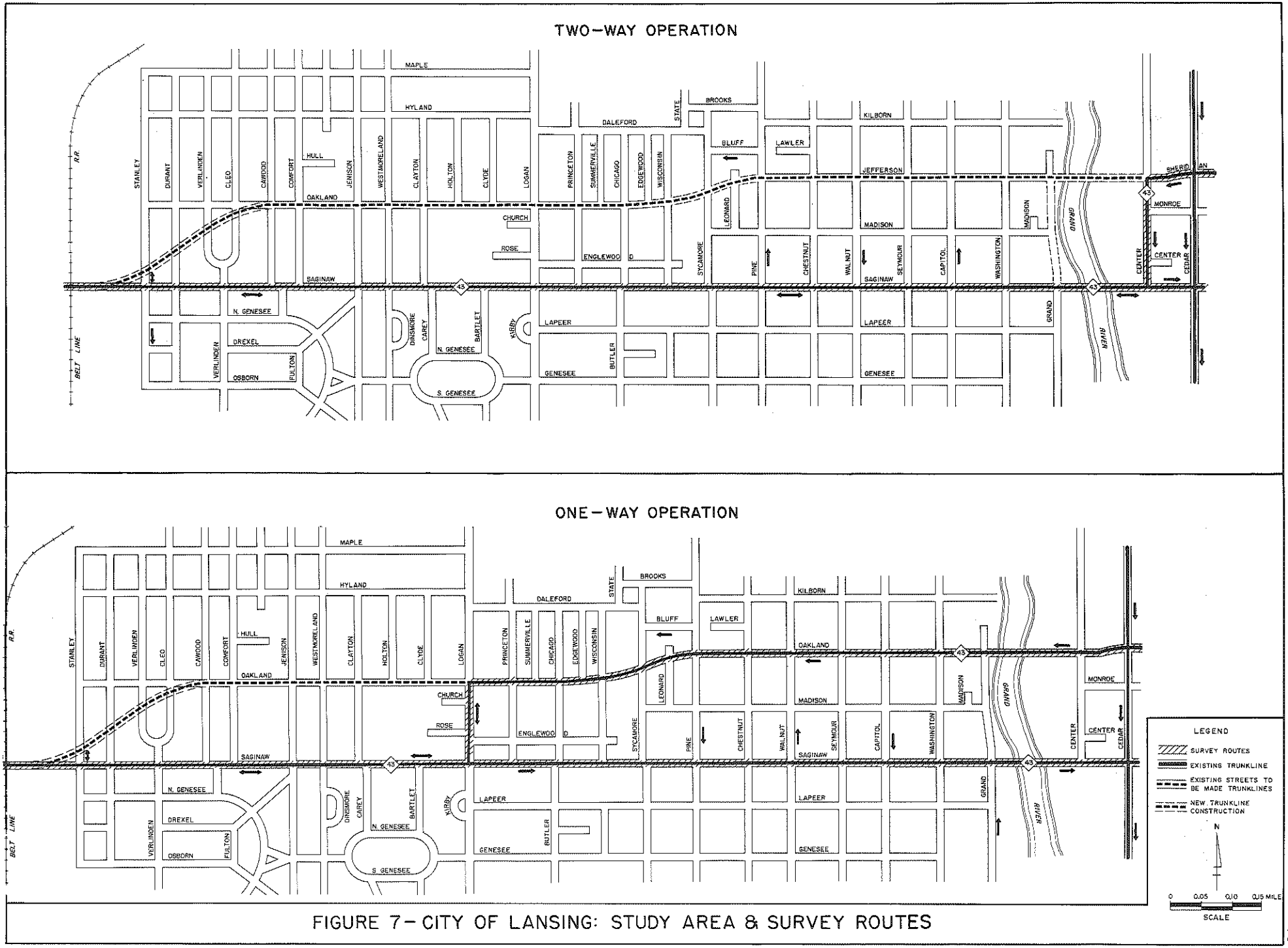


FIGURE 7 - CITY OF LANSING: STUDY AREA & SURVEY ROUTES

evluation. 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 drivers ample time to get used to the new situation and 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 1.

The details of accident information extracted from the individual police reports can be seen in the recording form in Appendix 2. The classification of the accident types is given in Appendix 3.

Lansing Study Area

The Lansing study area includes the street network shown in Figure 7. The area contains part of the northern fringe of the central business district. During the two-way operation of the state trunkline through this area (upper half of Figure 7) 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 trunkline. 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 7), a new bridge was built over the Grand River, and Jefferson and Oakland Streets

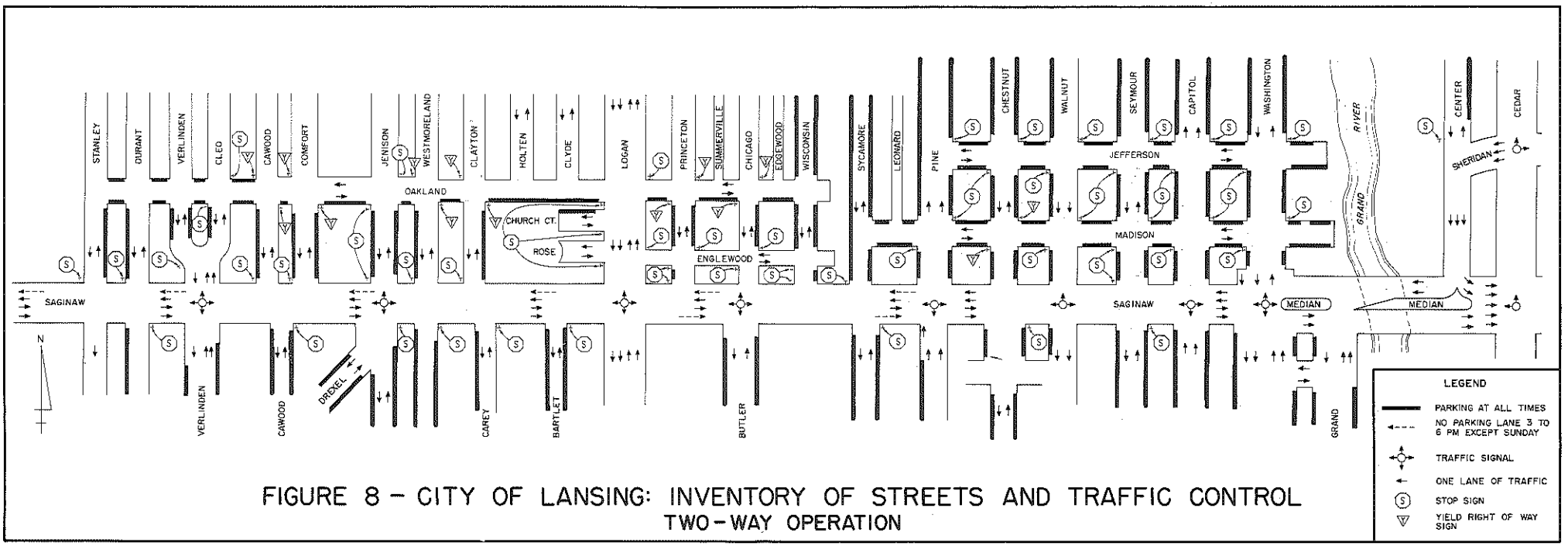


FIGURE 8 – CITY OF LANSING: INVENTORY OF STREETS AND TRAFFIC CONTROL
TWO-WAY OPERATION

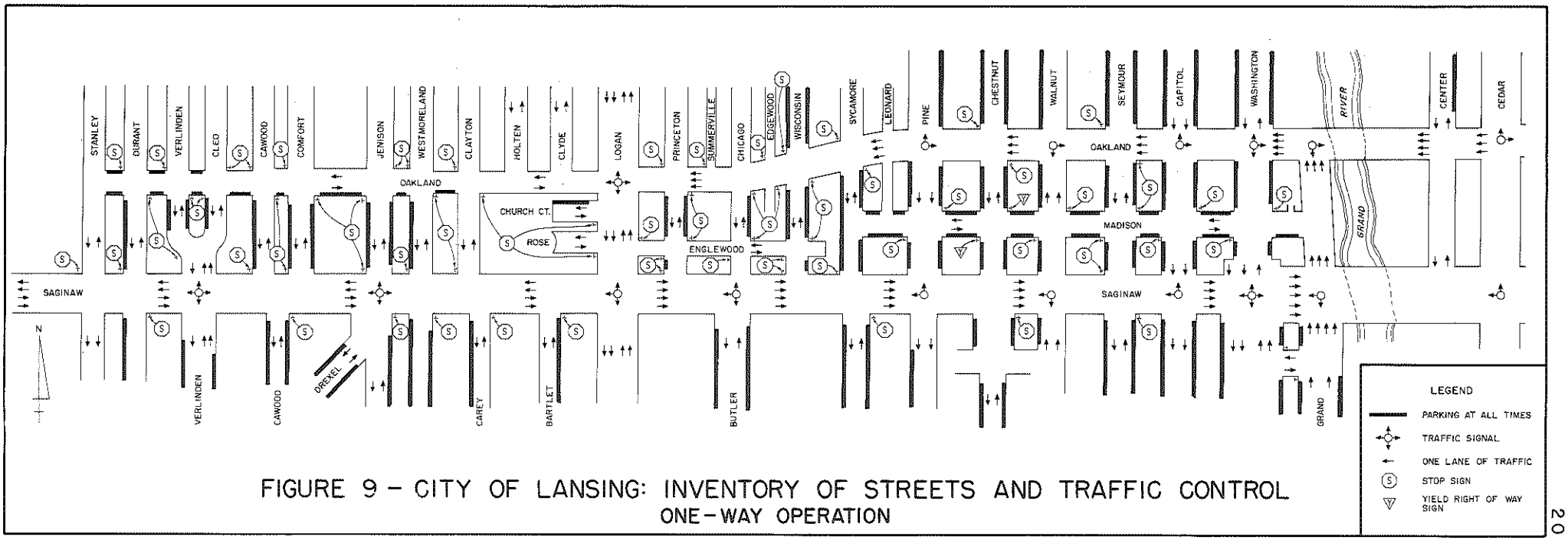


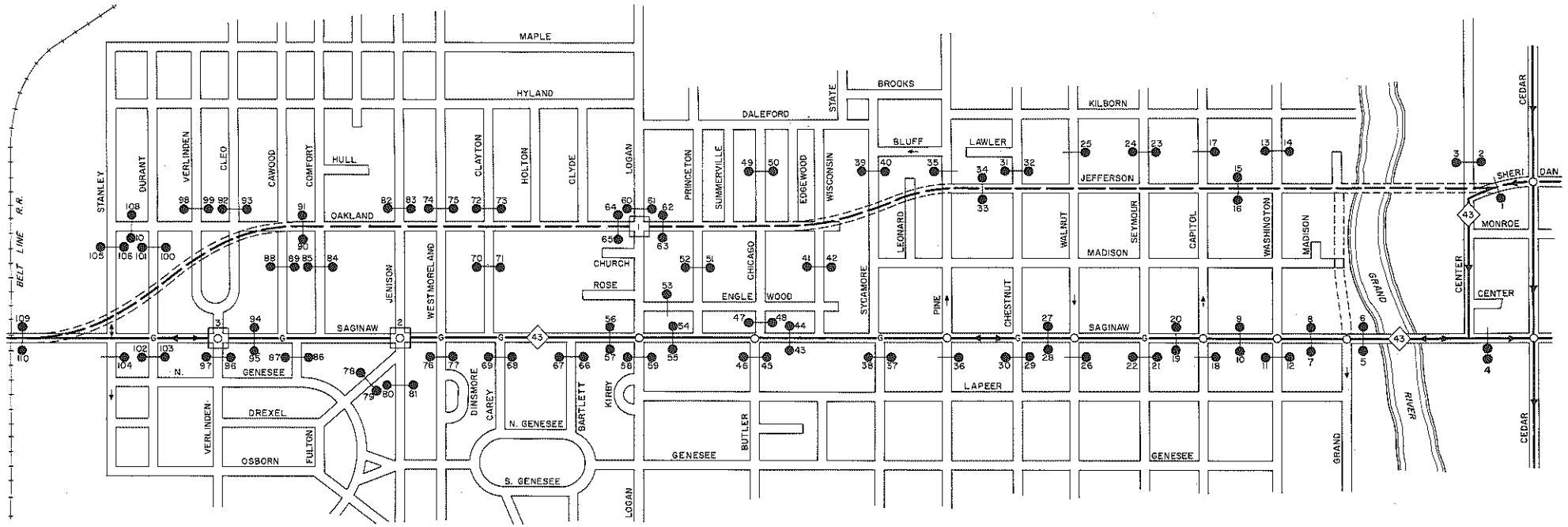
FIGURE 9 – CITY OF LANSING: INVENTORY OF STREETS AND TRAFFIC CONTROL
ONE-WAY OPERATION

were widened, reconstructed and joined to form a continuous westbound trunkline as far as Logan Street. The entire westbound road 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. The new one-way system went into operation 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 this 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 the completion of the east-west freeway through Lansing. Thus, Pine and Capitol Avenue became one-way southbound, and Walnut Street and Grand Avenue became one-way northbound.

Figures 8 and 9 show the laneage, parking and other traffic controls in the area during the "before" and "after" phases of the study, respectively.

Traffic Surveys in Lansing

Surveys for the sampling of the one-way trunkline operation were taken between July 8 and July 30, 1964. Volume counts by 15-minute totals were taken at a total of 48 locations (Figure 10). 24 of these locations are within the western section of the study



LEGEND

- EXISTING TRUNKLINES
- EXISTING STREETS TO BE MADE TRUNKLINES
- NEW TRUNKLINE CONSTRUCTION
- VOLUME COUNTS
- TURNING MOVEMENT COUNTS
- GAP STUDIES
- TRAFFIC SIGNAL

SCALE 0 0.05 0.10 0.15 MILE

N

FIGURE 10 – CITY OF LANSING: TRAFFIC & GAP SURVEY STATIONS

area which will go into one-way operation some time in the future. This leaves 24 locations within the area which is now under one-way operation.

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. The last four intersections are outside the present study area.

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. Again, the last two intersections are outside of the present study area. 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 11.)

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.

Cross-street running time surveys were taken on seven streets. Two of these streets, Jenison and Verlinden, are outside the area of the present study. The remaining five runs were: (See Figure 11.)

1. Washington (southbound)
2. Capitol (northbound)

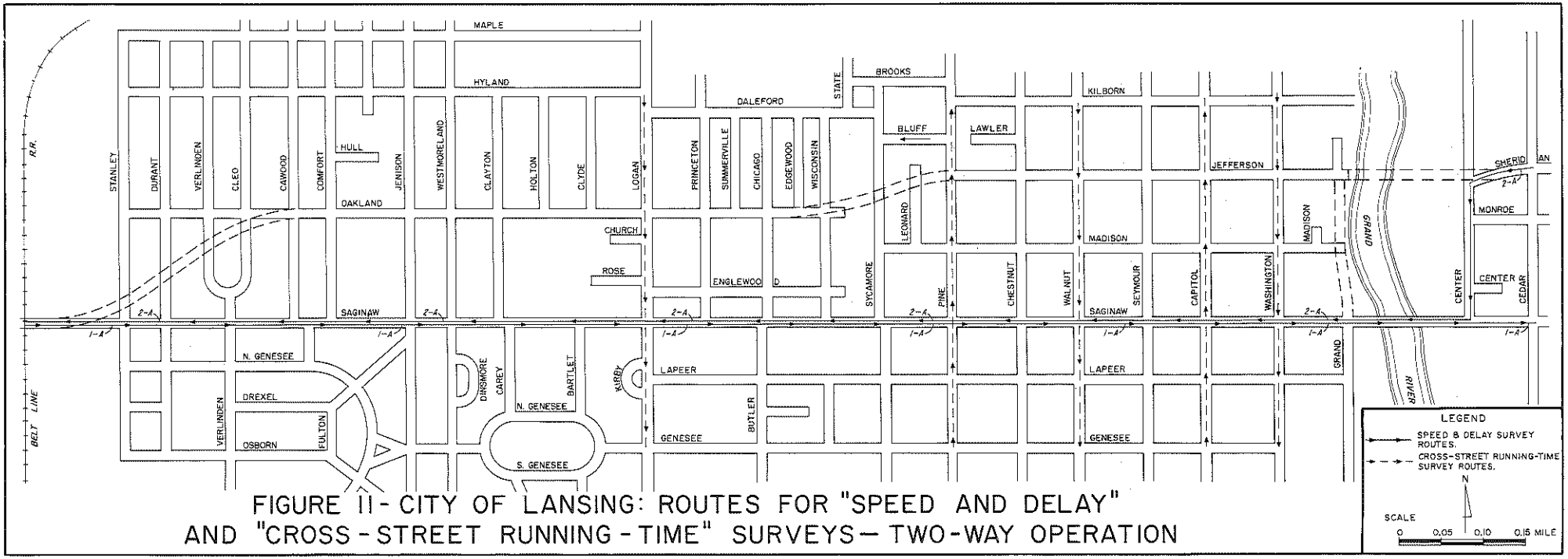


FIGURE 11 - CITY OF LANSING: ROUTES FOR "SPEED AND DELAY" AND "CROSS - STREET RUNNING - TIME" SURVEYS — TWO-WAY OPERATION

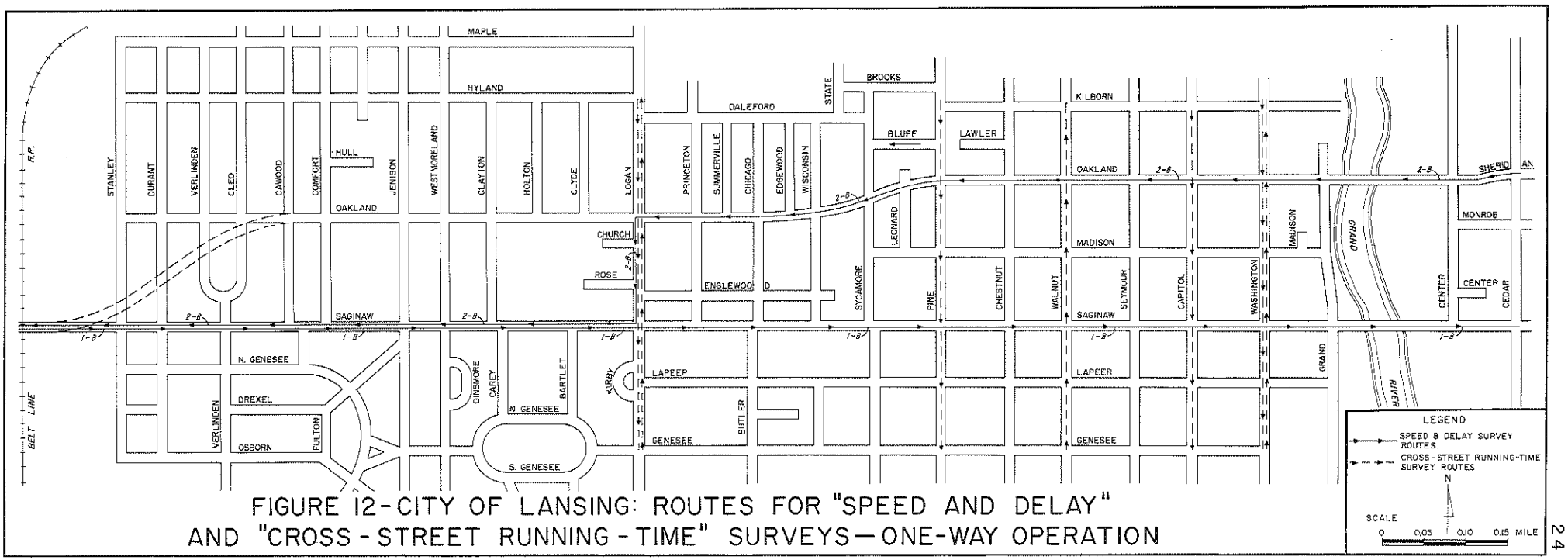


FIGURE 12 - CITY OF LANSING: ROUTES FOR "SPEED AND DELAY" AND "CROSS - STREET RUNNING - TIME" SURVEYS — ONE-WAY OPERATION

3. Walnut (southbound)
4. Pine (northbound)
5. Logan (southbound)

Traffic surveys to reflect the "after" phase of this study (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 the "after" 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 during the "after" survey. Traffic gap studies were repeated at the four intersections that are within the present study area. Turning-movement counts were repeated at the Oakland and Logan intersection.

Speed-and-delay survey routes for the "after" study were as follows: (See Figure 12.)

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.

Cross-street travel-time runs were also repeated on the five streets. 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 trunklines, the travel directions of some of the test trips were different from the "before"

runs, and they were as follows: (Figure 12)

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

Accident Data for Lansing

Accident reports from Lansing City Police, compiled by the City Traffic Engineer, were studied for a one-year-before and one-year-after evaluation as in Kalamazoo. Those streets in the area which might have been affected by the one-way trunkline were covered. A full description of these streets will be found in Appendix 4. The extent of detail required for each accident was the same as in the Kalamazoo study.

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 trunklines in that immediate area. The changes in the traffic characteristics of the state trunklines themselves and of the adjacent cross-streets have been examined. The trunklines 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. 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. A separate study, already mentioned, on the influence of one-way highways on land use, housing and property values is expected to throw some light on some of the cost aspects of such projects.

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

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 Running 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 Running Time	Average Over-All Speed(m.p.h.)	Average Number of Stops	Average Delay (sec./mi.)	% Delay Time	Average Running 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	-2.4	-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	-1.9	-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"	22.2	1.6	23	14	-0'29"	+2.5	-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	-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	-2.0	-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	-3.7	-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	-3.0	-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	-3.7	-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	-1.2	-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	-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	-5.0	-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	-5.3	-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	-4.3	-34	-10

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 circumstances. 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 trunklines 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. Averages of several runs (described in STUDY PROCEDURES) for each peak traffic period are given in the table. The first four columns after the route descriptions, in both the two-way and one-way sections, are self explanatory. "Average Running 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 running time. "Average Number of Stops" 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 running 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 5 and 6.)

Route 2-A was a westbound trip mostly on Kalamazoo Avenue which was not a state trunkline 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 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 running 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 latter is one-way for most of its length. 55 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 running 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 running 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. 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 trunkline 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

TABLE 2

CITY OF LANSING

SPEED AND DELAY COMPARISONS

DURING TWO-WAY OPERATION											DURING ONE-WAY OPERATION										CHANGE IN:				
Route	Direction	Length (miles)	Date (1964)	Period	Average Running 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 Running Time	Average Over-All Speed(m.p.h.)	Average Number of Stops	Average Delay (sec./mi.)	% Delay Time	Average Running Time	Average Over-All Speed(m.p.h.)	Average Number of Stops	Average Delay (sec./mi.)	% Delay Time
1-A											1-B														
From Beltline RR to Cedar St. Via Saginaw St.	EB	1.9	7/14-16	Morn.	4'27"	26.0	1.9	15	10		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	-34"	+4.0	-0.9	-6	-2
" "	"	"	"	Noon	4'33"	25.2	2.3	18	12		" "	"	"	"	Noon	4'03"	28.3	1.4	12	9	-30"	+3.1	-0.9	-6	-3
" "	"	"	"	Aft.	5'00"	23.2	3.4	22	14		" "	"	"	6/28	Aft.	4'36"	25.4	2.0	17	12	-24"	+2.2	-1.4	-5	-2
2-A											2-B														
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		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	-19"	+2.1	-0.7	-2	-1
" "	"	"	"	Noon	4'53"	25.9	1.8	9	6		" "	"	"	"	Noon	4'06"	30.8	0.2	1	0	-47"	+4.9	-1.6	-8	-6
" "	"	"	"	Aft.	5'07"	25.0	2.0	12	8		" "	"	"	6/29-30	Aft.	4'47"	26.0	1.5	11	8	-20"	+1.0	-0.5	-1	0

running time (% delay time) during peak traffic was found to be as high as 29%, whereas during one-way operation the highest ratio was found to be 17% even though running time itself was also shorter.

Table 2 contains the results of the speed-and-delay surveys in Lansing. Route 1-A was eastbound M-43 along Saginaw Street when this street was two-way between Logan and Center Streets. Route 1-B is the same trip after Saginaw became one-way. It should be pointed out that these trips include the section of Saginaw Street west of Logan which is still a two-way trunkline. A gain in running time of more than 30 seconds has been attained most of the time on this trip. Optimum speeds of travel have been reached as indicated by average over-all speeds of up to 30 miles per hour 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 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 westbound 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 one out of the total of 27 westbound runs had any delay on this one-way section.

TABLE 3

SPEED AND DELAY SUMMARY

	Kalamazoo			Lansing		
	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	+2.9
Average Stops per Mile	2.7	0.8	-1.9	1.1	0.6	-0.5
Average Delay (Seconds per Mile)	39	17	-22	14	10	-4
Average Delay Ratio	18%	11%	-7%	10%	7%	-3%

In order to make a general review of the results of speed-and-delay studies in both cities, an effort has been made in Table 3 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 3 is that the one-way operation has resulted in larger speed increases and delay elimination in Kalamzoo than in Lansing. It can also be said that traffic flow progression initially was better in Lansing than in Kalamazoo, and therefore, there was more room for improvement in the latter city.

Cross-Street Speed Study Results

In a grid system of streets made up of state trunklines 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 trunklines 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 trunkline operation, cross-street running time studies were made as outlined before.

Table 4 lists the average results obtained from these cross-street running-time studies in Kalamazoo. It will be seen by examining the last column that the changes in average running time vary all the way from a reduction of 62 seconds to an

TABLE 4

CITY OF KALAMAZOO

CROSS-STREET RUNNING-TIME COMPARISONS

Run	TWO-WAY OPERATION			ONE-WAY OPERATION			CHANGE IN AVERAGE RUNNING TIME
	Date (1964)	Period	Average Running Time	Date (1966)	Period	Average Running 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"
" " " " " " " "	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"
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"
On Rose St. from W. South to Ransom Sts.	10/27-28	Morning Peak	1' 38"	5/10	Morning Peak	1' 50"	+12"
" " " " " " " "	10/22	Morn. off "	1' 48"	5/4	Morn. off "	1' 45"	− 3"
" " " " " " " "	"	Noon "	1' 48"	5/3,9	Noon "	1' 50"	+ 2"
" " " " " " " "	10/28	Aft. off "	1' 59"	5/3	Aft. off "	1' 48"	−11"
" " " " " " " "	10/22,27	Afternoon "	1' 48"	5/5,9	Afternoon "	2' 11"	+23"
On Rose St. from Ranson to W. South Sts.	10/27-28	Morning Peak	1' 32"	5/10	Morning Peak	1' 37"	+ 5"
" " " " " " " "	10/22	Morn. off "	1' 58"	5/4	Morn. off "	1' 25"	−33"
" " " " " " " "	"	Noon "	1' 32"	5/9	Noon "	1' 29"	− 3"
" " " " " " " "	10/28	Aft. off "	1' 13"	5/4	Aft. off "	1' 38"	+25"
" " " " " " " "	10/22,27	Afternoon "	1' 52"	5/5,9	Afternoon "	1' 45"	− 7"
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"
" " " " " " " "	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"

increase of 41 seconds. No pattern seems to exist for these variations in the change in running time. Timing of traffic signals to provide for the needed traffic capacity for conflicting street approaches and to provide for progession is the major factor affecting these running times. Slight increase in some of the cross-street running times is a small sacrifice that can be afforded to compensate for even smaller gains in travel time on the trunklines, since these gains benefit much larger volumes of traffic. It can be said, nevertheless, that the introduction of the new one-way trunkline pair has not resulted in delays of any objectionable duration on the cross-streets.

Table 5 presents the average results from the cross-street running-time trips in Lansing. In this city, as mentioned earlier, changes in the directions of travel of the one-way streets crossing the state trunklines were made, concurrently with the operation of the new one-way state trunklines. Consequently, in Table 5 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 5

CITY OF LANSING
CROSS-STREET RUNNING-TIME COMPARISONS

Run	TWO-WAY OPERATION Date (1964)	Period	Average Running Time	Run	ONE-WAY OPERATION Date (1966)	Period	Average Running Time	CHANGE IN AVERAGE RUNNING 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"
" "	"	Noon "	1' 04"	" "	"	Noon "	1' 18"	+ 14"
" "	"	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"
" "	"	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"
" "	"	Noon "	1' 14"	" "	"	Noon "	1' 31"	+ 17"
" "	"	Afternoon "	1' 24"	" "	6/28-30	Afternoon "	1' 20"	- 4"
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"
" "	"	Noon "	55"	" "	"	Noon "	1' 25"	+ 30"
" "	"	Afternoon "	1' 03"	" "	6/28-30	Afternoon "	1' 19"	+ 16"
				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"	

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

For the sake of an over-all comparison of the results of the before and after surveys in both cities, simple averages of all the peak-period running times have been shown in Table 6. 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 6) 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. 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.

Table 6

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

	Two-Way	One-Way	Change
Kalamazoo	106.5"	103.6"	-2.9"
Lansing	69.0"	79.6"	+10.6"

Results of Gap Studies

The gap study is another test of the quality of traffic service on the streets intersecting the one-way trunklines. This applies to streets controlled by stop signs. Any trunkline 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

TABLE 7

CITY OF LANSING

VEHICLE GAP STUDY

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
6-10 sec.	40	40	62	39	58	37	49	43	39	44	248	203
10-15 sec.	18	29	31	22	22	34	13	30	27	32	111	147
15-20 sec.	13	19	10	18	5	18	5	21	9	13	42	89
Over 20 sec.	5	23	3	27	2	21	0	13	7	16	17	100
Total	76	111	106	106	87	110	67	107	82	105	418	539

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
6-10 sec.	49	35	70	34	39	41	27	41	35	34	220	185
10-15 sec.	45	33	49	32	17	37	15	26	20	32	146	160
15-20 sec.	14	18	18	23	4	14	4	11	9	19	49	85
Over 20 sec.	6	24	7	30	0	27	0	32	3	32	16	145
Total	114	110	144	119	60	119	46	110	67	117	431	575

ON SAGINAW ST. AT SYCAMORE ST:

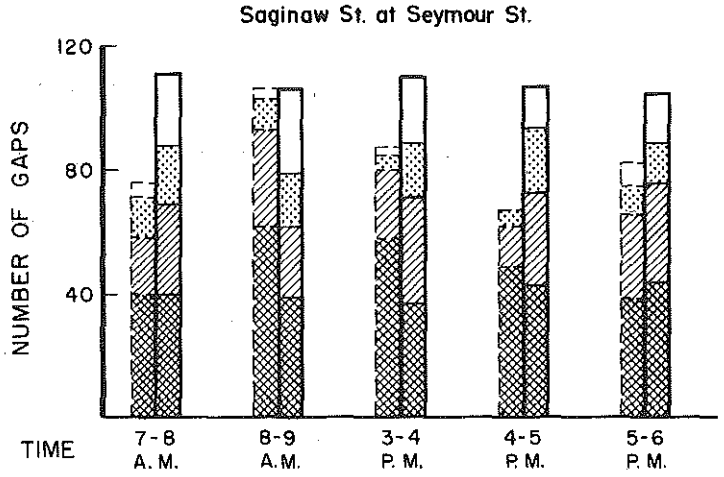
Gap Sizes (Seconds)	7-8 A.M.		8-9 A.M.		3-4 P.M.		4-5 P.M.		5-6 P.M.		Total for (5) Hours	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
6-10 sec.	56	42	57	51	50	40	56	47	58	52	277	232
10-15 sec.	21	36	27	27	23	40	20	34	22	50	113	187
15-20 sec.	12	13	25	14	7	12	5	18	3	19	52	76
Over 20 sec.	18	29	12	47	1	26	1	25	2	24	34	151
Total	107	120	121	139	81	118	82	124	85	145	476	646

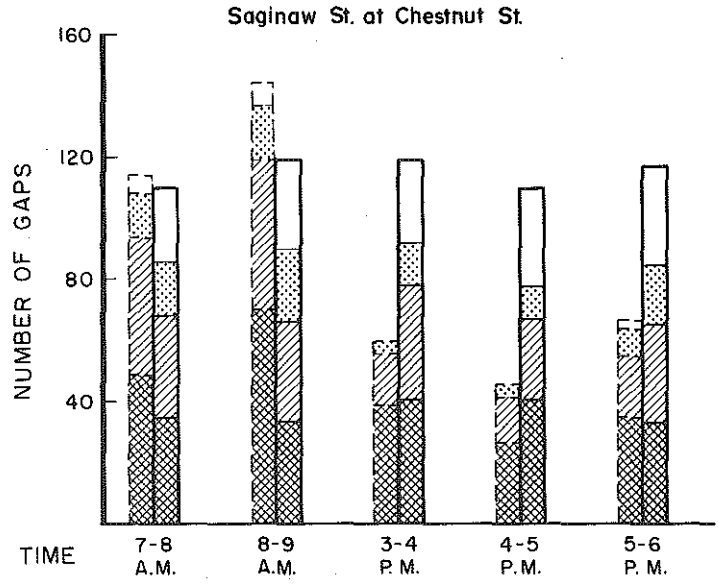
major street. Earlier traffic engineering research[1] indicates that a gap of smaller size than six seconds is not utilized by the majority of drivers desiring to cross or to make a turn onto a street from a stopped position. Consequently, no gaps smaller than six seconds have been recorded or analyzed, as mentioned above.

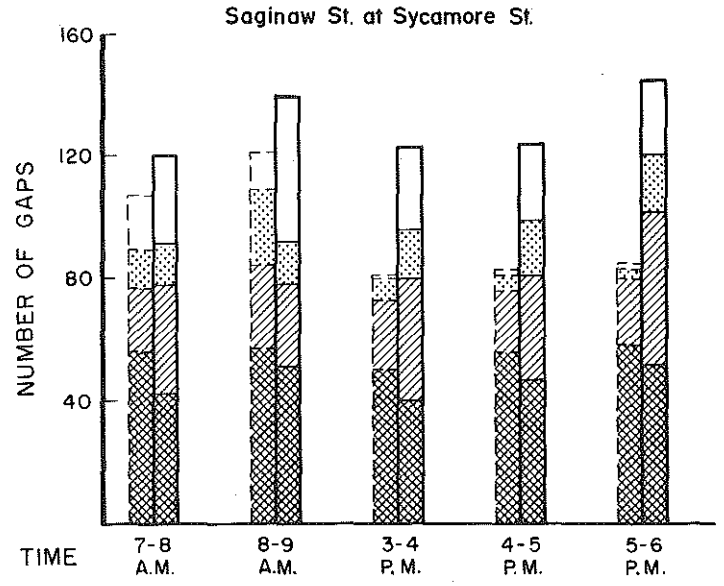
Table 7 shows the numbers and sizes of gaps as surveyed at three intersections in Lansing. The "before" figures relate to the two-way, and the "after" figures relate to the one-way operation on Saginaw Street. Hourly totals during the morning and afternoon peak periods, and 5-hour totals are given. Figure 13 is a graphical representation of the same information, and reveals two significant facts. The first is that more total gaps were available during all but two of the survey hours in the one-way period. 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.

A quantitative evaluation of this improvement would require the calculation of 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 5. No.

(1) B. D. Greenshields, D. Schapiro, E. L. Erickson, "Traffic Performance at Urban Intersections", Yale University, Bureau of Highway Traffic, Technical Report 1, New Haven, Connecticut, 1947.







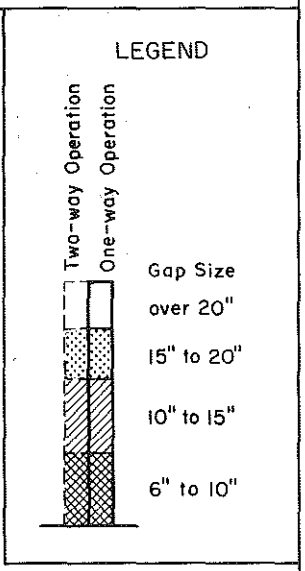


FIGURE 13 - CITY OF LANSING

TRAFFIC GAPS ON SAGINAW STREET

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 are as follows:

Gap size	Vehicles
6-10 seconds	1
10-15 "	2
15-20 "	3
> 20 "	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.

Applying the above information to the gap study results in Table 7, capacities added to the three intersections in Lansing during five hours of peak traffic are shown in Table 8. This amounts to a total improvement in the capacity of the three streets of 4,178 vehicles in five hours.

Table 9 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 10 and 11. Figures 14 and 15 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.

TABLE 8

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 Number 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

(*) For two approaches of the minor road

TABLE 9

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 sec.	72	61	24	81	27	79	14	63	24	75	161	359
10-15 sec.	23	26	9	43	7	30	3	19	3	30	45	148
15-20 sec.	4	25	5	14	4	13	3	9	0	21	16	82
Over 20 sec.	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 sec.	70	39	74	27	77	47	71	34	54	35	346	182
10-15 sec.	43	18	15	30	23	51	31	51	30	44	142	192
15-20 sec.	19	23	6	13	2	30	16	16	15	13	58	95
Over 20 sec.	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 10

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 II

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

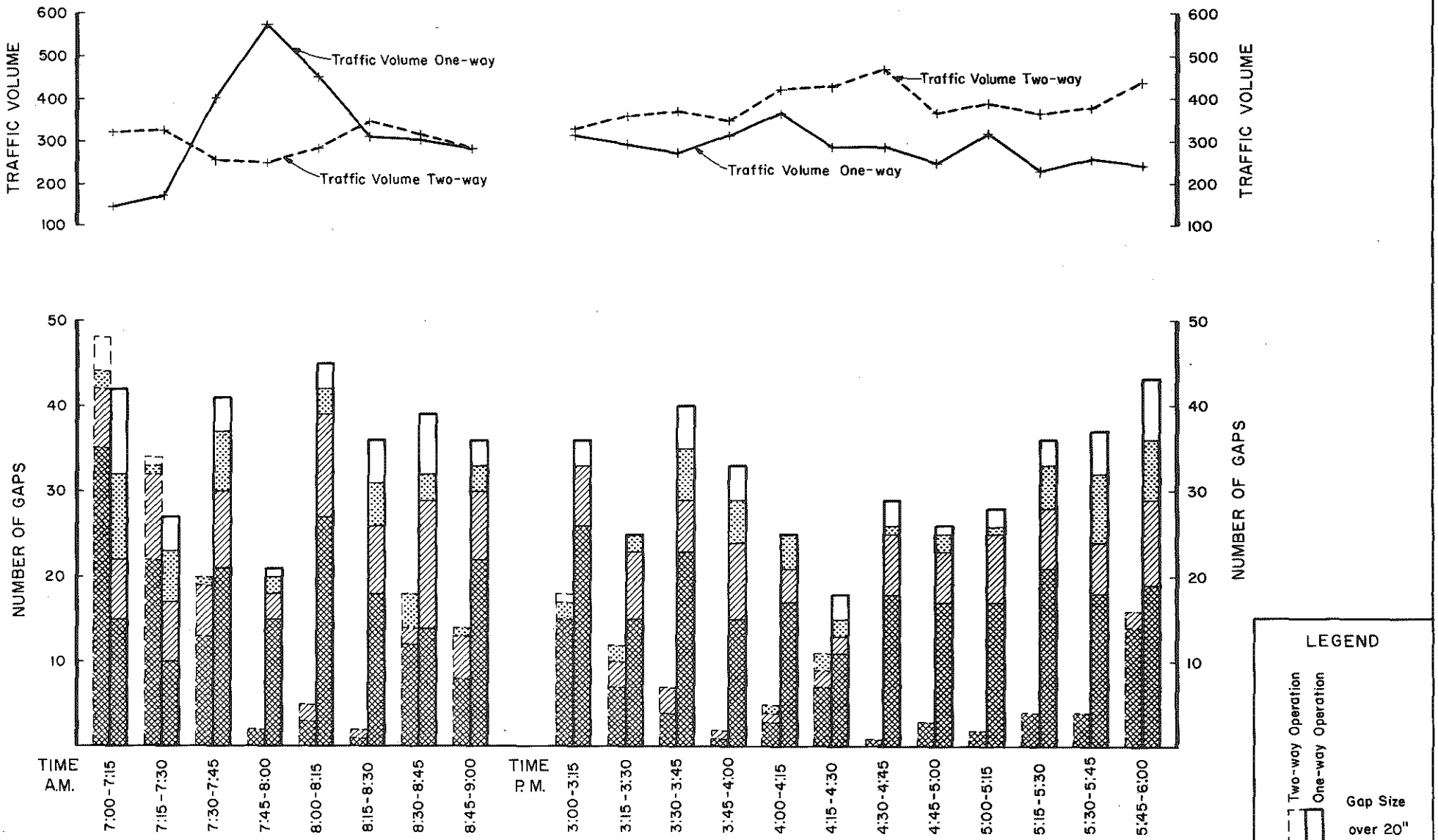


FIGURE 14 — CITY OF KALAMAZOO

TRAFFIC GAPS ON MICHIGAN AVE. AT CHURCH ST.

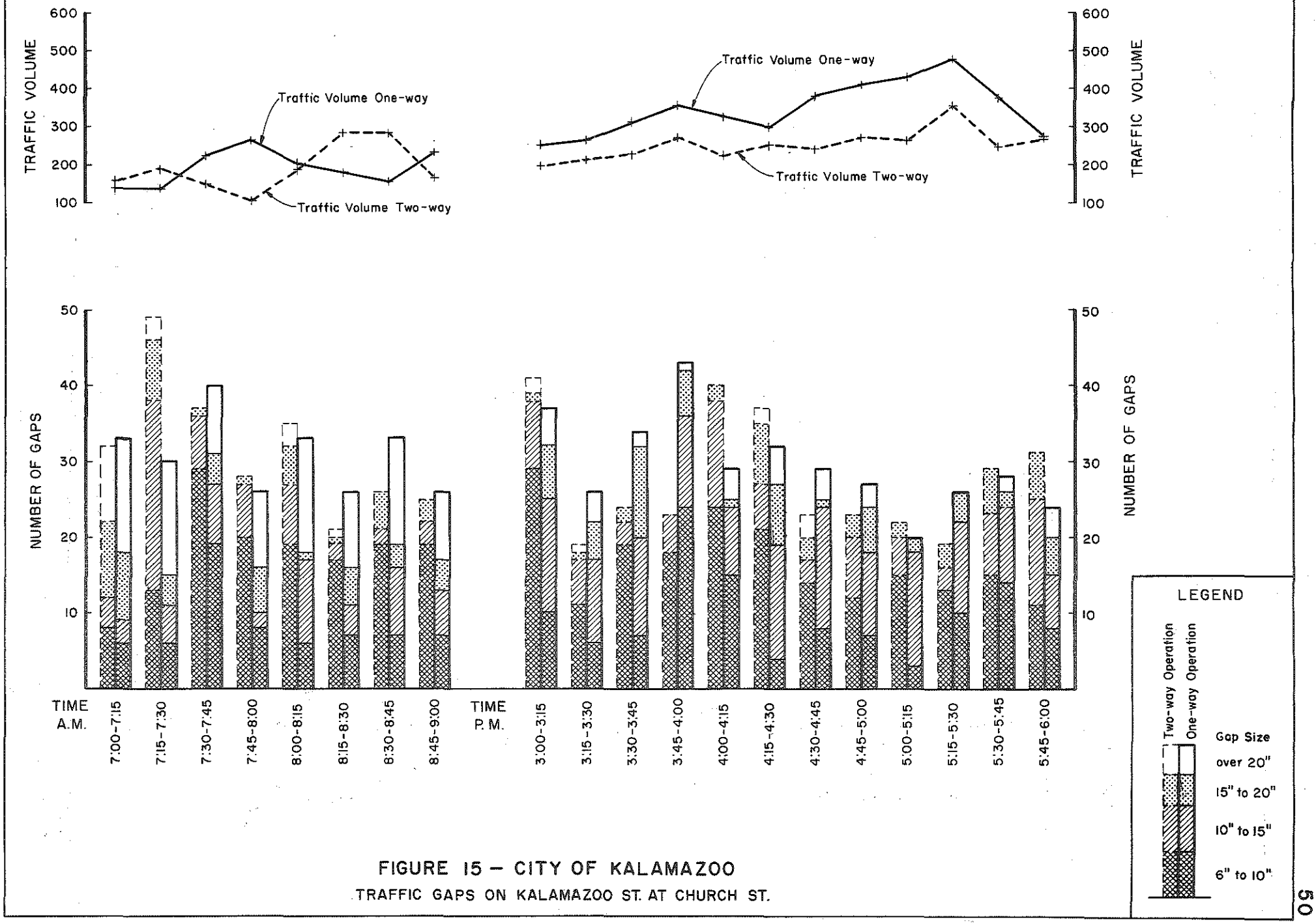


FIGURE 15 – CITY OF KALAMAZOO

TRAFFIC GAPS ON KALAMAZOO ST. AT CHURCH ST.

TABLE 12

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 13

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

Figure 14 shows the gaps on Michigan Avenue at Church Street. When Michigan Avenue was a two-way trunkline, it carried more traffic than later when it became a one-way trunkline. The 15-minute volume variation graph in Figure 14 indicates, however, a larger peak in the morning during the one-way period. It is natural to expect more and larger traffic gaps as the volume decreases, 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 12 contains the volume data for this intersection.

Figure 15 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 9. Volume figures for this intersection are given in Table 13.

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 both cities were the traffic corridors served by the state trunklines already described.

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 recorders. The records were cumulative volumes by 15-minute increments up to a full hour and reset to zero on the hour. In the office, each count station was identified by key-punching a header card for each tape to show the card number, station location, direction of flow, starting time, and other minor information. The volume records were punched consecutively on data cards following the header card and carrying the same 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.

Three tabulation printouts for the analyses of the 15-minute volumes and vehicle-miles of travel were obtained. Appendix 6 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.

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. A sample of this information can be seen in Appendix 7.

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 them together yielded comparative tabulations of entering or leaving traffic totals by 15-minute periods. (Appendix 8).

Additional programs processed the volume data to printout 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 9 to 11.

A flow chart showing the computer-processing of the traffic volume data is presented in Appendix 12.

The purpose in processing the 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

Table 14

CITY OF LANSING

TRAFFIC VOLUMES ENTERING STUDY AREA

TIME	"BEFORE" PERIOD					"AFTER" PERIOD					% 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 15-minute peak times are different in the "before" and "after" periods.

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 fluctations. These three parameters of entering, circulating and leaving traffic are admittedly somewhat interdependent, especially when the area under consideration is small, nevertheless each has its significance in evaluating the over-all picture.

In Table 14, the summation of inbound traffic counted at the volume stations in Lansing 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 trunklines and city streets. Under the category of trunklines, both in the before and in the after periods, are included those streets which were not state trunklines under the two-way operation and were made trunklines under the one-way operation.

Considering first the total network made up of state trunklines and city streets, it is seen in Table 14 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, which took place during the intervening two years, as shown in the last column of Table 14. Examination of the 15-minute morning

Table 15

CITY OF LANSING

TRAFFIC VOLUMES LEAVING STUDY AREA

TIME	"BEFORE" PERIOD					"AFTER" PERIOD					% 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 15-minute peak times are different in the "before" and "after" periods.

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 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. 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 to daily 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 15, which is similar to Table 14, shows the total of vehicles counted as they leave the study area in Lansing. 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 in Table 14 and leaving traffic in Table 15 do not agree for the same survey periods. This situation does not, however, detract from the value of the comparison

Table 16

CITY OF LANSING

VEHICLE–MILES OF TRAVEL WITHIN STUDY AREA

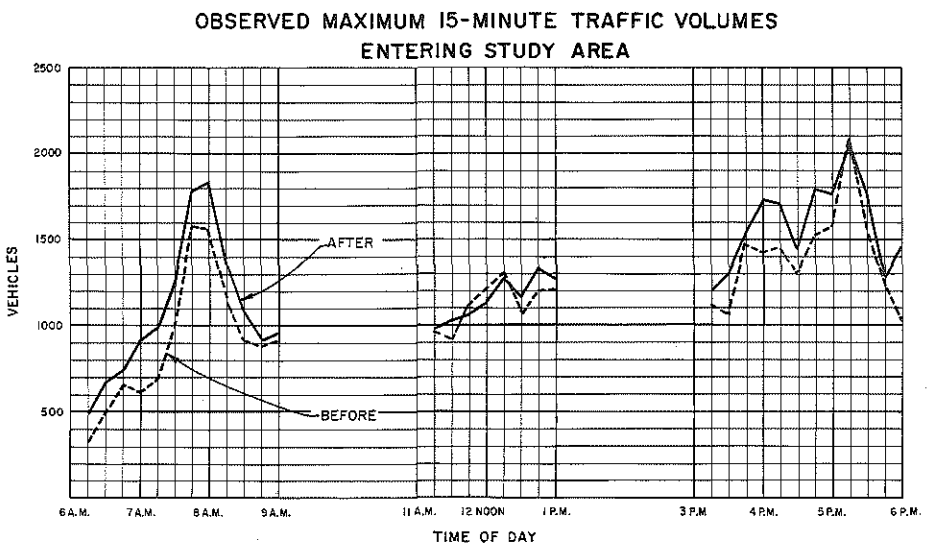
TIME	"BEFORE" PERIOD					"AFTER" PERIOD					% CHANGE		
	Trunklines		City Streets		System Total	Trunklines		City Streets		System Total	T.L.	City	System Total
15– Minute Peaks	Volume	% of System	Volume	% of System		Volume	% of System	Volume	% of System				
7:45–8:00 A.M.	648	(54.3)	546	(45.7)	1194	780	(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

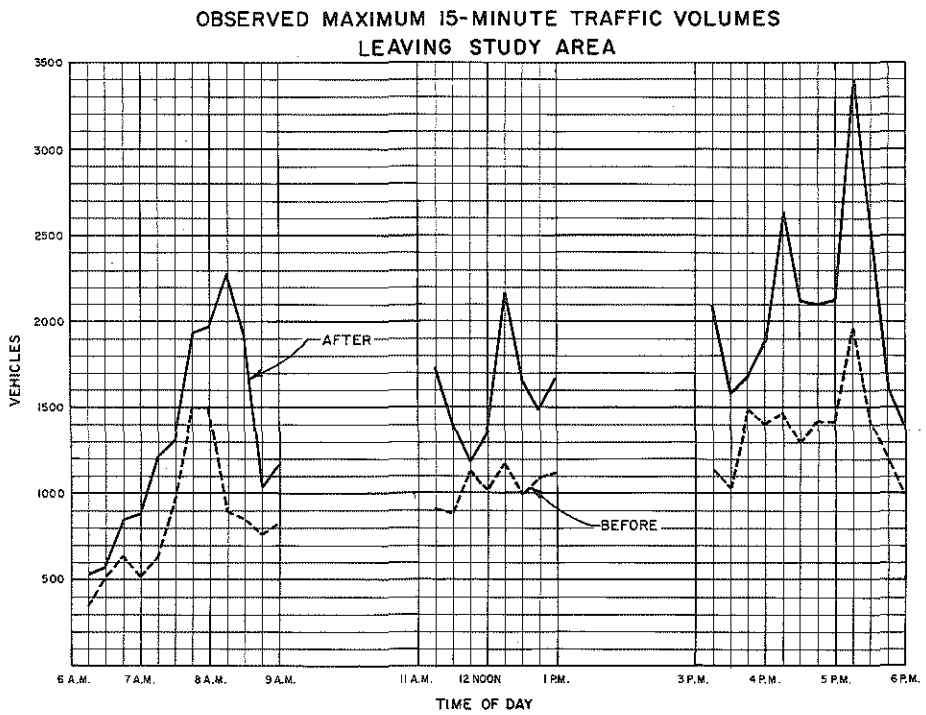
* The 15–minute peak times are different in the "before" and "after" periods.

of the before and the after periods since the same stations were used each time even though they did not provide one hundred 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 15, 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, were 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 is experiencing in traveling out of the area in shorter time as a direct result of better traffic service provided by the one-way trunkline operation.

Table 16 is a similar tabulation of the peak and daily travel totals within the Lansing study area, measured in vehicle-miles. These are computed by multiplying the volume counts obtained from stations dispersed within the area, by the travel distance which is controlled by each count station and summing them up. 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





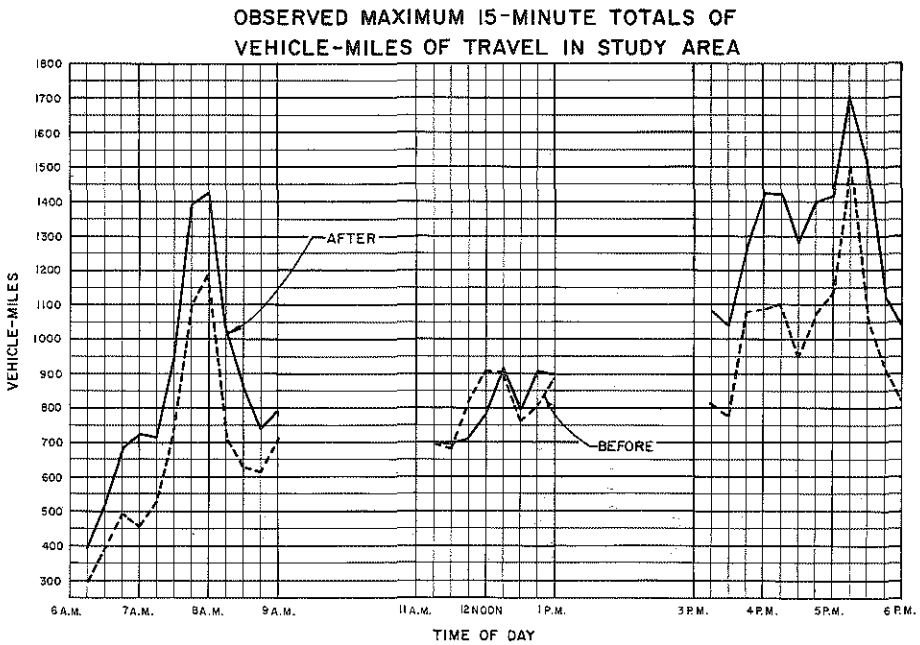


FIGURE 16- CITY OF LANSING: PEAK TRAFFIC

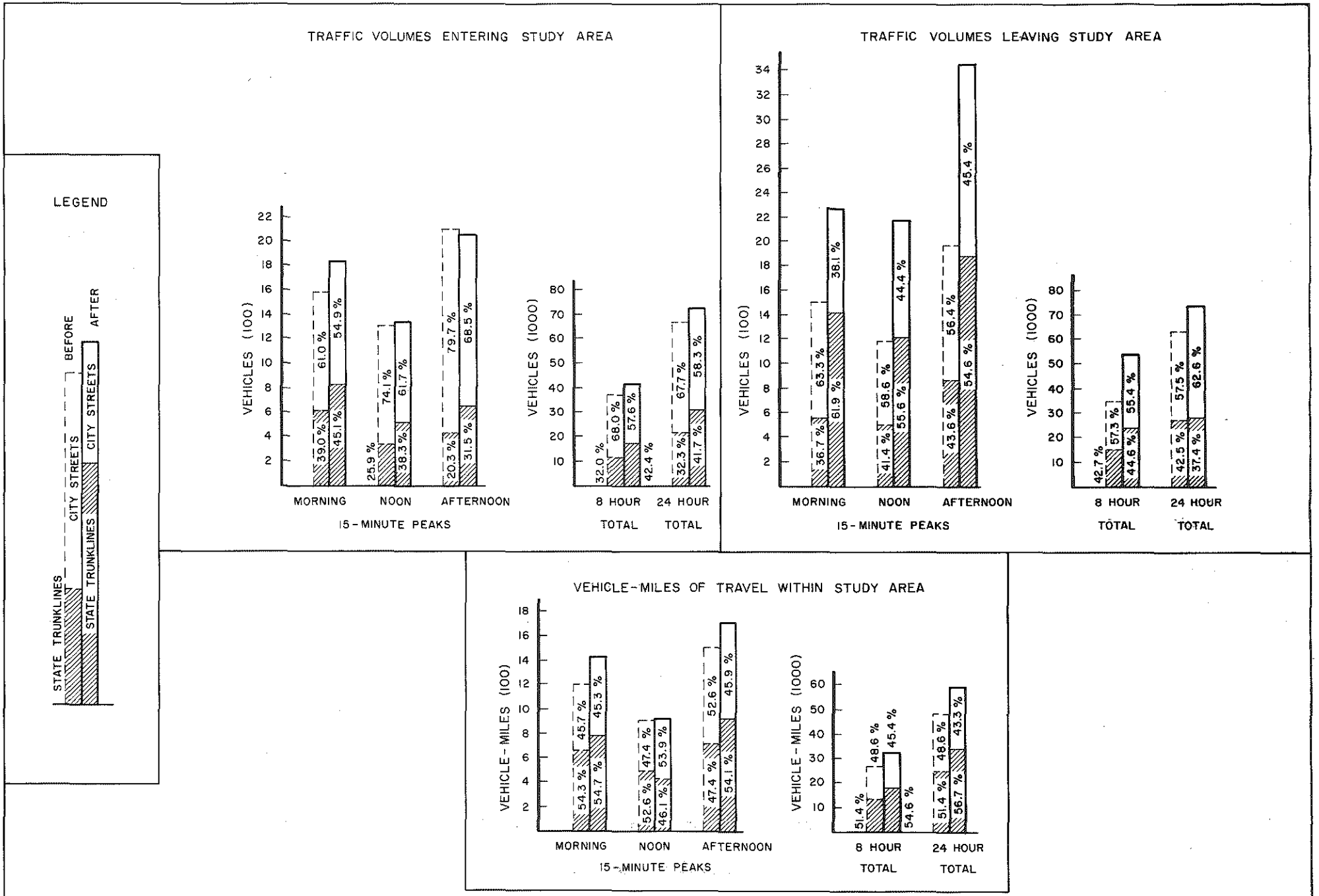


FIGURE 17 – CITY OF LANSING

TRAFFIC VOLUME CHARACTERISTICS

Table 17

CITY OF KALAMAZOO

TRAFFIC VOLUMES ENTERING STUDY AREA

TIME	"BEFORE" PERIOD					"AFTER" PERIOD					% 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 18

CITY OF KALAMAZOO

TRAFFIC VOLUMES LEAVING STUDY AREA

TIME	"BEFORE" PERIOD					"AFTER" PERIOD					% 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 19

CITY OF KALAMAZOO

VEHICLE–MILES OF TRAVEL WITHIN STUDY AREA

TIME	"BEFORE" PERIOD					"AFTER" PERIOD					% 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.	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.

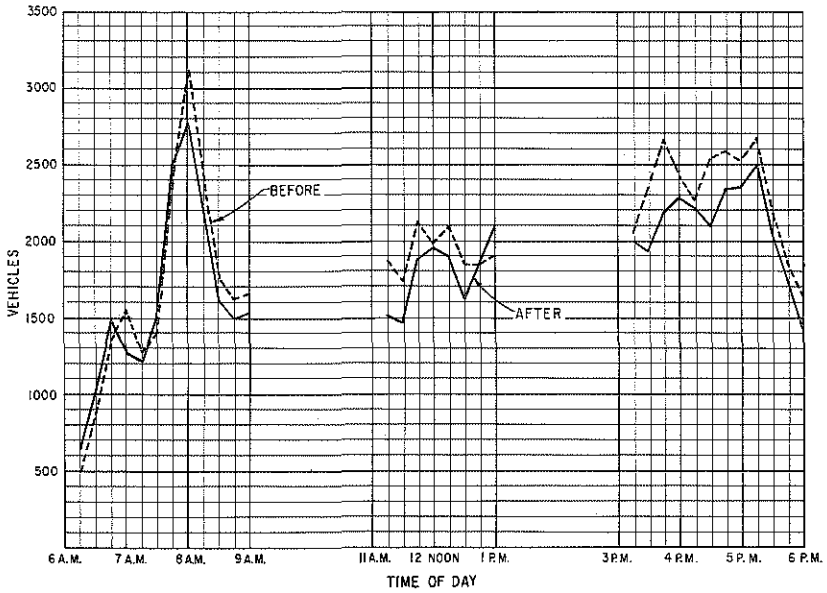
though the peak travel totals do not indicate a relatively sharper rise in comparison to the 24-hour travel totals, as was in the case in "entering" and "leaving" traffic, there is no question but that the street network is able to move the peak loads which have increased substantially between the before and after phases of the study.

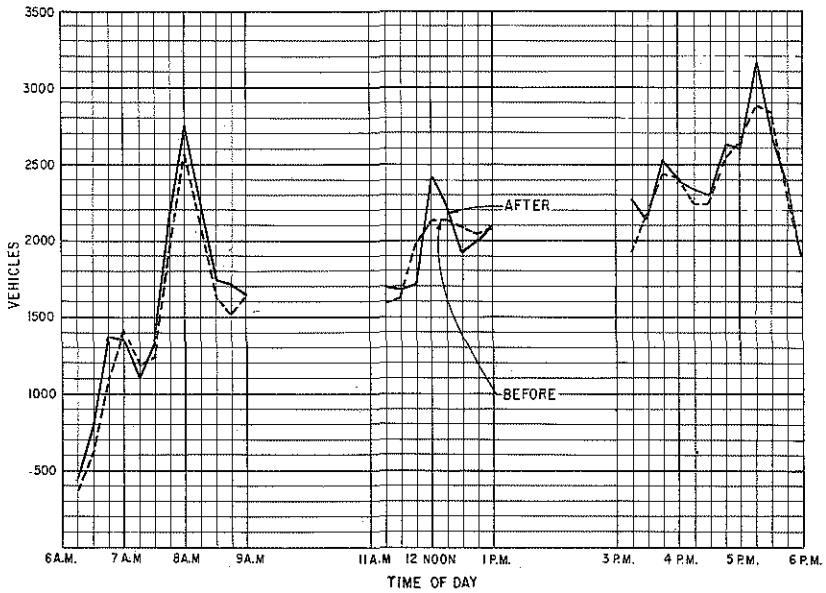
Figure 16 shows three graphs depicting the 15-minute peak values, during eight highest hours, of total traffic entering the study area, leaving the area, and traveling within the area in Lansing. Almost all except some of the noon-period peaks are found to be higher for the after period. The most significant differences between the before and after peaks are seen in the graph for leaving traffic.

Figure 17 shows the share which state trunklines and city streets take in Lansing in carrying the traffic, as counted while entering and leaving the area and while circulating within the street network. In all but a few minor cases, these sets of bar charts reveal that the percent of the traffic load carried by the state trunkline 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 trunkline carried 36.7 percent of all traffic leaving the area, whereas in the after period it carried 61.9 percent of this load. This is a relief for the city streets since their burden is lightened by drawing the traffic to the state trunkline during the rush hours.

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 optimum 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, variations 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 17-19 show the analyses of peak traffic volumes entering, leaving and circulating within the Kalamazoo study area. Trunkline and city portions of these volumes are also indicated. As seen in Table 17, the "after" surveys show drops in all the peaks of total entering traffic. Nevertheless, the trunkline





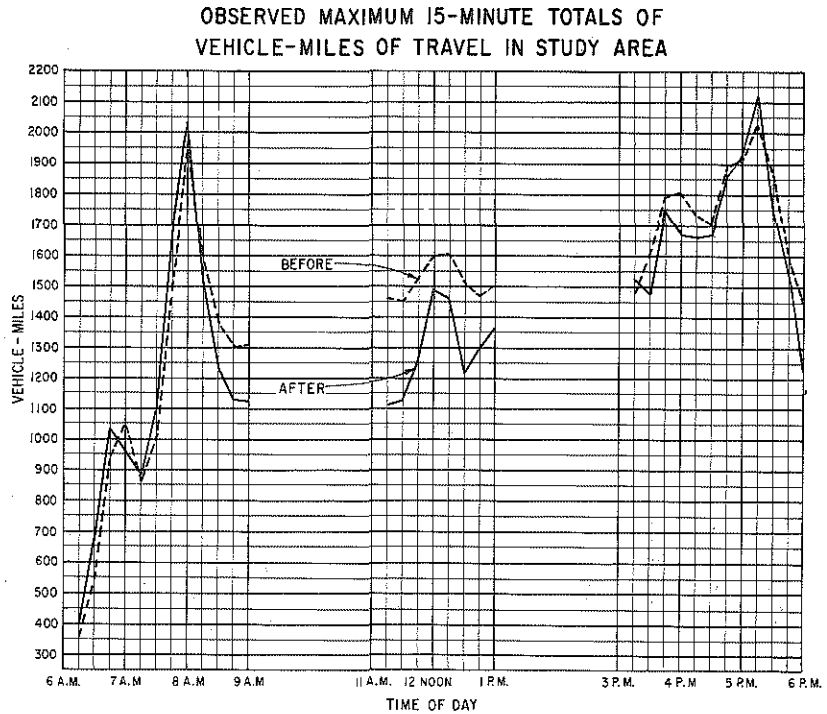


FIGURE 18 – CITY OF KALAMAZOO: PEAK TRAFFIC

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 18, are found to indicate increases in the after period. Table 19 represents the peak-period and 24-hour comparisons of travel in the area.

Figure 18 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 are 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 19, which is a graphical presentation of Tables 17-19, is interesting in showing once again that traffic entering or leaving the study area during peak periods has shifted to the use of state trunklines from the other city streets, as witnessed by percentage figures depicting the shares of the two classes of streets.

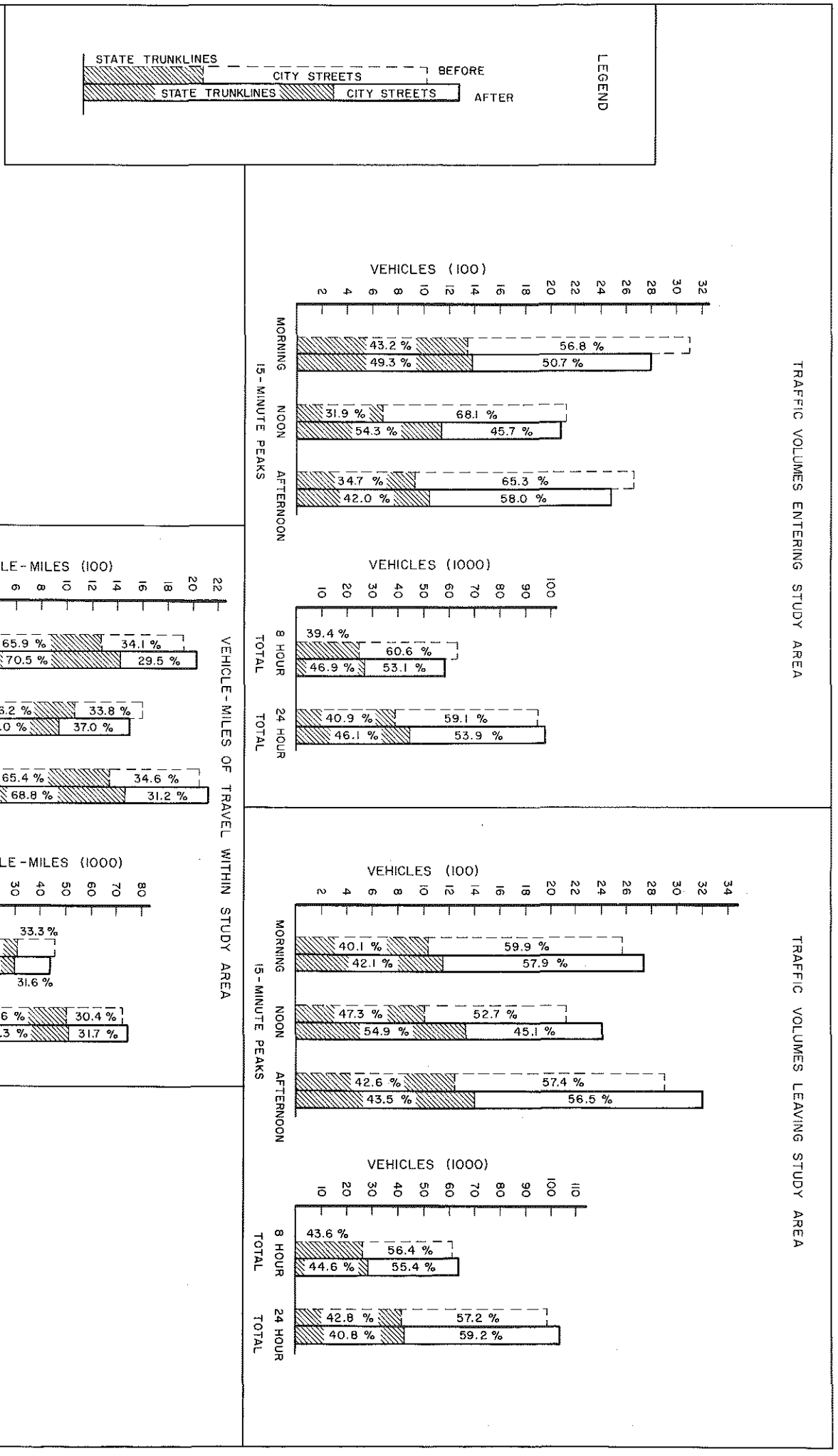


FIGURE 19-CITY OF KALAMAZOO

TRAFFIC VOLUME CHARACTERISTICS

TABLE 20

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.	12A.M.	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.

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 20 gives the highest observed hourly flows per lane. No further analyses of the volumes per lane have been made. An inspection of Table 20 reveals that higher maximum flows per lane existed in Kalamazoo than in Lansing, both under two-way and one-way operation. Also, higher maximum flows per lane were observed during the "after" period than the "before" period in Kalamazoo. The opposite situation was found in Lansing where higher flows were observed during the "before" counts than the "after" counts.

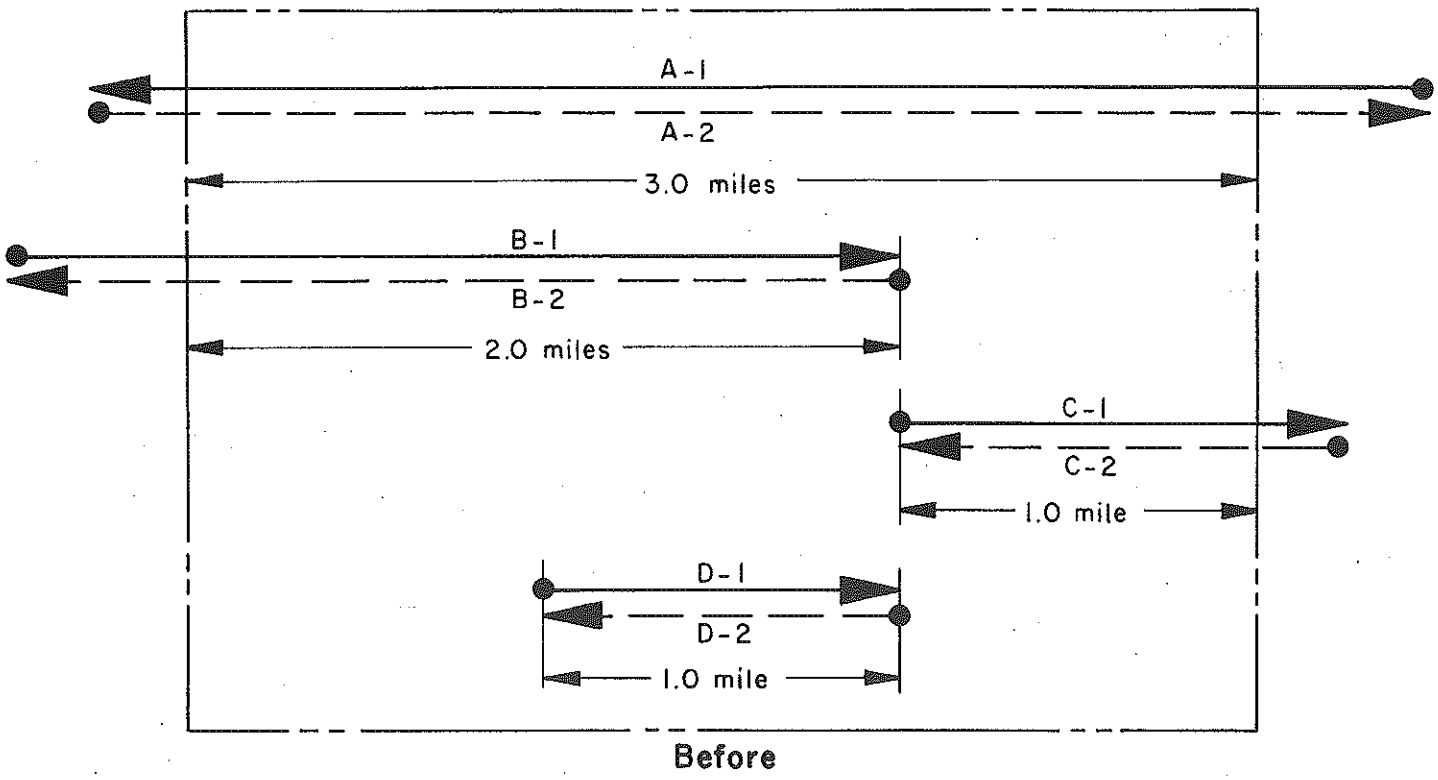
An Approximate Comparison of Average Travel Distances

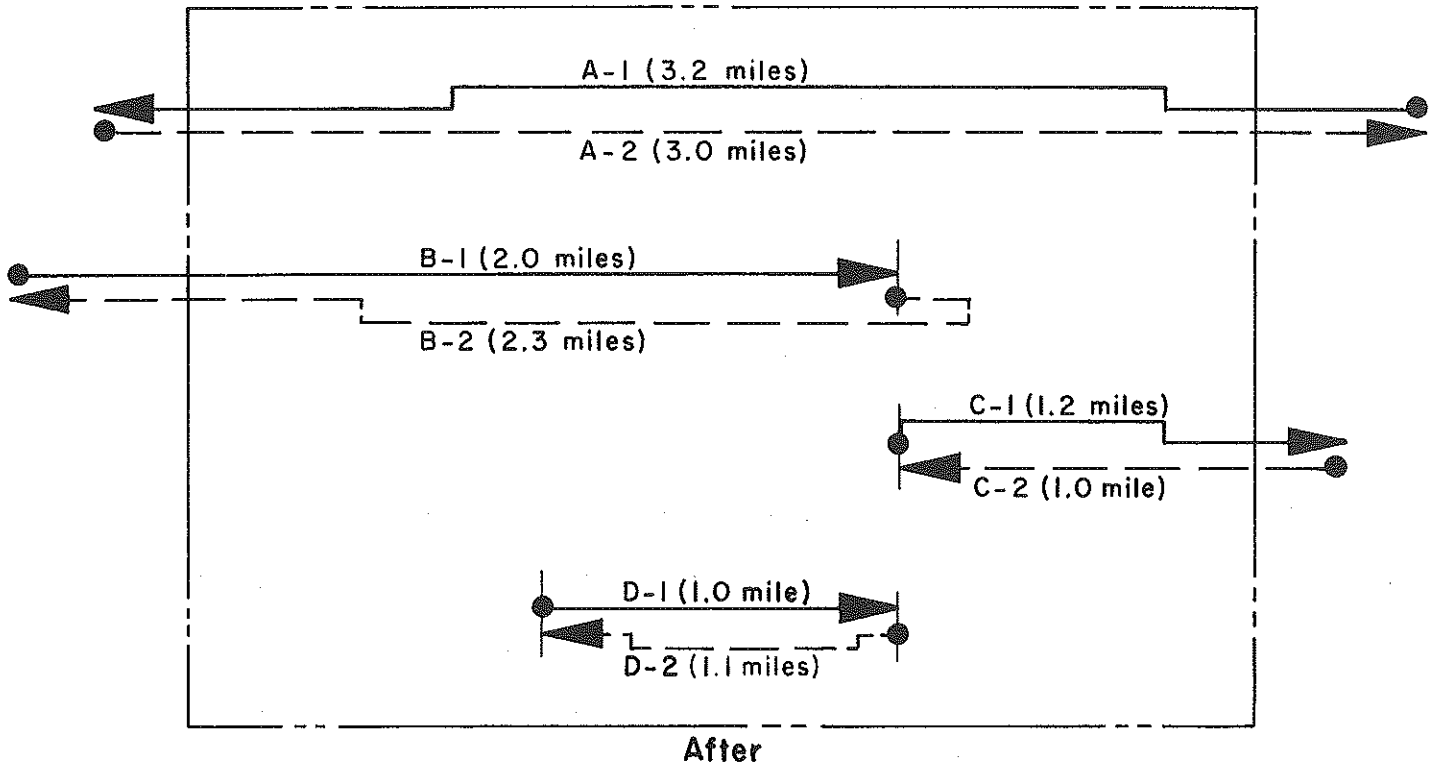
The average layman's first reaction to a change to one-way traffic usually is his dislike of the necessity to double back in the opposite direction for some of his usual trips in the city. Even though no specific surveys were planned in this study to obtain data on this so-called adverse travel distance, 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 20. 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

Figure 20

TRIP PATTERNS IN AN AREA





trips, (B) trips into the area by commuters who 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 trunkline traffic traverses the area. In the case of the cities of Kalamazoo and Lansing no surveys were conducted to count the number of internal trips (category D) even though 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 ÷ 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 ÷ 8 = 1.85 miles. In this hypothetical case, then, there was 0.10 mile 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 14-16. 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 14 and 15, was 67,000 + 63,000 = 130,000 vehicles. Total travel, from Table 16, was 48,000 vehicle-miles. Consequently, the average travel length generated by each vehicle counted at the area boundary was 48,000 ÷ 130,000 = 0.37 mile. Using the figures from Tables 14-16 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 ÷ 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.

Similar calculations for Kalamazoo, using the information from Tables 17-19, 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.

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 suspected.

Results of Turning-Movement Studies

Turning-movement counts of 6-hour duration were taken in Kalamazoo at the intersection of Kalamazoo Avenue and Rose Street, and at the intersection of Michigan Avenue and Lovell Street. Any stoppage of traffic due to vehicles waiting to turn left were also recorded.

Table 21 shows the comparison of turning-volumes by 15-minute periods during the before and after phases of the study at the intersection of Kalamazoo and Rose. In the after phase, since Kalamazoo Avenue was made one-way westbound, some of the turning-movements were eliminated. 175 vehicles turning left from the north on Rose Street in six hours was thus discontinued. On the other hand, right turns from the north increased by 133 vehicles. From south on Rose, 319 right turns were eliminated and 292 left turns were added. From the east on Kalamazoo, left turns gained 491 and right turns gained 56. The heaviest turning-movement during the before period was the right-turn from the west on Kalamazoo: 444 in six hours. The

TABLE 21 - CITY OF KALAMAZOO
Turning-Movement Study

INTERSECTION OF KALAMAZOO & ROSE

TIME	From N. on Rose St.					From S. on Rose St.					From E. on Kalamazoo						From W. on Kazoo.			
	L. Turn		Right Turn			Left Turn			Rt. Turn		Left Turn			Right Turn			L. Turn		Rt. Turn	
	Before	After	Before	After	Change	Before	After	Change	Before	After	Before	After	Change	Before	After	Change	Before	After	Before	After
6:00-6:15 A	4		0	0	0	1	0	-1	2		1	1	0	3	3	0	3		0	
6:15-6:30 A	3		3	5	+2	3	2	-1	2		3	7	+4	5	2	-3	3		6	
6:30-6:45 A	8		5	2	-3	7	7	0	12		4	9	+5	7	4	-3	4		16	
6:45-7:00 A	5		2	8	+6	5	12	+7	20		13	10	-3	4	7	+3	10		4	
7:00-7:15 A	4		2	13	+11	2	6	+4	4		11	14	+3	5	7	+2	4		6	
7:15-7:30 A	9		5	5	0	4	3	-1	6		5	12	+7	6	4	-2	4		12	
7:30-7:45 A	10		4	11	+7	11	20	+9	12		6	33	+27	2	2	0	14		31	
7:45-8:00 A	6		12	10	-2	9	17	+8	8		14	43	+29	4	7	+3	7		51	
8:00-8:15 A	5		3	5	+2	14	9	-5	13		18	38	+20	6	11	+5	13		40	
8:15-8:30 A	4		3	6	+3	12	10	-2	9		15	27	+12	5	9	+4	7		22	
8:30-8:45 A	8		7	9	+2	10	24	+14	10		13	11	-2	8	7	-1	7		21	
8:45-9:00 A	4		6	15	+9	7	22	+15	13		16	55	+39	8	14	+6	7		22	
3:00-3:15 P	7		7	12	+5	18	43	+25	16		18	47	+29	5	12	+7	5		21	
3:15-3:30 P	9		9	15	+6	19	45	+26	16		25	69	+44	7	11	+4	8		20	
3:30-3:45 P	10		15	28	+13	18	22	+4	22		28	43	+15	15	14	-1	5		19	
3:45-4:00 P	10		13	18	+5	12	36	+14	26		35	76	+41	12	12	0	7		18	
4:00-4:15 P	5		7	20	+13	32	51	+19	14		18	74	+56	14	17	+3	6		22	
4:15-4:30 P	10		12	16	+4	19	45	+26	21		22	45	+23	6	12	+6	11		22	
4:30-4:45 P	13		13	25	+12	28	51	+23	24		31	61	+30	11	17	+6	9		15	
4:45-5:00 P	10		21	35	+14	22	50	+28	19		30	64	+34	9	17	+8	9		11	
5:00-5:15 P	16		12	16	+4	38	44	+6	17		24	45	+21	12	13	+1	7		24	
5:15-5:30 P	8		10	20	+10	27	44	+17	14		26	50	+24	13	13	0	3		21	
5:30-5:45 P	4		11	17	+6	29	50	+21	12		18	28	+10	9	11	+2	9		14	
5:45-6:00 P	3		5	9	+4	13	39	+26	7		6	29	+23	6	12	+6	4		6	
6 hr. total	175		187	320	+133	360	652	+292	319		400	891	+491	182	238	+56	166		444	

No left-turns on account of one-way operation.

No right-turns on account of one-way operation.

No traffic from west on account of one-way operation.

No traffic from west on account of one-way operation.

Note: Total of 6-hr. approaching traffic on all legs of intersection: "Before" = 8024
"After" = 9029

TABLE 22

Cumulative Left Turn Lane Stoppages
Kalamazoo St. and Rose St.
City of Kalamazoo, Kalamazoo Co.
Tues., Oct. 20, 1964 6-9A & 3-6P
Extent of Delay Shown in Seconds

Time:	From the N. on Rose St.	From the S. on Rose St.	From the E. on Kalamazoo St.	From the W. on Kalamazoo St.
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

heaviest turn during the after period was 891 vehicles turning left from the east on Kalamazoo. The highest 15-minute rate of this movement was 76 which is a rate equal to 305 left-turns per hour.

The left turns at the Kalamazoo and Rose intersection were within the capacity available under the opposing traffic volumes during the before period. However, most of the left-turns caused stoppage of traffic on the lanes which were also used for through traffic. Table 22 shows these delays. Comparison of these delays with the left-turns shown in Table 21 reveals that maximum delays generally occurred at times of maximum left-turning volumes. During the after period, the only left-turn movement conflicting with opposing traffic was the one from the south on Rose Street, and no stoppage of through-lanes due to left-turns was observed.

Turning-movement counts at the intersection of Michigan and Lovell did not contribute any useful information to the study because Lovell was already a one-way street during the before period, and the only left-turn allowed were from this street and caused no problems or lane stoppages.

In Lansing, turning-movement and back-up surveys were made at three intersections, but only one of these is within the limits of this phase of the study. This is Oakland and Logan intersection, and even that is not yet operating in its ultimate condition since Oakland Street west of this intersection is

TABLE 23 - CITY OF LANSING

Turning-Movement Study

INTERSECTION OF OAKLAND & LOGAN

TIME	From N. on Logan					From S. on Logan				From E. on Oakland						From W. on Oakland					
	L. Turn		R. Turn			L. Turn		R. Turn		L. Turn			R. Turn			L. Turn		R. Turn			
	Before *	After	Before	After	Change	Before	After	Before *	After	Before *	After	Change	Before *	After	Change	Before	After	Before	After	Change	
6:00-6:15A	0		1	1	0	1		0		0	111	+111	0	17	+17	1		0	3	+3	
6:15-6:30A	0		2	2	0	1		0		0	150	+150	0	18	+18	0		1	1	0	
6:30-6:45A	0		1	10	+9	2		0		1	199	+198	0	17	+17	1		3	4	+1	
6:45-7:00A	0		1	4	+3	4		0		0	120	+120	0	28	+28	0		2	4	+2	
7:00-7:15A	0		3	1	-2	3		1		1	68	+67	0	22	+22	4		2	5	+3	
7:15-7:30A	0		2	1	-1	1		0		0	72	+72	0	15	+15	0		6	0	-6	
7:30-7:45A	0		1	2	+1	4		0		0	93	+93	0	25	+25	2		12	10	-2	
7:45-8:00A	0		1	4	+3	4		0		0	110	+110	0	44	+44	1		6	4	-2	
8:00-8:15A	0		0	1	+1	5		0		0	91	+91	0	31	+31	2		3	3	0	
8:15-8:30A	0		0	4	+4	5		0		0	70	+70	0	26	+26	0		5	4	-1	
8:30-8:45A	1		0	0	0	7		0		0	78	+78	0	28	+28	2		4	1	-3	
8:45-9:00A	0		0	3	+3	3		0		0	94	+94	0	28	+28	0		3	0	-3	
3:00-3:15P	0		0	4	+4	5		0		0	198	+198	0	60	+60	2		4	20	+16	
3:15-3:30P	0		0	4	+4	9		0		0	151	+151	0	39	+39	5		9	5	-4	
3:30-3:45P	0		1	1	0	7		0		1	183	+182	0	62	+62	7		12	15	+3	
3:45-4:00P	1		2	3	+1	7		1		0	171	+171	0	46	+46	6		8	12	+4	
4:00-4:15P	0		3	2	-1	12		0		0	202	+202	0	57	+57	5		8	19	+11	
4:15-4:30p	1		1	0	-1	4		0		1	242	+241	0	63	+63	3		4	6	+2	
4:30-4:45P	0		0	4	+4	4		1		1	144	+143	0	49	+49	5		13	5	-8	
4:45-5:00P	0		3	5	+2	10		1		0	173	+173	0	78	+78	4		12	6	-6	
5:00-5:15P	1		4	3	-1	21		1		1	213	+212	0	78	+78	3		8	5	-3	
5:15-5:30P	0		0	1	+1	11		0		0	232	+232	0	95	+95	1		9	3	-6	
5:30-5:45P	0		0	3	+3	12		1		0	192	+192	1	76	+75	3		7	3	-4	
5:45-6:00P	0		0	3	+3	3		1		0	140	+140	0	58	+58	2		5	3	-2	
6 hr. total	4		26	66	+40	145		7		6	3497	3491	1	1060	1059	59		146	141	-5	

No left-turns on account of one-way operation.

Not allowed

No right-turns on account of one-way operation.

Not allowed

*East Oakland closed to thru traffic

not yet a state trunkline. During the before survey, northbound left lane was obstructed due to left-turning vehicles during most of the observed period. The longest cumulative time that this lane was stopped was 80 seconds between 5 and 5:15 p.m. All left turns except from the east on Oakland were prohibited during the after survey and therefore there were no back-ups due to left-turns. Table 23 compares the before and after turning movements at this intersection. Perhaps the only important information in this table is the left turns from the east on Oakland. A maximum of 242 left turns in 15 minutes, or an hourly rate of 968 have been counted. This movement takes place on two adjacent lanes and the intersection is signal-controlled.

Results of Accident Studies

Degree of traffic safety is a parameter which does not always reflect accurately the change in any one aspect of highway transportation. Recent national 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

TABLE 24

CITY OF LANSING

Accident Types on Saginaw Street

Between Logan (Excluded) and Grand (Included)

Type of Accident	One-Year Before		One-Year After	
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		58	
Sideswipe, opposite direction	3	22	2	60
Right angle	41		22	
Involving parking or 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 25

CITY OF LANSING

Accident Types on Saginaw Street

Between Belt Line RR and Logan (Inclusive)

Type of Accident	One-Year Before		One-Year After	
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		19	
Sideswipe, opposite direction	2	16	2	21
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 26

CITY OF LANSING

Accident Types Within Study Area

Type of Accident	One-Year Before		One-Year After	
Rear-end, straight	147)		163)	
Rear-end involving left turn	16)	174	13)	199
Rear-end involving right turn	11)		23)	
Head-on, straight	3		-	
Head-on involving left turn	27		25	
Sideswipe, same direction	85)		166)	
Sideswipe, opposite direction	8)	93	8)	174
Right angle	139		138	
Involving parking or parked vehicle	29		28	
Hitting fixed object	27		27	
Backing vehicle	24		20	
Hitting pedestrian	2		12	
Unknown	2		1	
Total	520		624	

TABLE 27

CITY OF LANSING

Accidents Within Study Area by Day or Night

	One-Year Before	One-Year After
Day time	365	463
Night time	123	140
Twilight	32	21
Total	520	624

appears that, at least in the case of Lansing, 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. It would appear prudent not to arrive at specific conclusions on the accident phase of the study at this time before analyzing the results which are expected from the cities of Pontiac and Port Huron. A full analysis of the results in Lansing and Kalamazoo is, however, presented in the following discussion.

Table 24 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. Over-all performance of the one-way trunkline, expressed in accidents per million vehicle-miles, has worsened.

Table 25 is a similar comparison of the western section of Saginaw Street where traffic has continued to run in both directions. A general upward trend is noted in the number and rate of accidents in this section also.

Table 26 portrays the accident experience of the total area studied in Lansing. Table 27 is a breakdown of the same accidents by day, night and twilight. The number of accidents has gone up from 520 to 624. Sideswipes show an unproportionate increase. This accident type has an affinity to multi-lane

traffic flow, and one-way operation would normally aggravate this condition. Furthermore, there are some locations in Lansing which are conducive to sideswipe accidents. One of these is the transition on Oakland from four to three lanes at the Washington Avenue intersection. In addition to the lane drop at this intersection, there is a slight shift to the left in the alignment of the remaining three lanes, which was the result of a right-of-way problem during the reconstruction of this street. Another hazardous location which has been added with the interim phase of the one-way operation is Oakland-Logan intersection where two of the three westbound lanes are used for left-turns onto two southbound lanes of the four-lane two-way Logan Street.

The two above-mentioned intersections are responsible for an increase of 28 accidents in one year. (See Appendix 13). However, this is not enough to account for the net increase of 104 accidents (Table 26) in the general study area.

After the construction, widening and resurfacing of Oakland Avenue west of Logan Street, as the final phase of this one-way trunkline development, the Oakland-Logan intersection should lose some of its hazardous condition. This is also true for the Saginaw-Logan intersection where turning-movements will be materially reduced after Logan Street ceases to be a state trunkline.

One last remark concerning the accident experience in Lansing will be about the change in the safety record of the Saginaw-

TABLE 28

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		83	
Rear-end involving left turn	9	176	19	107
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	

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. 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 this one-year period, 12 property-damage and five injury-accidents were reported. This experience of rise in accidents upon signal installation is typical of numerous other intersections throughout the State.

The traffic safety record for Kalamazoo has improved in the study streets during the after phase of the study. Table 28 shows the accident experience on that section of Michigan Avenue where traffic was changed to one-way. Appreciable reduction is observed, especially in rear-end collisions and parking accidents. As a control section, the experience on the remaining section of Michigan Avenue where operation remained two-way is presented in Table 29. Table 30 contains the accidents on Kalamazoo Avenue which was a local two-way street during the before period. Even though the total number has increased on this street, the rate has actually decreased since there was heavier traffic volumes as a trunkline. Table 31 is the experience of the study area as a whole. Table 32 is a further breakdown of the same accidents by day or night.

TABLE 29

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 30

CITY OF KALAMAZOO

Accident Types on Kalamazoo Avenue

Type of Accident	One-Year Before		One-Year After	
Rear-end, straight	36		40	
Rear-end invovlving 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 31

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 32

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

Appendix 15 is a list of the intersections in the study area and their safety record. Attention is called to the intersection of Michigan and Kalamazoo and the intersection of Main and Douglas. 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.

Midblock accidents in the study area by street names in Kalamazoo will be found in Appendix 16.

Table 33 is a general summary of accidents in the two cities, arranged for ease of comparison. There are four sections to this rather long tabulation. Section I contains information on the streets which were changed from two-way trunkline operation to one-way trunkline. Section II contains the results for the same trunkline but where the traffic operation remained two-way. Section III summarizes the experience on the previously non-trunkline two-way street which was made a one-way trunkline. Section IV is for the whole of the streets studied in the area. Finally, Section V contains total figures for the whole city. It will be noticed, on page 108, under Section III-A for the street which changed from two-way non-trunkline to one-way trunkline, that in Lansing a very large increase in accidents, from 9 to 115 a year, has taken place on this section. It

should be pointed out, however, that the 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 trunkline was built, where these streets existed before, to carry heavy traffic, and the accident experience became proportionately severe.

As mentioned earlier, no attempt will be made at this time to draw any general conclusions from the evaluation of accidents in these two cities. When data from the remaining two cities are compiled, Table 33 will be expanded to include the results of their analyses. The only remark which will be made here is the fact that in general all the accident rates, based on traffic volumes, in Kalamazoo are about twice as high as in Lansing. Accident reporting levels may vary from city to city, and this may have caused some of the differences in the general safety records of the two cities even though no evident differences in the procedures used are known to exist, and both cities use the uniform accident report forms designed by the State of Michigan.

TABLE 33

COMPARATIVE ACCIDENT SUMMARY

One Year Before and One Year After
Change to One-Way Traffic

	City of Lansing	City of Kalamazoo	Average of Change-Percentages (Two Cities)
I. STREET WHICH CHANGED FROM TWO-WAY TRUNKLINE TO ONE-WAY TRUNKLINE: (1)			
I-A. Total Accidents			
1. Before: Number	173	357	
2. After: Number	133	267	
3. Percent Change in Number	-23.1%	-25.2%	-24.2%
4. Before: Rate per million vehicle-miles	24.7	57.5	
5. After: Rate per million vehicle-miles	26.8	52.3	
6. Percent change in rate	+8.5%	-9.0%	*
I-B. Injury Accidents:			
1. Before: Number	39**	53	

(1) In Lansing: Saginaw Street between Logan and Grand. In Kalamazoo: Michigan Avenue between Main and Porter.

* Results are dissimilar.
** Includes one fatal.

TABLE 33 - Sheet 2

		City of Lansing	City of Kalamazoo	Average of Change-Percentages (Two Cities)
2.	After: Number	28	27	
3.	Percent change in number	-28.2%	-49.1%	-38.7%
4.	Before: Rate per million vehicle-miles	5.6	8.5	
5.	After: Rate per million vehicle-miles	5.6	5.3	
6.	Percent change in rate	0.0	-37.7%	*
I-C.	Property-damage Accidents:			
1.	Before: Number	134	304	
2.	After: Number	105	240	
3.	Percent change in number	-21.6%	-21.0%	-21.3%
4.	Before: Rate per million vehicle-miles	19.1	49.0	
5.	After: Rate per million vehicle-miles	21.2	47.1	
6.	Percent change in rate	+11.0%	-3.9%	*

*Results are dissimilar.

TABLE 33 - Sheet 3

	City of Lansing	City of Kalamazoo	Average of Change-Percentages (Two Cities)
I-D. Rear-end Collisions:			
1. Before	83	176	
2. After	34	107	
3. Percent change	-59.0%	-39.2%	-49.1%
I-E. Sideswipes:			
1. Before	22	57	
2. After	60	58	
3. Percent change	+172.7%	+1.8%	*
I-F. Right-angle Collisions:			
1. Before	41	35	
2. After	22	40	
3. Percent change	-46.4%	+14.3%	*
I-G. Pedestrian Accidents:			
1. Before	1	5	
2. After	2	7	

*Results are dissimilar.

TABLE 33 - Sheet 4

	City of Lansing	City of Kalamazoo	Average of Change-Percentages (Two Cities)
3. Percent change	+100.0%	+40.0%	+70.0%
I-H. Day Accidents:			
1. Before	123	232	
2. After	96	193	
3. Percent change	-21.9%	-16.8%	-19.4%
I-J. Night Accidents:			
1. Before	39	111	
2. After	31	63	
3. Percent change	-20.5%	-43.2%	-31.9%
I-K. Twilight Accidents:			
1. Before	11	14	
2. After	6	11	
3. Percent change	-45.4%	-21.4%	-33.4%
I-L. Peak-traffic Accidents			
1. Before	94	172	
2. After	67	140	

TABLE 33 - Sheet 5

	City of Lansing	City of Kalamazoo	Average of Change-Percentages (Two Cities)
3. Percent change	-28.7%	-18.6%	-23.7%
I-M. Off-peak Traffic Accidents:			
1. Before	78	181	
2. After	66	123	
3. Percent change	-15.4%	-32.0%	-23.7%
I-N. Accidents at Signalized Intersections: (2)			
1. Before	69	147	
2. After	46	125	
3. Percent change	-33.3%	-15.0%	-24.2%
I-P. Accidents at Non-Signalized Intersections: (2)			
1. Before	36	19	
2. After	38	21	
3. Percent change	+5.6%	+10.5%	+8.1%
I-Q. Midblock Accidents:			
1. Before	65	180	

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

TABLE 33 - Sheet 6

	City of Lansing	City of Kalamazoo	Average of Change Percentages (Two Cities)
2. After	32	111	
3. Percent change	-50.8%	-38.3%	-44.6%
I-R. Percent change in vehicle-miles of travel	-29.2%	-11.9%	-20.6%
II. A SECTION OF SAME TRUNKLINE AS IN SECTION I BUT WHERE OPERATION REMAINED TWO-WAY: (3)			
II-A. Total Accidents:			
1. Before: Number	121	82	
2. After: Number	134	80	
3. Percent change in number	+10.7%	-2.4%	*
4. Before: Rate per million vehicle-miles	19.6	59.5	
5. After: Rate per million vehicle-miles	21.5	55.6	
6. Percent change in rate	+9.7%	-6.6%	*

(3) In Lansing: Saginaw Street between Beltine Railroad and Logan Street.
In Kalamazoo: Michigan Avenue between Lovell and Main.

* Results are dissimilar.

TABLE 33 - Sheet 7

		City of Lansing	City of Kalamazoo	Average of Change-Percentages (Two Cities)
II-B.	Injury Accidents:			
1.	Before: Number	30	9	
2.	After: Number	26	19	
3.	Percent change in number	-13.3%	+111.0%	*
4.	Before: Rate per million vehicle-miles	4.8	6.5	
5.	After: Rate per million vehicle-miles	4.2	13.2	
6.	Percent change in rate	-12.5%	+103.0%	*
II-C.	Property-damage Accidents:			
1.	Before: Number	91	73	
2.	After: Number	108	61	
3.	Percent change in number	+18.7%	-16.4%	*
4.	Before: Rate per million vehicle-miles	14.7	53.0	
5.	After: Rate per million vehicle-miles	17.3	42.4	

*Results are dissimilar.

TABLE 33 - Sheet 8

	City of Lansing	City of Kalamazoo	Average of Change-Percentages (Two Cities)
6. Percent change in rate	+17.7%	-20.0%	*
II-D. Rear-end Collisions:			
1. Before	57	42	
2. After	68	48	
3. Percent change	+19.3%	+14.3%	+16.8%
II-E. Sideswipes:			
1. Before	20	16	
2. After	29	14	
3. Percent change	+45.0%	-12.5%	*
II-F. Right-angle Collisions:			
1. Before	25	13	
2. After	24	3	
3. Percent change	-4.0%	-77.0%	*
II-G. Pedestrian Accidents:			
1. Before	1	1	

* Results are dissimilar.

TABLE 33 - Sheet 9

	City of Lansing	City of Kalamazoo	Average of Change-Percentages (Two Cities)
2. After	2	0	
3. Percent change	+100.0%	-100.0%	*
II-H. Day Accidents:			
1. Before	94	52	
2. After	97	52	
3. Percent change	+3.2%	0.0	*
II-J. Night Accidents:			
1. Before	22	26	
2. After	31	24	
3. Percent change	+40.9%	-7.7%	*
II-K. Twilight Accidents:			
1. Before	5	4	
2. After	6	4	
3. Percent change	+20.0%	0.0	*

*Results are dissimilar.

TABLE 33 - Sheet 10

		City of Lansing	City of Kalamazoo	Average of Change-Percentages (Two Cities)
II-L.	Peak-Traffic Accidents			
	1. Before	73	44	
	2. After	82	38	
	3. Percent change	+12.3%	-13.6%	*
II-M.	Off-peak Traffic Accidents			
	1. Before	48	38	
	2. After	52	41	
	3. Percent change	+8.3%	+7.9%	+8.1%
II-N.	Accidents at Signalized Intersections:			
	1. Before	55	56	
	2. After	61	58	
	3. Percent change	+10.9%	+3.6%	+7.3%
II-P.	Accidents at Non-Signalized Intersections:			
	1. Before	22	2	
	2. After	30	0	

*Results are dissimilar.

TABLE 33 - Sheet 11

		City of Lansing	City of Kalamazoo	Average of Change-Percentages (Two Cities)
	3. Percent change	+36.4%	-100.0%	*
II-Q.	Midblock Accidents:			
	1. Before	44	24	
	2. After	43	22	
	3. Percent change	-2.3%	-8.3%	-5.3%
II-R.	Percent change in vehicle-miles of travel	+0.6%	+0.5%	+0.6%
III.	STREET WHICH CHANGED FROM TWO-WAY NON-TRUNKLINE TO ONE-WAY TRUNKLINE: (4)			
III-A.	Total Accidents:			
	1. Before	9	157	
	2. After	115	149	
	3. Percent change	+1180%	-5.1%	*
III-B.	Injury Accidents:			
	1. Before	2	26	
	2. After	26	21	

*Results are dissimilar.

(4) In Lansing: Oakland and Jefferson Streets between Logan and Grand,
In Kalamazoo: Kalamazoo Street between Douglas and Michigan.

TABLE 33 - Sheet 12

		City of Lansing	City of Kalamazoo	Average of Change-Percentages (Two Cities)
	3. Percent change	+1200%	-19.2%	*
III-C.	Property-damage Accidents:			
	1. Before	7	131	
	2. After	89	128	
	3. Percent change	+1170%	-2.3%	*
III-N.	Accidents at Signalized Intersections:			
	1. Before	(5)	94	
	2. After	58	101	
	3. Percent change	-	+7.4%	*
III-P.	Accidents at Non-Signalized Intersections:			
	1. Before	6	26	
	2. After	31	25	
	3. Percent change	+417%	-3.8%	*

*Results are dissimilar.

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

TABLE 33 - Sheet 13

	City of Lansing	City of Kalamazoo	Average of Change-Percentages (Two Cities)
III-Q. Midblock Accidents:			
1. Before	3	37	
2. After	26	23	
3. Percent change	+767%	-37.8%	*
III-S. Number of Signalized Intersections:			
1. Before	0	7	
2. After	6	6	
IV. ALL STREETS IN STUDY AREA:			
IV-A. Total Accidents:			
1. Before: Number	520	1380	
2. After: Number	624	1291	
3. Percent change in number	+20.0%	-6.4%	*
IV-B. Injury Accidents:			
1. Before	114	188	
2. After	133	176	
3. Percent change	+16.7%	-6.4%	*

*Results are dissimilar.

TABLE 33 - Sheet 14

	City of Lansing	City of Kalamazoo	Average of Change-Percentages (Two Cities)
IV-G. Pedestrian Accidents:			
1. Before	2	23	
2. After	12	22	
3. Percent change	+500%	-4.3%	*
V. WHOLE CITY:			
V-A. Total Accidents:			
1. Before	7,000	5,153	
2. After	7,980	5,077	
3. Percent change	+14.0%	-1.5%	*
V-B. Injury Accidents:			
1. Before	1,500	1,084	
2. After	1,862	1,020	
3. Percent change	+24.1%	-5.9%	*
V-G. Pedestrian Accidents:			
1. Before	149	80	
2. After	141	97	
3. Percent change	-5.4%	+21.2%	*

*Results are dissimilar.

CONCLUSIONS

With the limited information now available from only two cities for this interim report, some definite conclusions can already be drawn. From the analyses of the results presented in the previous section, the following general observations are substantiated.

One-way state trunklines through cities expedite the movement of large volumes during peak-traffic periods. Improvements of up to 10.6 miles per hour in average over-all speeds during peak periods have been observed after conversion of a street from two-way to one-way operation. Average of speeds on all of the examined routes have been found to increase from 18.1 to 23.1 miles per hour in Kalamazoo and from 25.3 to 28.2 miles per hour in Lansing. Better signal progression has resulted in fewer stops at intersections. In one typical trip through a study area during a morning peak period, the average number of stops has decreased from 6.3 to 1.0. Average delay (stopped time) during such trips have been reduced in one case from 71 to 11 seconds per mile. More gains in expediting traffic were experienced in Kalamazoo than in Lansing. (Lansing one-way scheme is only partially complete.) Travel time on streets crossing the one-way trunklines have not increased to any excessive degree, and even gains in time have been observed in some instances.

One-way operation on the trunklines has caused the number and especially the size of gaps in the traffic stream to increase,

with the result that traffic from side streets desiring to cross or turn onto the trunklines has had more opportunity to do so within less time. An approximate evaluation of increased capacity of some typical stop-controlled cross-streets in Lansing showed that 1500 additional vehicles could theoretically enter the trunkline from the two legs of the street during five hours of peak traffic.

In general, higher peak-traffic demands can be accommodated by one-way arterials, as evidenced by 15-minute volume counts whereby traffic entering, circulating within, and leaving the study area have been summed up for evaluation. 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. One-way state trunklines have drawn a larger share of the total traffic in the cities, thus relieving the local streets of congestion and hazard.

Volume studies have indicated in an indirect way that the average length of trips through an area served by one-way arterials have not increased as much as generally suspected.

Back-ups of vehicles caused by other vehicles waiting to turn left at some signalized intersections during two-way trunkline operation were eliminated by the conversion to one-way traffic.

Conclusions on accident studies are deferred until data from the one-way system in Pontiac and Port Huron are analyzed,

since few results are in agreement for the cities of Lansing and Kalamazoo.

ACKNOWLEDGMENT

The study engineer, on behalf of the Michigan Department of State Highways, wishes to extend his appreciation to Messrs. Keith Bushnell and Walter Roth for their suggestions concerning the analyses and evaluation of some of the results of this study; to Mr. Allen Hayes, Traffic Engineer of the City of Lansing, to Captain Adams of Kalamazoo Police Department, and to Messrs. Glenwood Baker and Edwin Miller, District Traffic Engineers, for their guidance and cooperation for compiling accident information; to Mr. Albert McCallum, the former study engineer, for initial planning of the surveys; to Mrs. Jacqueline Hollingsworth for her work in developing the computer programs used in processing the traffic volume data; to Messrs. Herbert Schoepke, Dean Derks and Wilbur Grams for their help in street inventory and drafting work; to the Mesdames Edna Cohen and Dorothy Billings for typing and clerical work; and special recognition to the Transportation Survey and Analysis Section of the Transportation Planning Division who participated in conducting the various traffic surveys and in processing the data.

APPENDIX 1

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 January 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 "

KALAMAZOO ACCIDENT STUDY

Street	From (Inclusive)	To (Inclusive)
18. Arcadia Ct.	North end	Westnedge Intersection
19. Eleanor Pl.	Eleanor St. Intersection	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 " " " " " "

Items 20 thru 33 " " " " " "

Street	From (Inclusive)	To (Inclusive)
15. Elm Pl.	Elm Intersection	East End
16. Allen	Michigan "	North End

KALAMAZOO ACCIDENT STUDY

Street	From (Inclusive)	To (Inclusive)
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 2: 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 3

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 4

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 "

LANSING ACCIDENT STUDY

Street	From (Inclusive)	To (Inclusive)
19. Logan	Lapeer Intersection	Daleford Intersection
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:

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 "

LANSING ACCIDENT STUDY

Street		From (Inclusive)	To (Inclusive)
9.	Drexel	Genesee Intersection	Jenison Intersection
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 5

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 " non-usable remainder

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

Headway used by 2 cars = 2 x 4 = 8 " (deduct)
4 " not usable

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

Headway used by 3 cars = 3 x 4 = 12 " (deduct)
5 " not usable

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

Headway used by 5 cars = 5 x 4 = 20 " (deduct)
1 second not usable

APPENDIX 6

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			15.756			+0063			207
	6-7 AM					353	177		29.123					458	92		37.785			+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			-0010			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	259			21.368			+0043			207
7	03.45P	.0825	2	64-07-23	303			24.998		.0825	5	66-07-06	356			29.370			+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	343			28.298			+0031			207
7	04.30P	.0825	2	64-07-23	285			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					1471	295		121.523			+0138	-0373	
7	05.15P	.0825	2	64-07-23	519			42.818		.0825	5	66-07-06	427			35.228			-0092			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			+0052			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					6495		577.090						8944			737.882					

APPENDIX 6 - - 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 7

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	553.0650	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	429.1646	363.1782	-64.9864
COMPOSITE 8 HR TOTAL	15589.6547	14007.7919	-1581.8628

APPENDIX 8

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 8 HR TOTAL	34713	35264	+551

APPENDIX 9

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	0068	0061	0054	0078	0070	0081	0104	0134	0116	0092	0073	0100	0079	0066	0055	001608
0030	0029	0047	0023	0010	0019	0029	0094	0078	0042	0067	0077	0090												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	008651
0124	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 10

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	123.9835	59.9038	-64.0397
04 - 05 AM	92.8916	67.4355	-25.4561
05 - 06 AM	151.6988	152.4427	+.7683
06 - 07 AM	776.5092	812.1930	+35.6838
07 - 08 AM	1552.7428	1587.6481	+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	584.5654	-102.5316
11 - 12 AM	638.2067	417.3377	-220.8690
COMPOSITE 24 HR TOTAL	29233.3003	25434.5717	-3798.7286

APPENDIX 11

OPERATIONAL ASPECTS OF ONE-WAY AND TWO-WAY STREETS

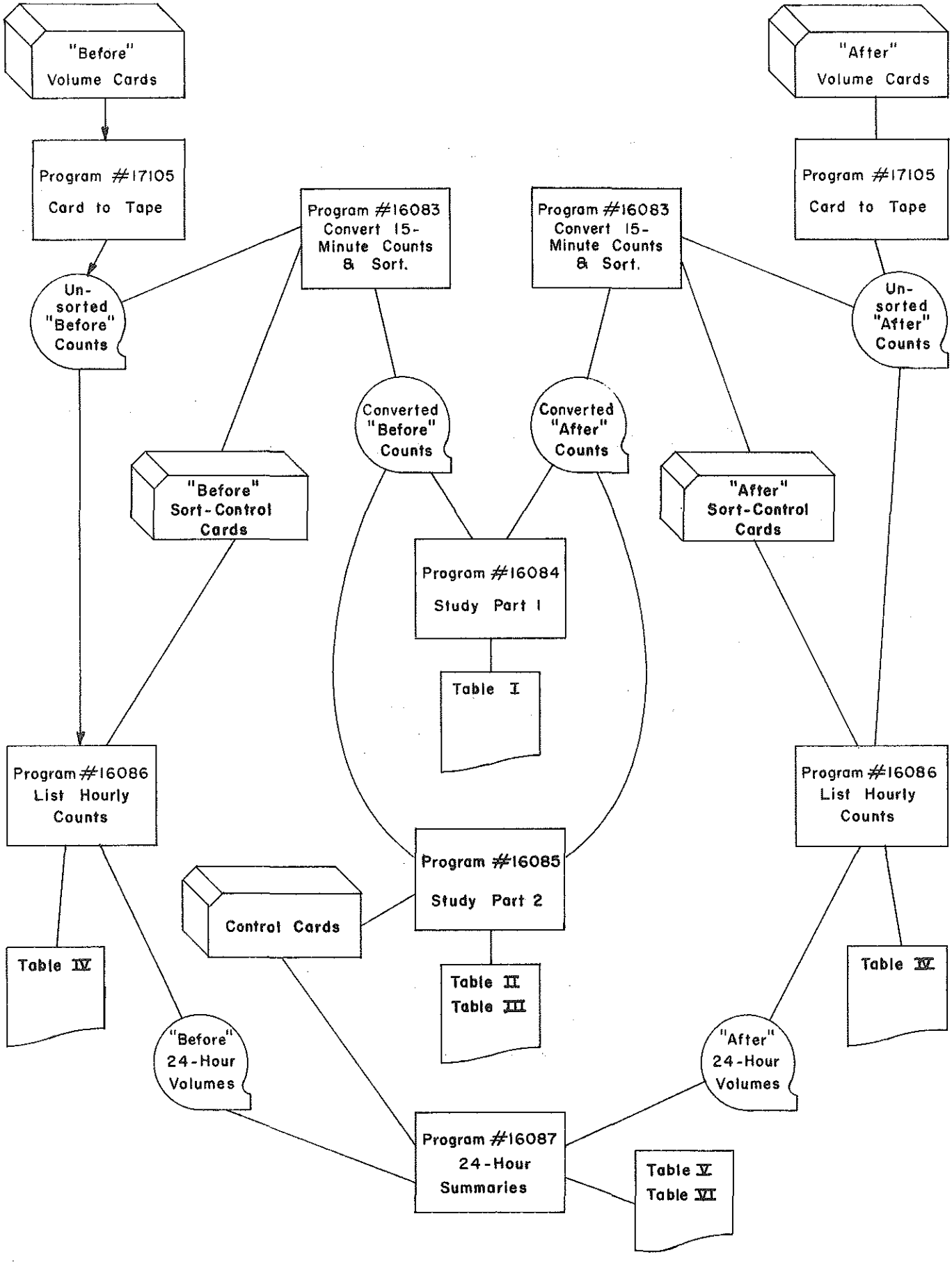
TABLE VI - 24-HOUR SUMMARY OF TRAFFIC VOLUMES LEAVING THE STUDY AREA - KALAMAZOO

GROUP 2R

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	346	140	-206
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	64067	64852	-1215

Appendix 12

COMPUTER PROCESSING FLOW CHART



APPENDIX 13

CITY OF LANSING

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
Saginaw @ Belt Line RR	3	2	4	4
" " Stanley	4	-	2	5
" " Durant	4	1	5	-
" " Verlinden (S)	11	2	20	3
" " Cawood	-	1	1	-
" " Comfort	4	-	-	-
" " Jenison (S)	12	7	12	5
" " Westmoreland	1	-	2	-
" " Clayton	-	2	3	-
" " Carey	-	-	2	-
" " Bartlett	-	-	2	-
" " Logan (S)	18	5	18	3
" " Princeton	5	1	14	3
" " Butler-Chicago (S)	11	2	7	-

(S) Signal-controlled intersection

APPENDIX 13 - Sheet 2

Intersection	One-Year "Before" Period		One-Year "After" Period	
	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Saginaw @ Wisconsin	1	-	3	-
" " Sycamore	3	2	4	-
" " Pine (S)	7	2	9	3
" " Chestnut	3	1	2	-
" " Walnut (S)	6	3	11	2
" " Seymour	14	6	7	4
" " Capitol (S)	13	5	4	2
" " Washington (S)	14	6	6	3
" " Grand (S-A)	3	-	12	5
" " Spur RR	1	-	-	-
" " Center	3	-	6	-
" " Cedar (S)	34	9	23	10
Oakland " Stanley	1	1	-	-
" " Cleo	-	-	-	1
" " Cawood	1	-	-	1
" " Comfort	1	-	-	1
" " Jenison	1	-	2	1

(S) Signal-controlled intersection
(S-A) Intersection was signal-controlled during the "after" period only

APPENDIX 13 - Sheet 3

Intersection	One-Year "Before" Period		One-Year "After" Period	
	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Oakland @ Westmoreland	3	2	1	-
" " Clayton	-	-	-	1
" " Logan (S-A)	-	1	14	3
" " Princeton	1	-	3	2
" " Summerville	-	-	2	-
" " Chicago	1	-	5	-
" " Edgewood	-	-	1	-
" " Leonard	-	-	-	1
" " Pine (S-A)	-	-	5	2
" " Chestnut	-	-	3	2
" " Walnut (S-A)	-	-	3	2
" " Seymour	-	-	6	6
" " Capitol (S-A)	-	-	5	3
" " Washington (S-A)	2	1	14	1
" " Grand (S-A)	-	-	5	1
" " Center	5	1	8	4
" " Cedar (S)	20	2	27	6

(S) Signal-controlled intersection
(S-A) Intersection was signal-controlled during the "after" period only

APPENDIX 13 - Sheet 4

Intersection	One-Year "Before" Period		One-Year "After" Period	
	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
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
Englewood @ Princeton	-	-	2	-
Butler @ Lapeer	1	-	2	-
Chestnut @ Lapeer	3	1	-	-
Capitol @ Kilborn	-	-	1	-
" " Madison	-	1	-	1
" " Lapeer	-	-	4	1
Genesee @ Verlinden	1	-	-	-
" " Westmoreland	-	1	-	-
Hyland @ Jenison	-	1	1	-
" " Westmoreland	-	-	1	-
Genesee @ Jenison	2	-	6	3
Drexel @ Genesee	1	1	1	1

APPENDIX 13 - Sheet 5

Intersection	One-Year "Before" Period		One-Year "After" Period	
	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Drexel @ Jenison	2	-	-	-
Lapeer @ Logan	1	1	2	1
" " Seymour	1	-	2	1
" " Pine	-	-	-	1
" " Sycamore	2	-	-	-
" " Walnut	3	-	-	-
" " Washington	7	1	10	1
Chicago @ Daleford	-	-	1	-
Daleford @ Logan	1	2	1	-
Daleford @ Princeton	-	-	-	1
Kilborn @ Walnut	3	1	-	-
" " Seymour	-	2	1	-
" " Washington	4	-	3	-
Madison @ Washington	2	1	-	-
Walnut @ Madison	-	1	-	-
Madison @ Seymour	-	-	2	-
Pine @ Madison	2	-	-	-

APPENDIX 13 - Sheet 6

Intersection	One-Year "Before" Period		One-Year "After" Period	
	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Grand @ Lapeer	1	-	2	-
" " Madison	-	-	1	-
Center @ Monroe	1	-	-	-
Cedar @ Monroe	1	1	-	-
Total intersection accidents	258	81	341	105

APPENDIX 14

CITY OF LANSING

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
Saginaw west of Logan	34	10	37	6
Saginaw east of Logan	59	14*	34	6
Oakland	6	2	27	5
Durant	1	0	0	1
Verlinden	-	-	1	-
Cleo	-	-	2	-
Comfort	1	-	-	-
Jenison	2	2	5	-
Westmoreland	3	-	1	-
Holton	1	-	-	-
Logan	4	1	9	4
Princeton	2	-	5	-
Butler	5	-	2	-
Chicago	-	-	1	1
Wisconsin	1	-	-	-

*Includes one fatality

APPENDIX 14 - Sheet 2

Street	One-Year "Before" Period		One-Year "After" Period	
	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Sycamore	-	1	-	-
Pine	1	-	-	-
Chestnut	1	-	3	-
Walnut	1	-	2	1
Seymour	5	-	-	1
Capitol	4	1	3	1
Washington	9	2	14	-
Center	2	-	-	-
Cedar	6	-	4	2
Total midblock accidents	148	33	150	28

APPENDIX 15

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	12	1
" " Pitcher	(S)	11	2	7	3
" " Porter		3	-	6	3
" " Walbridge		2	-	1	1

(S) Signal-controlled intersection

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

APPENDIX 15 - Sheet 2

Intersection		One-Year "Before" Period		One-Year "After" Period	
		Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Michigan @ 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	-

(S) Signal-controlled intersection

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

APPENDIX 15 - Sheet 3

Intersection		One-Year "Before" Period		One-Year "After" Period	
		Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
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	-	-	-
" " Church		2	1	3	-
" " Cooley		-	-	-	1

(S) Signal-controlled intersection

APPENDIX 15 - Sheet 4

Intersection		One-Year "Before" Period		One-Year "After" Period	
		Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Water @ Church		3	2	12	-
South @ Burdick	(S)	4	-	-	-
" " Henriett		1	1	1	-
Lovell @ Burdick	(S)	4	-	8	-
" " John		2	-	-	-
" " Henriett		1	-	1	-
" " Jasper		2	1	1	1
Main @ Douglas	(S-B)	15	-	4	-
" " Stuart		3	-	6	-
" " Catherine		2	-	2	-
" " Woodward		4	-	6	-
" " Elm		5	1	7	-
Douglas @ Forbes		-	1	1	-
" " Jefferson		2	-	-	1
Catherine @ Academy		-	1	-	-
Westnedge @ Lovell	(S)	7	1	9	1
" " South	(S)	5	1	21	1

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

APPENDIX 15 - Sheet 5

Intersection		One-Year "Before" Period		One-Year "After" Period	
		Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Westnedge @ 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	-

(S) Signal-controlled intersection

APPENDIX 15 - Sheet 6

Intersection		One-Year "Before" Period		One-Year "After" Period	
		Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
Burdick @ 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	606	111

(S) Signal-controlled intersection

APPENDIX 16

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

APPENDIX 16 - Sheet 2

Street	One-Year "Before" Period		One-Year "After" Period	
	Property Damage Accidents	Injury Accidents	Property Damage Accidents	Injury Accidents
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 17

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 4. 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 were spread over a period of 12 days due to the 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 were 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 running time, and points and duration of all delays were recorded in these runs using automatic recording equipment. (See Figure 5)

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 running 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 5).

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 the next day), two runs during morning off-peak period (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 survey 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 6.)

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.

Running-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 taken at a total of 48 locations (Figure 10). 24 of these locations are within the western section of the study area which will go into one-way operation some time in the future. This leaves 24 locations within the area which is now under one-way operation. At three of these locations, volume counts were continued for at least seven days and as long as other traffic surveys were in progress. At the remaining 21 locations, counts were recorded for 48 hours. Since a number of the count locations were bi-directional, the actual number of counts taken during the "before" survey was 39. 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. The last four intersections are outside the present study area.

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. Again, the last two intersections are outside of the present

study area. 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 11.)

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 noon peak, two runs were made during each of the three days. For the afternoon peak, four runs were made during each of the three days.

Cross-street running time surveys were taken on seven streets. Two of these streets, Jenison and Verlinden, are outside the area of the present study. The remaining five runs started or terminated at Kilborn and Hyland Streets which are situated one block north of Jefferson and Oakland Streets, respectively, and at Genesee Street which is two blocks south of Saginaw Street. (See Figure 11.) 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)

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 "after" phase of this study (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 the "after" 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 during the "after" survey. The 48-hour counts were all taken at the same time, using as many machines.

Traffic gap studies were repeated at the four intersections that are within the present study area. Turning-movement counts were repeated at the Oakland and Logan intersection.

Speed-and-delay survey routes for the "after" study were as follows: (See Figure 12.)

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 period 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 each were made during morning and noon peaks.

Cross-street travel-time runs were also repeated on the five streets. 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 trunklines, the travel directions of some of the test trips were different from the "before" runs, and they were as follows: (See Figure 12.)

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.