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July 22, 1980

H-3-87

MEMORANDUM TO: G. F. Kemper
State Highway Engineer
Chairman, Research Committee

SUBJECT: "Evaluation of Reversible Lanes (Nicholasville Road; Lexington, Kentucky)," Research Report 549, KYP-79-87; HPR-PL-1(15), Part III B

A reversible-lane system was implemented on a section of Nicholasville Road (US 27) in Lexington on March 5, 1979. The installation is unique in that left turns are allowed at signalized intersections during operation of the reversible lanes. The objectives of the study were to evaluate its effectiveness in reducing delays and develop recommendations for operational improvements.

The system has been a success. Some experts had doubts and misgivings about the probability of its successful and safe operation. Delays have been reduced substantially in the direction of peak traffic flow during both AM and PM operation. The benefit-cost ratio was 6.90. A one-year before-and-after analysis indicated no significant increase in accidents. Operation of the control system has proven to be extremely reliable; however, the data indicate an additional improvement may be realized with better coordination of signals. Delays in the off-peak direction, particularly during PM operation, increased. An effort should be made to encourage the use of alternate routes by motorists travelling in the off-peak direction. Also, consideration should be given to having the PM peak cutoff at 5:30 rather than 6:00. However, the higher traffic volume at 5:30 might make the transition period more difficult.

Consideration was given to installing reversible lanes on other arterials in Lexington. Specifically, Harrodsburg Road and Tates Creek Pike, which are parallel streets on either side of Nicholasville Road, have been mentioned. However, data gathered on those arterials indicated that reversible lanes are not warranted there. Also, those arterials provide alternate routes to Nicholasville Road. Traffic in the direction of peak flow has been diverted from these routes to Nicholasville Road, and traffic in the off-peak direction may travel these routes instead of Nicholasville Road. Therefore, installation of reversible lanes on those streets could adversely affect traffic on Nicholasville Road.

Respectively submitted,

Jas. H. Havens
Director of Research

KRA:ckd

cc: Research Committee

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Evaluation of Reversible Lanes (Nicholasville Road; Lexington, Kentucky)		5. Report Date July 1980
		6. Performing Organization Code
7. Author(s) Agent, K. R. and Clark, J. D.		8. Performing Organization Report No. 549
9. Performing Organization Name and Address Division of Research Kentucky Department of Transportation 533 South Limestone Street Lexington, KY 40508		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. KYP-79-87
12. Sponsoring Agency Name and Address		13. Type of Report and Period Covered Final
		14. Sponsoring Agency Code
15. Supplementary Notes Study Title: Improved Traffic Flow Through Innovations in Traffic Signal Systems		

16. Abstract

The study involved an evaluation of reversible lanes as a method of increasing traffic flow. A unique feature of the system was allowing left turns during the period of reversible flow, which meant that the left-turn lanes had to be moved and the signal displays shifted during operation and without interrupting traffic flow. The evaluation involved a comparison of data taken before and after installation of the reversible lanes. Types of data included delays, volumes, accidents, speeds, traffic conflicts, fuel consumption, and environmental factors.

Installation of the reversible lanes resulted in a significant savings in travel time in the peak direction. There was a large increase in travel times in the off-peak direction in the afternoon. An economic analysis based on current operating times showed a benefit-cost ratio of 6.90.

The reversible-lane system was successful; although, better signal coordination would improve operation. Data taken on two parallel arterial streets indicated reversible lanes on those streets are not warranted.

17. Key Words	18. Distribution Statement
Reversible Lanes Delay Volumes Accidents Environmental Factors Economic Analysis Traffic Speeds Fuel Consumption Traffic Conflicts	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

RESEARCH REPORT
-549-

EVALUATION OF REVERSIBLE LANES
(Nicholasville Road; Lexington, Kentucky)

KYP-79-87; HPR-PL-1(15), Part III B

by

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July 1980

INTRODUCTION

Increased traffic congestion is a major problem in metropolitan areas. During rush hours, many streets operate at or near capacity. This results in forced flow at low speeds and queues of vehicles backing up from restrictions downstream. In many instances, the restrictions are signalized intersections.

Coordination of signals is a common method of improving operational efficiency. Computerized signal systems provide the best coordination -- the traffic flow is continuously monitored to determine optimum timing of signals and progression. When the directional distribution of traffic on a multilane highway is greatly out of balance during peak hours, the capacity of a given section can be appreciably increased by assigning more than half of the lanes to the predominant direction of flow.

This study involved an evaluation of reversible lanes as a method of improving traffic flow. The objectives were to evaluate the effectiveness of reversible lanes in reducing delay and develop recommendations for operational improvements.

Nicholasville Road in Lexington, Kentucky was selected as a Federal Highway Administration demonstration project and qualified for 100-percent federal funding under Section 146 of the Federal Highway Act of 1976. The goals of this program are to demonstrate the potential for increased capacity for existing highways, conservation of fuel, decrease in travel time and traffic congestion, improvement in air quality, reduction of noise, and improvement of highway safety. This is to be accomplished through the installation and improvement of traffic signal control systems and technology not now in general use. One of the requirements for selection as a demonstration project is extensive collection of data, analysis, and reporting. This requirement, coupled with a lack of information on existing reversible-lane installations, resulted in this research.

BACKGROUND

A reversible-lane system was installed on a 2.6-mile (4.2-km) section of Nicholasville Road in Lexington, Kentucky (200,000 population). The system was activated on March 5, 1979. The reversible-lane section is five lanes wide (57 feet (17.5 m)) and carries approximately 35,000 vehicles per day. Two lanes served each direction, and a center lane served as a two-way, left-turn lane (a 2-1-2 configuration). The center lane served as a left-turn lane at eight signalized intersections. The speed limit is 40 mph (64.4 m/s) at the north end and 45 mph (72.4 m/s) at the south end of the project.

Reversible lanes had been considered for some time; however, a less than optimal directional split and the large number of left turns created problems. One commonly used warrant for reversible lanes involves the ratio of directional traffic volumes and states that the ratio of major to minor movements should be at least 2:1 and preferably 3:1 (1). Whereas the morning peak conditions did provide a 2:1 split, the evening peak conditions provided only a 1.5:1 split. However, it was theorized that traffic diverted from parallel routes to the reversible-lane route during peak hours would increase this ratio. Also, it was anticipated that some motorists would find alternate routes rather than travel in the restricted number of lanes provided in the off-peak direction. Overall, the expected result was a more favorable directional split. The large number of left turns during the peak hours prevented prohibition of left turns. This meant that left-turn lanes and signal displays had to be shifted during reversible-lane times.

The periods of lane reversal were from 7:00 a.m. to 9:00 a.m. and 4:00 p.m. to 6:00 p.m. (Monday through Friday). During these periods, the lane configuration changed from the 2-1-2 configuration to a 3-1-1 configuration, and the heavy-flow direction received the additional lane. A two-way, left-turn lane was maintained. The PM period, originally extending until 6:30 p.m., was moved back to a cutoff time of 6:00 p.m. after the delay data were analyzed.

INSTALLATION

Nicholasville Road is one of three arterial streets serving the south portion of Fayette County (Figure 1). There is not an adequate grid street system nor are there connector streets so that left turns on any of the three arterials could be prohibited. Nicholasville Road, being the most heavily traveled of the three and located between the other two, was the logical choice for the lane-reversal project.

Because the need to turn left was great (as high as 500 vehicles per hour at one intersection) and because a project goal was to minimize inconvenience to the motorist, the decision was made to accomodate left-turning vehicles. Eight signalized intersections were located within the project limits. Four were controlled by five-phase, semi-actuated traffic signal controllers which provided detection and protection of the left-turn movements from Nicholasville Road. Three intersections had two-phase controllers but no protected left-turn movement. One intersection operated under the control of a three-phase controller which provided split-phase (dual left turns) operation on the side street but no protected left turns on Nicholasville Road. The obvious problem was how to clear the left-turn lanes prior to changing the lane configuration.

The decision was made to force all intersections to the left-turn phase during the changing of lane assignments. This call to the left-turn phase lapsed after a set time (0-30 seconds) had elapsed. The left-turn phase terminated at each intersection after the left-turn demand had been satisfied. The next phase following was Nicholasville Road green at all intersections. The lane - assignment signals would then change as the Nicholasville Road through traffic advanced to enable transition into the proper lanes prior to arrival at the next intersection.

External logic was also used to switch the left-turn lane detectors and signal displays to correspond with the location of the left-turn lane. To clear the left-turn phase throughout the project, it was necessary to add left-turn phases at three intersections. An example of operation of an intersection during reversible - lane operation is shown in Figure 2. The remaining intersection which did not have a left turn phase was at the end of the project, and left turns were prohibited during the periods of reverse flow.

All existing and the three new controllers were of a solid state circuitry design, and all detector amplifiers were a digital, self-tuning type. The lane-use-signal master controller utilized a cam with an electro-mechanical clock input. Manual control is also available. Lane-use signals (Figure 3) and the signal spans were installed so a minimum of two spans were visible at any location. The lane-assignment signals contained 150-watt incandescent bulbs. Blank-out signs were used to indicate lane closures and mandatory turns in the lane transition areas (Figure 4). Blank-out signs were also used at the split-phase, side street location to reduce dual turning lanes to single lanes during the periods of reversed flow. Details are given in APPENDIX A.

The cost of the project, including lane-use signals and detectors and signal-head modifications, was approximately $250,000. The time from award of the contract to system turn-on was approximately seven months. The original electro-mechanical clocks used for the master controller were replaced by digital clocks to eliminate a time-drift problem. Failures have been few since that date.

PROCEDURE

The evaluation involved a comparison of data taken before and after installation of the reversible lanes. A test car was equipped with a tachograph, a device that furnished a continuous graph of speed versus time as the test vehicle was driven in traffic at the prevailing

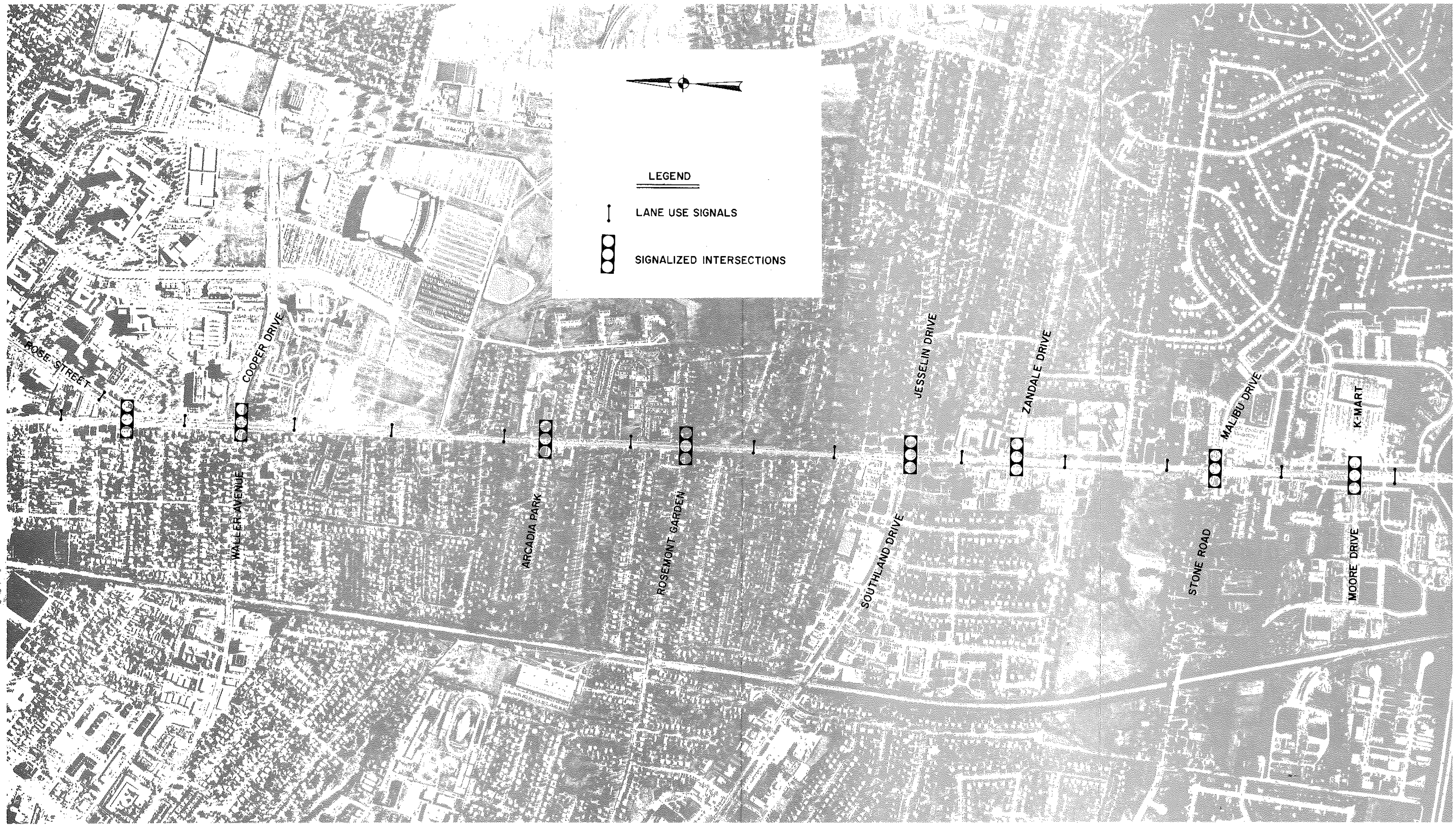

Figure 1. Street Configuration around Reversible-Lane Location.

Figure 2. Example of Intersection Signal Operation during Reversible Lanes Period.

Figure 3. Lane-Use Signals.

Figure 4. Blank-Out Sign.

speed. Tachograph data were collected primarily on Nicholasville Road; however, data were taken on the two parallel arterials and two cross streets. This was done to determine what effect the reversible-lane system had on other streets in the vicinity. A chart from a test run is given in Figure 5. Data were taken from this chart and input into the "Runcost" computer program developed by the Federal Highway Administration for the purpose of analyzing speed and delay data. Inputs for this program include grade and horizontal curve distribution on the roadway, distribution of vehicle types, roadway length, and fuel and operating costs. The output from the program includes average time, cost per vehicle to travel the section, overall speed and stopped time, fuel consumption, and pollutants emitted per vehicle. A sample printout is given in Figure 6. Stopwatch times were recorded for each run. Numerous runs were made, and a representative sample was selected for analysis. Travel times before and after installation were compared. Costs were calculated using output from the "Runcost" program and traffic volumes. A benefit-cost ratio was calculated using the installation cost, maintenance cost, and increased accident cost and the benefits from reduction in time and operating cost.

Volume counts were analyzed to determine the effect of the reversible lanes on traffic patterns. Accidents for a one-year period before and after installation were analyzed. The number and types of accidents were analyzed. Traffic conflicts were studied to estimate the change in accident potential. Conflicts were counted during the morning and afternoon at six signalized intersections.

Certain environmental factors were studied. The "Runcost" program output enabled analysis of air pollutants, and traffic-stream noise recordings were made. Computer simulation, using the UTCS-1 Network Simulation Model, was done before installation of the reversible lanes to predict their effectiveness. However, the extent of the volume which would be diverted to and from the adjacent streets was unknown at that time. Using the traffic before, the simulation results did not indicate any significant change in delays from addition of reversible lanes.

RESULTS

VOLUME

For reversible lanes to operate effectively, the ratio of major to minor movements should be at least 2:1 and preferably 3:1. The change in the directional split which occurred after installation of reversible lanes is shown in Table 1. During the AM peak period of operation (7:00-9:00 a.m.), the split increased from 2:1 to 3:1. This resulted from an increase in volume of 597 vehicles in the direction of peak traffic flow (northbound) and a decrease of 222 vehicles in the off-peak direction (southbound). The directional split also increased during the PM peak period but varied according to the peak period considered. From 4:00-6:00 p.m., which had been the period used after the initial cutoff time was changed from 6:30 a.m., the directional split increased from 1.4:1 to 2:1. This resulted from an increase in volume of 420 vehicles in the peak direction (southbound) and a decrease of 480 vehicles in the off-peak direction (northbound). The directional split was higher for a cutoff time at 5:30 p.m.

The average daily traffic (AADT) remained about the same (AADT of 35,320 before and 35,125 after). Plots of the traffic counts are given in Figures 7 and 8. The volumes were fairly constant before and after except for the change which occurred during operation of the reversible lanes. Volumes before and after installation are given in Table 2. Considering the morning peak period of operation (7:00-9:00 a.m.), the volume increased 22 percent in the peak direction and decreased 17 percent in the off-peak direction. The largest volume increase in the peak direction occurred from 7:00-8:00 a.m. Considering the afternoon peak period from 4:00-6:00 p.m., the volume in the peak direction increased by 15 percent, and the off-peak direction

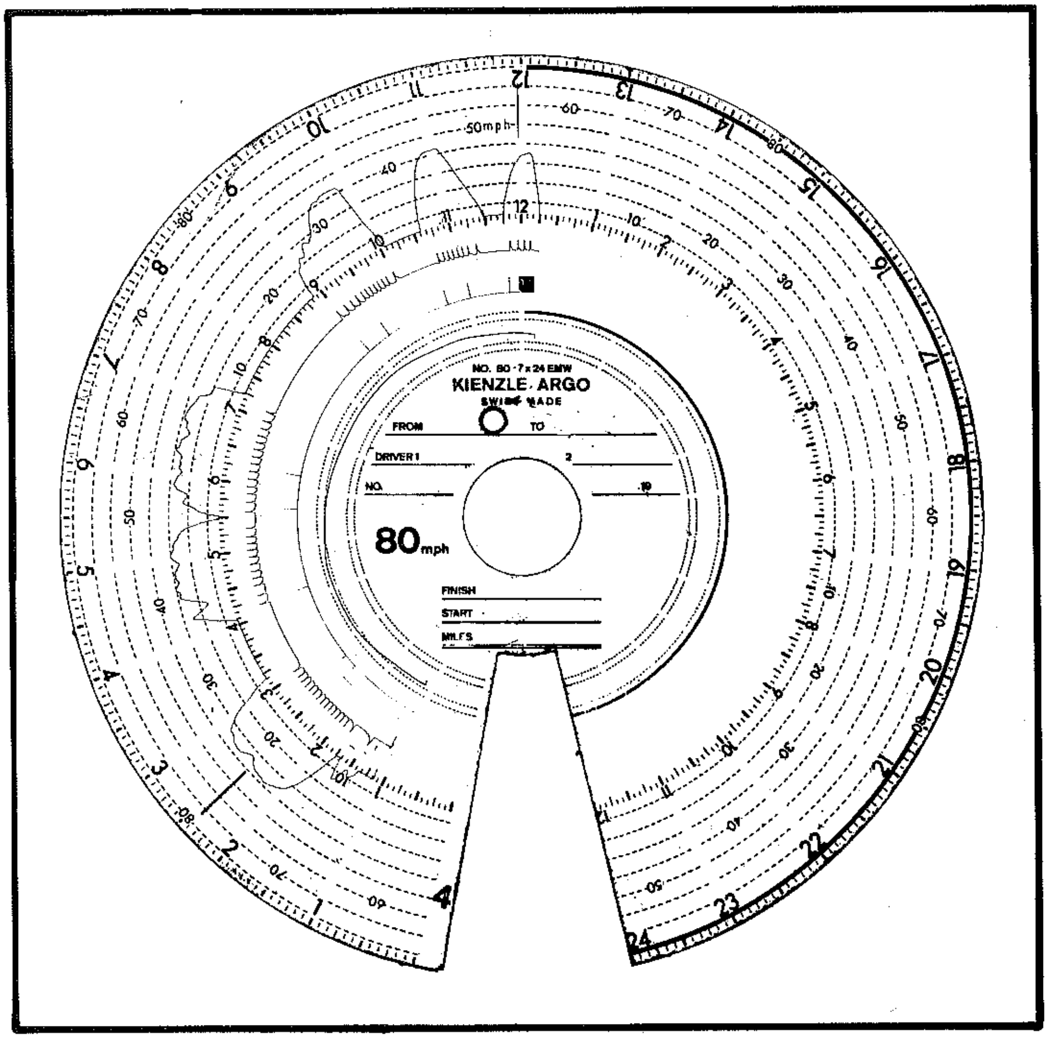

Figure 5. Sample of Tachograph Data.

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NICH RD    041679 AM PEAK      NB#9 BEG  7:10 TOT  8:09  5 STOPS

     INPUT DATA

 FRACTION OF GRADES
AT -8% 0.0      AT -7% 0.0      AT -6% 0.0      AT -5% 0.0      AT -4% 0.0      AT -3% 0.0
AT -2% 0.0      AT -1% 0.0      AT  0% 1.00000  AT +1% 0.0      AT +2% 0.0      AT +3% 0.0
AT +4% 0.0      AT +5% 0.0      AT +6% 0.0      AT +7% 0.0      AT +8% 0.0

FRACTION OF ROADWAY WITH A CURVATURE OF
  1% = 0.0        2% = 0.0       3% = 0.0       4% = 0.0       5% = 0.0
  6% = 0.0        8% = 0.0      10% = 0.0      12% = 0.0      14% = 0.0
 16% = 0.0       18% = 0.0      20% = 0.0      25% = 0.0      30% = 0.0

 THE VEHICLE DISTRIBUTION IS AS FOLLOWS
0.9000 ARE PASSENGER CARS, 0.0700 ARE 2.5-TON TRUCKS, 0.0300 ARE 6-TON TRUCKS,
0.0    ARE 20-TON TRUCKS,  AND  0.0     ARE 25-TON DIESEL TRUCKS.

 THE TOTAL NUMBER OF VEHICLES USING THE SECTION IS  1000., OVER A SECTION DISTANCE OF     2.8700 MILES.

 AN INFLATION FACTOR OF 1.760 HAS BEEN APPLIED TO ALL OPERATING COSTS

1.42 MPH WAS ADDED TO ALL NON-ZERO SPEEDS, ALL SPEEDS WERE MULTIPLIED BY 1.017

 A FUEL CONSUMPTION FACTOR HAS BEEN APPLIED TO THE 1969 WINFREY TABLES AS FOLLOWS

      CARS        2.5-TON        6-TON        20-TON        25-TON

   1.0900       1.0900        1.0000        0.9000        0.9000

 AN EMISSION ADJUSTMENT FACTOR OF 1.000 WAS APPLIED TO  COMPUTED VEHICLE EMISSIONS.

        OPERATING COSTS PER VEHICLE USING THIS HIGHWAY SECTION

                        (IN CENTS)

      CARS       2.5-TON        6-TON       20-TON       25-TON      AVERAGE

   36.8931      42.2949       81.8283     221.9374     263.0354     38.6192

 TOTAL USER COST BY VEHICLE TYPE FOR ALL VEHICLES USING THIS SECTION

                (IN DOLLARS)

      CARS         2.5-TON        6-TON          20-TON          25-TON

    332.0          29.61          24.55          0.0             0.0

        OPERATING COSTS PER VMT FOR VEHICLES USING THIS HIGHWAY SECTION

                (IN CENTS)

    CARS           2.5-TON        6-TON          20-TON          25-TON          AVERAGE

    12.85          14.74          28.51          77.33           91.65           13.46

AN OVERALL TRAVEL SPEED INCLUDING STOPS FOR THE SECTION IS 21.261 MPH.

THE VEHICLE WAS STOPPED FOR  0.0509350 HOURS.

COMPUTED SECTION DISTANCE IS     2.7871 MILES.

THE TOTAL ELAPSED TIME TO TRAVERSE THIS SECTION IS     0.13499 HOURS.

                                               CARS    2.5-TON    6-TON     20-TON     25-TON    AVERAGE

AT A VALUE OF TIME (IN $/VEH./HR.) OF       5.25000   6.20000   7.85000   9.17000   9.99000   5.39450
THE TOTAL TIME COST PER VEH. (IN $) IS       637.83     58.59     31.79      0.0        0.0

TIME COST PER VMT TO AVERAGE USER (IN CENTS) IS   25.37321

TIME COST PER VEH. USING THIS SECTION (IN CENTS) IS      70.72

       FUEL CONSUMPTION PER VEHICLE FOR ALL VEHICLES USING THIS HIGHWAY SECTION

                       (IN GALLONS)

     CARS          2.5-TON        6-TON          20-TON          25-TON        AVERAGE

  0.2467         0.2479         0.4835          1.168          0.7720        0.2539

 TOTAL FUEL CONSUMPTION BY VEHICLE TYPE FOR ALL VEHICLES USING THIS SECTION

                 (IN GALLONS)

     CARS          2.5-TON        6-TON          20-TON          25-TON

   222.0          17.35          14.51          0.0             0.0

                     POLLUTANTS EMITTED PER VEHICLE FOR ALL VEHICLES USING THIS HIGHWAY SECTION

                                               (IN POUNDS)

                        CARS         2.5-TON        6-TON         20-TON        25-TON        AVERAGE

NITROGEN OXIDES      0.2528E-01    0.2528E-01    0.6321E-01    0.6321E-01    0.0           0.2642E-01
HYDROCARBONS         0.2833E-02    0.2833E-02    0.7083E-02    0.7083E-02    0.0           0.2961E-02
CARBON MONOXIDE      0.2473        0.2473        0.6182        0.6182        0.0           0.2584

                TOTAL POLLUTANTS EMITED BY VEHICLE TYPE FOR ALL VEHICLES USING THIS HIGHWAY SECTION

                                               (IN POUNDS)

                        CARS         2.5-TON        6-TON         20-TON        25-TON

NITROGEN OXIDES        22.76         1.770         1.896         0.0           0.0
HYDROCARBONS           2.550         0.1983        0.2125        0.0           0.0
CARBON MONOXIDE        222.6         17.31         18.55         0.0           0.0
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Figure 6. Sample Printout of "Runcost" Data.

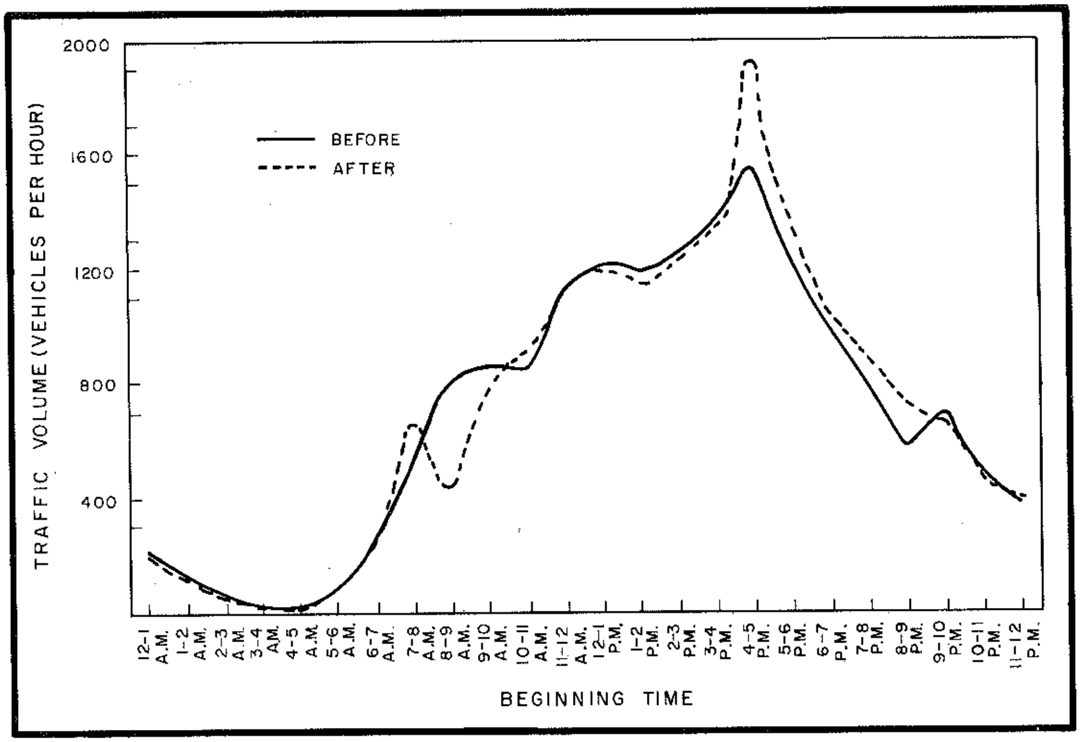

Figure 7. Traffic Volume versus Time of Day (Nicholasville Road, Southbound).

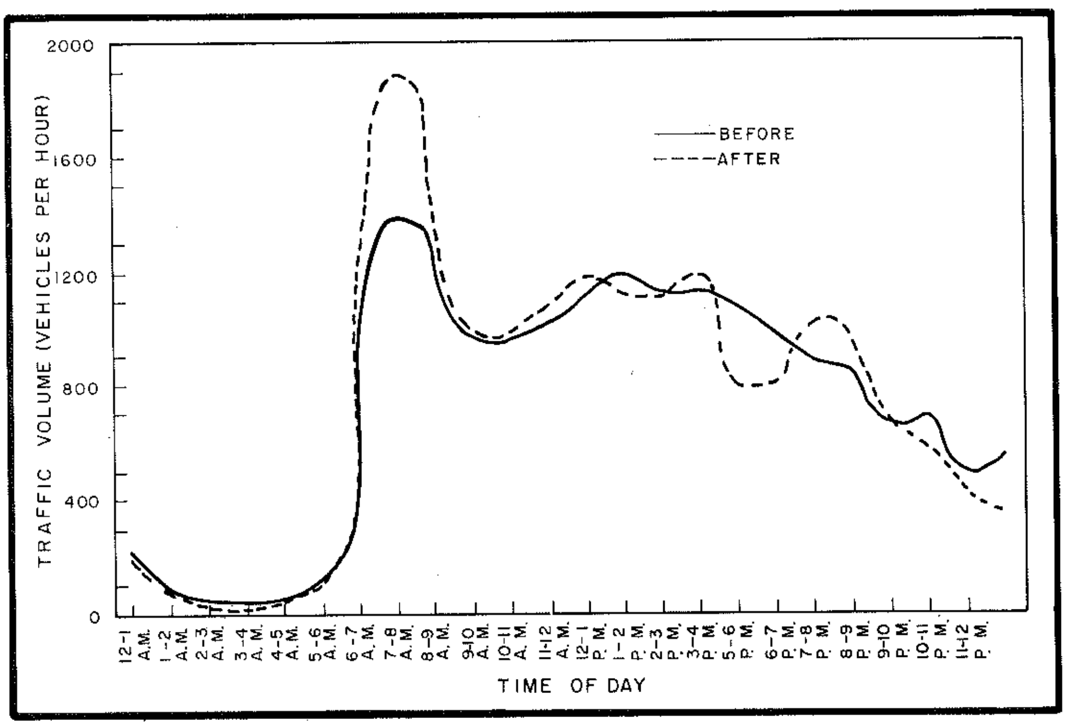

Figure 8. Traffic Volume versus Time of Day (Nicholasville Road, Northbound).

TABLE 1. RATIO OF PEAK TO OFF-PEAK DIRECTION VOLUMES

TIME PERIOD		BEFORE	AFTER
AM PEAK	7:00-9:00	2:1	3:1
PM PEAK	4:00-6:30	1.3:1	1.9:1
	4:00-6:00	1.4:1	2:1
	4:00-5:30	1.4:1	2.2:1

TABLE 2. CHANGE IN VOLUME ON NICHOLASVILLE ROAD AFTER INSTALLATION OF REVERSIBLE LANES

TIME PERIOD		BEFORE	AFTER	PERCENT CHANGE
AM NORTHBOUND (PEAK DIRECTION)	7:00-7:30	570	774	+36
	7:30-8:00	820	1114	+36
	8:00-8:30	704	758	+7
	8:30-9:00	576	621	+8
	7:00-9:00	2670	3267	+22
AM SOUTHBOUND (OFF-PEAK DIRECTION)	7:00-7:30	208	262	+26
	7:30-8:00	312	392	+26
	8:00-8:30	416	231	-44
	8:30-9:00	384	213	-45
	7:00-9:00	1320	1098	-17
PM SOUTHBOUND (PEAK DIRECTION)	4:00-4:30	753	934	+24
	4:30-5:00	785	973	+24
	5:00-5:30	711	741	+4
	5:30-6:00	559	582	+4
	6:00-6:30	489	541	+11
	4:00-5:30	2251	2648	+18
	4:00-6:00	2810	3230	+15
	4:00-6:30	3299	3771	+14
PM NORTHBOUND (OFF-PEAK DIRECTION)	4:00-4:30	550	395	-28
	4:30-5:00	550	395	-28
	5:00-5:30	534	440	-18
	5:30-6:00	437	360	-18
	6:00-6:30	445	378	-15
	4:00-5:30	1634	1230	-25
	4:00-6:00	2070	1590	-23
	4:00-6:30	2515	1968	-22

decreased by 23 percent. The largest changes in volume occurred between 4:00-5:00 p.m.

The analysis of the before and after volumes showed the reversible lanes generated trips in the peak direction and deterred trips in the off-peak direction. This resulted in a substantial increase in the directional split.

DELAYS

A representative sample of tachograph runs were selected for detailed analysis. A summary of the tachograph data is given in APPENDIX B. Plots of the time taken to drive the reversible-lane section versus the beginning time of the run are given in Figures 9 - 12. During the AM peak, there was a large reduction in travel time in the peak direction (Figure 9); there was a small increase in travel time in the off-peak direction (Figure 10). The maximum peak-direction travel times were reduced from about 22 minutes to 14 minutes. During the PM peak, travel times were reduced sharply in the peak direction (Figure 11); however, there was a large increase in travel times in the off-peak direction (Figure 12).

The changes in average travel times per vehicle, in 30-minute intervals, for the AM and PM peaks are given in Table 3. During the AM, the largest decrease was almost six minutes and occurred between 7:30 and 8:00 a.m. There were lesser decreases during other time periods, and a very small decrease (27 seconds) occurred from 7:00 to 7:30 a.m. Travel times in the off-peak direction increased in each time period; however, the increase in travel times in the off-peak direction was smaller than the decrease for the peak direction. During the PM peak, from 4:00 to 6:00 p.m., travel times were reduced from two to over six minutes in the peak direction. In the off-peak direction, travel times were increased from five to six minutes per vehicle. During part of the PM peak (4:00-4:30 p.m. and 5:30-6:30 p.m.), the increase in travel time in the off-peak direction was greater than the decrease in the peak direction.

The change in total travel time (vehicle-hours) was also determined (Table 4). Vehicle-hours were calculated by multiplying the average travel time per vehicle by traffic volume. Before-and-after comparisons (in 30-minute intervals) were made. There was a decrease in travel times during all time periods except 5:30 to 6:30 p.m. The original PM cutoff time was 6:30 p.m. The largest decrease occurred between 7:30 and 8:00 a.m. The largest decrease in the PM peak occurred between 4:30 and 5:00 p.m. The larger volume in the peak direction meant that, for a given change in travel time per vehicle, the resulting change would be larger in the peak direction.

Travel time per vehicle was calculated (weighted by volume) for the peak periods (Table 5). Considering both directions for both peak periods, there was an overall reduction of almost two minutes in travel time. There was an overall reduction in the peak directions of four minutes. The same type of analysis showed there was a decrease in stopped time of slightly over one minute (Table 6). There were very large changes in stopped time during the PM peak. The overall reduction in stopped time was almost three minutes in the peak directions.

This type of analysis was used also to analyze total stops per vehicle (Table 7). There was only a small reduction (0.5 stops) in stops. The decrease in the peak directions was over two stops per vehicle. This indicated an additional improvement in the signal system could be obtained with improved coordination.

To obtain a permanent record of traffic conditions before and after the reversible lanes were installed, photographs were taken at various locations. The photographs, shown in APPENDIX C, were taken at the same time and location in the before and after periods. They show effectively the changes which occurred. The reduction in delay during the AM peak is illustrated in Figures C1-C3. The reduction in peak-direction delay during the PM peak is illustrated in Figures C4 and C5; the increase in the PM off-peak direction delay is illustrated in Figure C6.

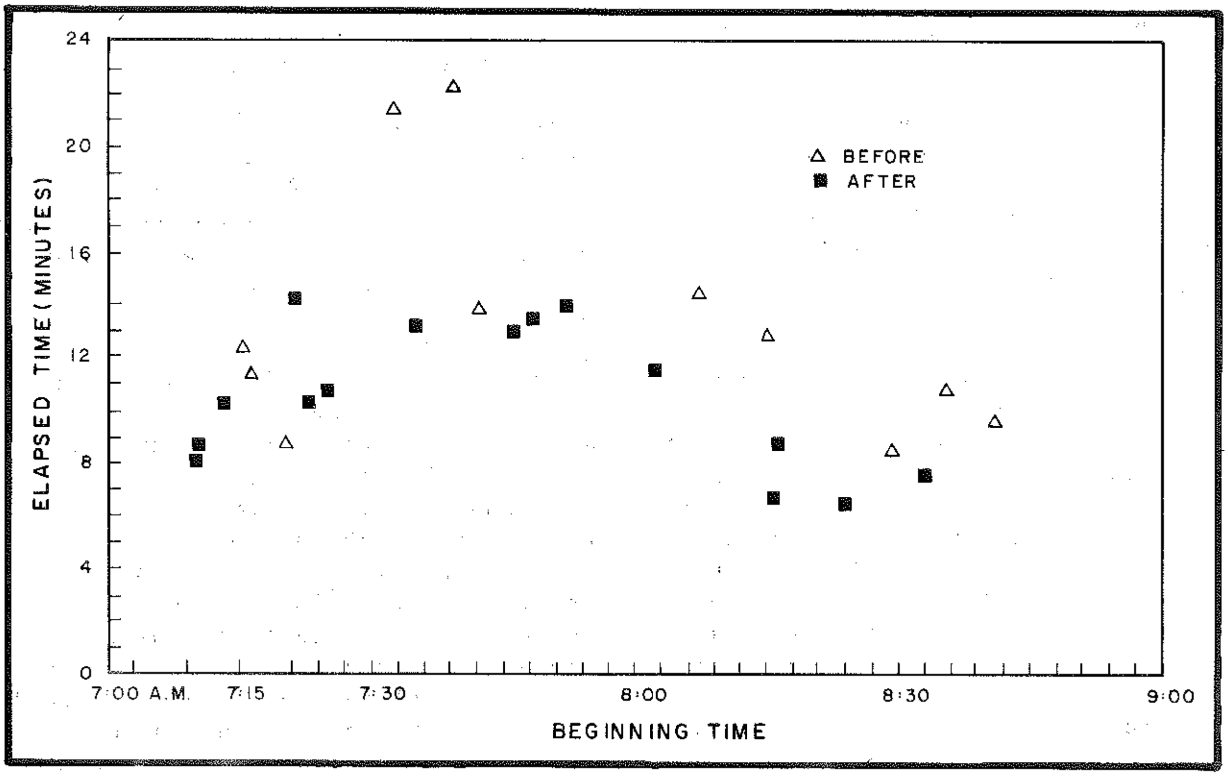

Figure 9. Nicholasville Road Time-Delay Runs, AM Peak, Northbound (Peak Direction).

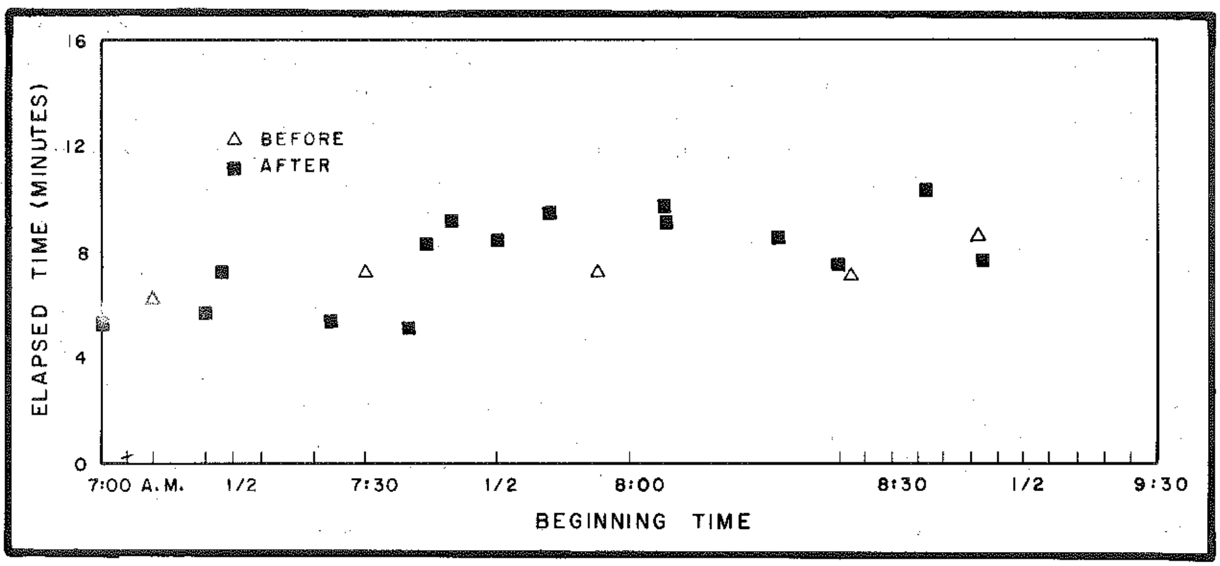

Figure 10. Nicholasville Road Time-Delay Runs, AM Peak, Southbound (Off-Peak Direction).

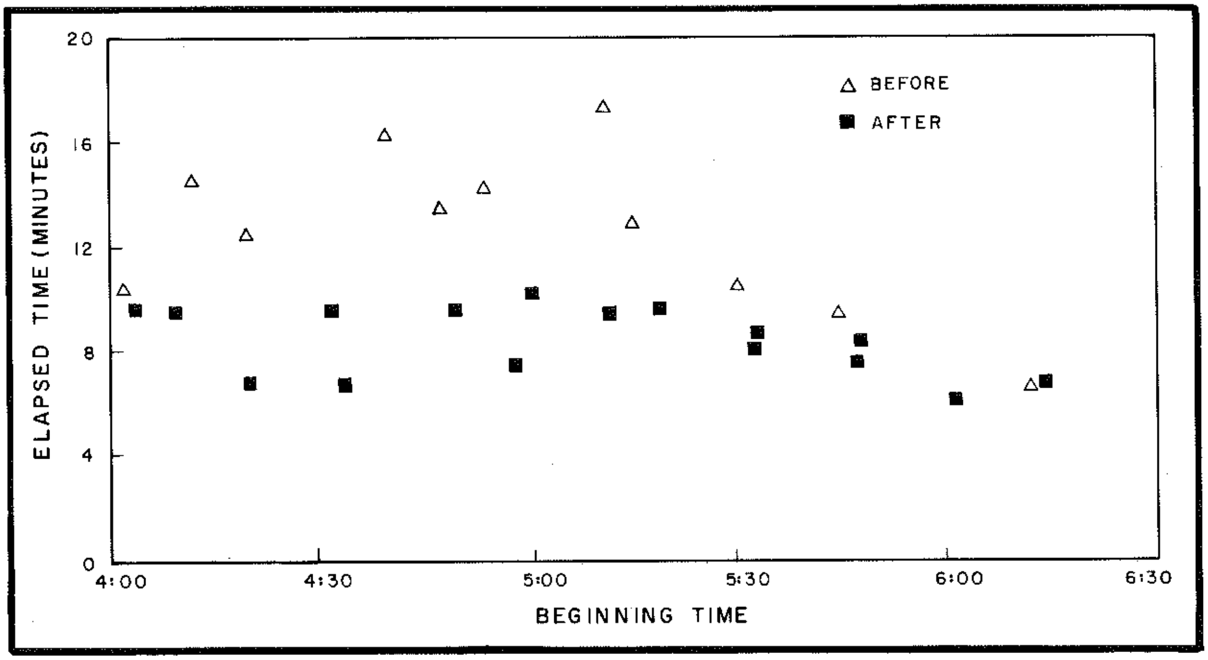

Figure 11. Nicholasville Road Time-Delay Runs, PM Peak, Southbound (Peak Direction).

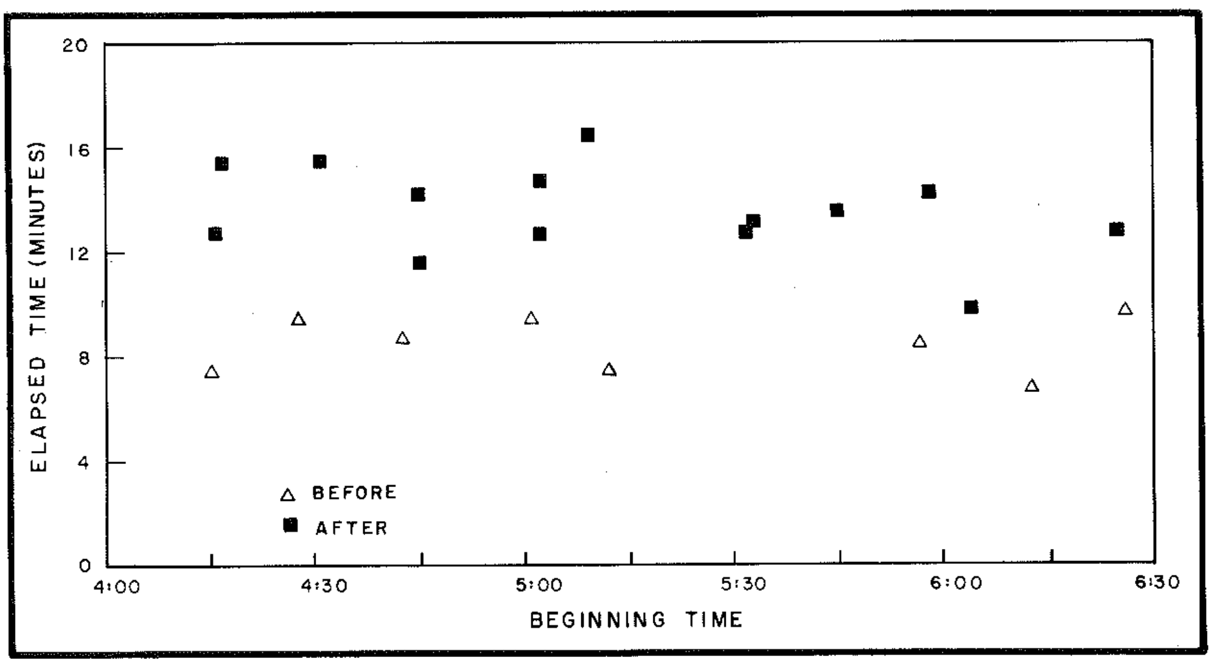

Figure 12. Nicholasville Road Time-Delay Runs, PM Peak, Northbound (Off-Peak Direction).

TABLE 3. CHANGE IN AVERAGE TRAVEL TIMES PER VEHICLE AFTER INSTALLATION OF REVERSIBLE LANES

	TIME PERIOD	TRAVEL TIME PER VEHICLE (MINUTES) SOUTHBOUND BEFORE	SOUTHBOUND AFTER	SOUTHBOUND CHANGE	NORTHBOUND BEFORE	NORTHBOUND AFTER	NORTHBOUND CHANGE
AM PEAK	7:00-7:30	6:48	6:54	+0:06	10:49	10:22	-0:27
	7:30-8:00	7:09	8:24	+1:15	19:10	13:29	-5:41
	8:00-8:30	7:05	9:25	+2:20	11:53	8:21	-3:32
	8:30-9:00	8:43	9:04	+0:21	10:23	7:41	-2:42
PM PEAK	4:00-4:30	12:32	8:44	-3:48	8:26	14:10	+5:44
	4:30-5:00	14:42	8:26	-6:16	8:38	13:45	+5:07
	5:00-5:30	15:20	9:41	-6:39	8:24	14:40	+6:16
	5:30-6:00	10:15	8:04	-2:11	8:09	13:22	+5:13
	6:00-6:30	6:45	6:29	-0:16	8:21	11:22	+3:01

TABLE 4. CHANGE IN TOTAL TRAVEL TIMES AFTER INSTALLATION OF REVERSIBLE LANES

	TIME PERIOD	TOTAL TRAVEL TIMES (VEHICLE-HOURS PER DAY) NB	SB	NET
AM PEAK	7:00-7:30	+0.4	-5.8	-5.4
	7:30-8:00	+8.2	-105.5	-97.3
	8:00-8:30	+9.0	-44.6	-35.6
	8:30-9:00	+1.2	-27.9	-26.7
PM PEAK	4:00-4:30	-59.2	+37.7	-21.5
	4:30-5:00	-101.6	+33.7	-67.9
	5:00-5:30	-82.1	+46.0	-36.1
	5:30-6:00	-21.2	+31.3	+10.1
	6:00-6:30	-2.4	+19.0	+16.6

TABLE 5. ANALYSIS OF DATA BY TOTAL TRAVEL TIME PER VEHICLE*

TIME PERIOD	BEFORE: TOTAL TRAVEL TIME PER DAY (VEHICLE-HOURS)	BEFORE: AVERAGE TRAVEL TIME PER VEHICLE (MINUTES)	AFTER: TOTAL TRAVEL TIME PER DAY (VEHICLE-HOURS)	AFTER: AVERAGE TRAVEL TIME PER VEHICLE (MINUTES)
AM PEAK NORTHBOUND	753	13:50	569	10:27
AM PEAK SOUTHBOUND	135	7:21	152	8:18
PM PEAK** NORTHBOUND	223	8:24	372	14:01
PM PEAK** SOUTHBOUND	722	13:25	472	8:46
PEAK DIRECTIONS (AM & PM)	1475	13:37	1041	9:37
OFF-PEAK DIRECTIONS (AM & PM)	358	7:59	524	11:42
BOTH DIRECTIONS (AM & PM)	1833	11:58	1563	10:13

* AVERAGES WERE WEIGHTED BY VOLUME.
** 4:00-6:00 P.M.

TABLE 6. ANALYSIS OF DATA BY STOPPED TIME*

TIME PERIOD	BEFORE: TOTAL STOPPED TIME PER DAY (VEHICLE-HOURS)	BEFORE: AVERAGE STOPPED TIME PER VEHICLE (MINUTES)	AFTER: TOTAL STOPPED TIME PER DAY (VEHICLE-HOURS)	AFTER: TOTAL STOPPED TIME PER DAY (VEHICLE-HOURS)
AM PEAK NORTHBOUND	321	5:54	221	4:05
AM PEAK SOUTHBOUND	28	1:31	44	2:24
PM PEAK* NORTHBOUND	51	1:56	159	6:00
PM PEAK** SOUTHBOUND	347	6:27	157	2:55
PEAK DIRECTIONS (AM & PM)	668	6:10	378	3:29
OFF-PEAK DIRECTIONS (AM & PM)	79	1:45	203	4:32
BOTH DIRECTIONS (AM & PM)	747	4:53	581	3:48

* AVERAGES WERE WEIGHTED BY VOLUME.
** 4:00-6:00 P.M.

TABLE 7. ANALYSIS OF DATA BY NUMBER OF STOPS PER VEHICLE*

TIME PERIOD	BEFORE TOTAL STOPS PER DAY	BEFORE STOPS PER VEHICLE	AFTER TOTAL STOPS PER DAY	AFTER STOPS PER VEHICLE
AM PEAK NORTHBOUND	27,553	8.4	22,323	6.8
AM PEAK SOUTHBOUND	4,146	3.8	4,623	4.2
PM PEAK** NORTHBOUND	6,710	4.2	15,470	9.7
PM PEAK** SOUTHBOUND	28,370	8.8	19,539	6.0
PEAK DIRECTIONS (AM & PM)	55,923	8.6	41,562	6.4
OFF-PEAK DIRECTIONS (AM & PM)	10,856	4.0	20,093	7.5
BOTH DIRECTIONS (AM & PM)	66,779	7.3	61,955	6.8

* AVERAGES WERE WEIGHTED BY VOLUME.
** 4:00-6:00 P.M.

ACCIDENTS

Accidents were summarized for a one-year period before and after conversion to the reversible lanes. The number of accidents during the AM and PM peak periods as well as all accidents for the one-year periods were compared. Separate analyses of the accidents were based on severity, type, location, and direction.

The before-and-after accident summaries are given in Table 8. The number of accidents during the first year of operation of the reversible lanes increased by 11 percent compared to the year before. This resulted from an increase during the PM peak. The number of accidents during the AM peak decreased. There were many more accidents during the PM compared to the AM. However, there was also an 11 percent increase in accidents during off-peak times and an overall increase in all accidents of 11 percent. The fact the increase in accidents during reversible-lane operation was identical to the increase during other times indicates the reversible lanes did not generate a significant number of accidents.

Accident severity was compared as shown in Table 9. There were no fatal accidents during the "before" or "after" periods. There were identical numbers of incapacitating (Type A) and non-incapacitating (Type B) accidents in the "before" and "after" periods during peak conditions. A severity index was used to compare the data (2). As the severity index increases, accident severity increases. The severity indexes in the AM and PM peaks "before" (1.73) was almost identical to the "after" period (1.72). There was a slight decrease in the severity index during the AM peak (from 1.82 to 1.62) and a slight increase during the PM peak (from 1.67 to 1.75). There was also a slight increase in the severity index during off-peak conditions (from 1.71 to 1.90). Low speeds resulted in low accident severities during both study periods, and the reversible lanes did not result in any increase in accident severity.

An analysis of the before and after accidents by type is given in Table 10. The number of rear-end and opposite-direction sideswipe or head-on accidents increased during operation of the reversible lanes. The opposite-direction sideswipe or head-on accidents were not severe. Of the five accidents of this type, four involved no injury, and the other involved one "possible" (Type C) injury. There were no severe head-on collisions as a result of a driver not understanding the reversible-lane system. Most injury accidents (10 of 12 A- or B-injury accidents) were angle accidents. Most of these involved a vehicle turning left from Nicholasville Road into the path of an oncoming vehicle.

A comparison of before-and-after accidents by location is given in Table 11. Accidents were identified by either the cross-street intersection at which it occurred or by the two cross-streets on either side of the accident. Large increases in accidents during the PM peak were noted at two locations, and the major contributing factors in these accidents were determined. One high-accident location was between Cooper Drive and Arcadia Park. A large number of accidents occurred at this location when drivers attempted to turn left onto Nicholasville Road from a sidestreet and collided with a vehicle in the left-turn lane. During the PM peak, vehicles back up from Cooper Drive in the off-peak direction. A driver in this line of cars would allow a vehicle to turn left from a sideroad. The left-turning vehicle would then collide with a vehicle proceeding in the off-peak direction in the left-turn lane. This illustrates a problem caused when a driver desiring to make a left-turn moved into the left-turn lane a long distance ahead of the left-turn location. The motive, of course, is to avoid the delay in the off-peak direction. Another high-accident location was in the Malibu and Moore Drive vicinity. This portion of Nicholasville Road has a large number of access points to commercial businesses. A large number of angle-type accidents resulted when drivers attempted to turn left into a driveway across the three opposing lanes of traffic.

A summary of accidents during peak periods, by direction, is given in Table

TABLE 8. BEFORE AND AFTER ACCIDENT SUMMARIES

	NUMBER OF ACCIDENTS				
	AM PEAK*	PM PEAK**	PEAK PERIODS TOTAL	OFF-PEAK	TOTAL
ONE-YEAR BEFORE	37	74	111	249	360
ONE-YEAR AFTER	30	93	123	276	399

* MONDAY THROUGH FRIDAY, 7:00 A.M.-9:00 A.M.
** MONDAY THROUGH FRIDAY, 4:00 P.M.-6:00 P.M.

TABLE 9. ACCIDENT SEVERITY SUMMARY

	NUMBER OF ACCIDENTS							
	AM PEAK		PM PEAK		OFF-PEAK		TOTAL	
ACCIDENT TYPE*	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
PDO	27	25	59	70	202	210	288	305
A	1	1	2	2	10	14	13	17
B	6	1	3	8	15	23	24	32
C	3	3	10	13	22	29	35	45
F	0	0	0	0	0	0	0	0

* ACCIDENT IS CLASSIFIED ACCORDING TO MOST SEVERE INJURY WHICH OCCURRED. PDO-NO INJURY, A-INCAPACITATING INJURY, B-NON-INCAPACITATING INJURY, C-POSSIBLE INJURY, F-FATALITY.

TABLE 10. SUMMARY OF ACCIDENTS BY ACCIDENT TYPE

ACCIDENT TYPE	NUMBER OF ACCIDENTS							
	AM PEAK		PM PEAK		OFF-PEAK		TOTAL	
	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
ANGLE	9	7	33	37	109	117	151	161
REAR-END	18	18	27	37	84	100	129	155
SAME DIRECTION SIDESWIPE	7	4	11	13	42	42	60	59
FIXED OBJECT OR SINGLE VEHICLE	1	0	1	1	11	7	13	8
PEDESTRIAN	2	0	1	0	1	3	4	3
OPPOSITE DIRECTION SIDESWIPE OR HEAD-ON	0	1	0	5	1	5	1	11
BICYCLE	0	0	1	0	1	2	2	2

TABLE 11. ACCIDENT SUMMARIES BY LOCATION

LOCATION	NUMBER OF ACCIDENTS							
	AM PEAK		PM PEAK		OFF-PEAK		TOTAL	
	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
ROSE*	4	0	1	0	4	2	9	2
ROSE-COOPER**	0	3	7	2	12	11	19	16
COOPER	1	6	1	1	16	23	18	30
COOPER-ARCADIA	11	4	7	15	18	31	36	50
ARCADIA	2	1	0	3	4	4	6	8
ARCADIA-ROSEMONT	4	1	2	5	27	28	33	34
ROSEMONT	0	0	3	1	8	5	11	6
ROSEMONT-SOUTHLAND	4	3	4	10	14	28	22	41
SOUTHLAND	1	1	3	2	14	14	18	17
SOUTHLAND-ZANDALE	1	0	1	2	13	9	15	11
ZANDALE	0	1	0	6	5	9	5	16
ZANDALE-MALABU	3	1	8	3	25	22	36	26
MALABU	2	2	6	4	20	12	28	18
MALABU-MOORE	1	3	14	22	35	37	50	62
MOORE	0	2	6	12	5	18	11	32
MOORE-NEW CIRCLE	0	2	6	5	11	13	17	20
NEW CIRCLE	3	0	5	0	18	10	26	10

* ACCIDENT OCCURRED AT INTERSECTION WITH GIVEN STREET.
** ACCIDENT OCCURRED BETWEEN GIVEN STREETS.

12. The largest increase in accidents occurred in the peak direction.

It was possible that the reversible-lane system could be confusing to non-local drivers, causing an increase in accidents involving these drivers in the "after" period. However, the percentage of accidents involving a non-local driver was almost identical in the "before" and "after" periods. Accidents involving a driver from outside Fayette County accounted for 45 percent of the accidents in both the "before" and "after" periods. Including adjacent counties with Fayette County reduced the percentage of non-local drivers to 24 percent in the "before" period compared to 25 percent in the after period.

ECONOMIC ANALYSIS

Another output from the "Runcost" program was the cost per vehicle to drive the reversible-lane section. The cost consisted of operating and time cost. Time costs made up the largest portion of the total and was responsible for the reduction in cost. The summary of the tachograph data given in APPENDIX B showed there was only a very small change in operating costs. The change in total cost per vehicle is given in Table 13. Data were summarized in 30-minute time intervals. There was a reduction in costs in the peak direction (except from 6:00-6:30 p.m.) and an increase in the off-peak direction. During the AM peak, the increases in costs in the off-peak direction were relatively small compared to the decreases in the peak direction. However, during the PM peak, the increases in costs in the off-peak direction were substantial and even larger than the decreases in the peak direction in some instances.

Multiplying the cost per vehicle by the volume yielded the total user cost for all vehicles within a given time period. The change in cost by direction and the net change in cost are given in Table 14. There was a decrease in total cost during each portion of the AM peak -- the largest decrease occurred between 7:30 and 8:00 a.m. This period had a larger decrease than any PM peak period. There was a decrease in total cost during the PM peak from 4:00 to 5:30 p.m., but there was an increase in total cost between 5:30 to 6:30 p.m. The largest PM cost decrease occurred between 4:30 to 5:30 p.m.

The cost savings for the entire AM and PM peak periods were summarized and converted to yearly savings (Table 15). It was assumed the system would operate five days a week for 52 weeks (260 days). The total savings during the AM peak (7:00-9:00 a.m.) was about $175,000, and the savings during the PM peak operation (4:00-6:00 p.m.) was about $154,000; this gave a total savings of $329,000 per year.

A benefit-cost ratio could be calculated if costs were summarized annually. A summary of the cost analysis is given in Table 16. The initial project cost was $250,000. Assuming a project life of 20 years and an interest rate of 10 percent gave a uniform annual cost of $40,750. An annual maintenance cost of $2,500 was assumed. The additional annual accident cost was estimated using the one-year before-and-after accident analysis and 1978 estimates of the costs of motor-vehicle accidents given by the National Safety Council (3). The costs of the injuries by severity was used. Since most accidents were property-damage-only and most injuries were classified as Type C, the additional cost was not large. A comparison of the cost of the one year of "before" and "after" accidents yielded an additional cost of $9,350 in the year afterwards. Adding the uniform annual installation cost, annual maintenance cost, and annual accident cost resulted in a total annual cost of $47,600.

A summary of the benefit-cost analysis is given in Table 17. Considering current operating times when determining benefits resulted in a benefit-cost ratio of 6.90. Changing the evening cutoff to 5:30 p.m. would increase the benefit-cost ratio to 7.12. However, the volume at 5:30 p.m. is higher; this would make the transition period more difficult.

SPEEDS

Another output from the tachograph was the average speed over the reversible-

TABLE 12. SUMMARY OF ACCIDENTS DURING PEAK PERIODS BY DIRECTION

	NUMBER OF ACCIDENTS															
	TIME OF DAY															
	AM PEAK								PM PEAK							
	7:00-7:30		7:31-8:00		8:01-8:30		8:31-9:00		4:00-4:30		4:31-5:00		5:01-5:30		5:31-6:00	
DIRECTION*	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER
NORTHBOUND	1	3	8	8	5	6	5	3	8	9	6	9	8	6	1	5
SOUTHBOUND	2	1	7	1	3	3	2	2	7	15	6	15	21	13	4	10
NORTHBOUND & SOUTHBOUND	2	0	1	1	1	0	0	0	0	2	3	1	6	1	2	3
SIDE STREET**	0	1	0	0	0	0	0	1	2	0	0	1	0	2	0	1

* REFERS TO THE VEHICLE TRAVELING ON NICHOLASVILLE ROAD IF CROSS-STREET TRAFFIC IS INVOLVED. REFERS TO VEHICLE PROCEEDING STRAIGHT AHEAD IF ONE VEHICLE TURNS INTO THE PATH OF ANOTHER.

** ONLY SIDE STREET VEHICLES INVOLVED.

TABLE 13. CHANGE IN TOTAL COST PER VEHICLE AFTER INSTALLATION OF REVERSIBLE LANES

	TIME PERIOD	TOTAL COST PER VEHICLE (CENTS) SOUTHBOUND BEFORE	SOUTHBOUND AFTER	SOUTHBOUND CHANGE	NORTHBOUND BEFORE	NORTHBOUND AFTER	NORTHBOUND CHANGE
AM PEAK	7:00-7:30	86.81	88.84	+2.03	121.69	119.63	-2.06
	7:30-8:00	85.82	98.12	+12.30	178.89	138.02	-40.87
	8:00-8:30	81.33	100.97	+19.64	124.90	101.69	-23.21
	8:30-9:00	98.78	108.69	+9.91	115.07	91.61	-23.46
PM PEAK	4:00-4:30	133.46	100.62	-32.84	104.81	144.95	+40.14
	4:30-5:00	140.33	99.36	-40.97	106.91	137.42	+30.51
	5:00-5:30	165.76	108.11	-57.65	103.38	149.10	+50.70
	5:30-6:00	116.00	93.81	-22.19	93.10	139.84	+46.74
	6:00-6:30	76.41	81.62	+2.21	92.50	123.66	+31.16

TABLE 14. CHANGE IN TOTAL COSTS AFTER INSTALLATION OF REVERSIBLE LANES

	TIME PERIOD	CHANGE IN TOTAL USER COSTS (DOLLARS PER DAY) NB	SB	NET
AM PEAK	7:00-7:30	+5.32	-15.94	-10.62
	7:30-8:00	+48.22	-455.29	-407.07
	8:00-8:30	+45.37	-175.93	-130.56
	8:30-9:00	+21.11	-145.69	-124.58
PM PEAK	4:00-4:30	-306.73	+158.56	-148.17
	4:30-5:00	-398.64	+120.51	-278.13
	5:00-5:30	-427.19	+223.00	-204.11
	5:30-6:00	-129.15	+168.26	+39.11
	6:00-6:30	+11.96	+117.78	+129.74

TABLE 15. TOTAL DELAY SAVINGS PER DAY AND YEAR

TIME PERIOD	SAVINGS PER DAY VEHICLE-HOURS	SAVINGS PER DAY COST (DOLLARS)	COST SAVINGS PER YEAR (DOLLARS)
7:00-9:00 A.M.	165	673	174,980
4:00-6:30 P.M.	99	462	120,120
4:00-6:00 P.M.	115	591	153,660
4:00-5:30 P.M.	126	630	163,800

TABLE 16. COST ANALYSIS

INITIAL PROJECT COST	$250,000
PROJECT LIFE	20 YEARS
INTEREST RATE	10 PERCENT
CAPITAL RECOVERY FACTOR	0.163
UNIFORM ANNUAL COST	$40,750
ANNUAL MAINTENANCE COST	$2,500
ANNUAL ACCIDENT COST	$4,350
TOTAL ANNUAL COST	$47,600

TABLE 17. BENEFIT-COST ANALYSIS

OPERATING HOURS	ANNUAL BENEFITS	ANNUAL COSTS	BENEFIT-COST RATIO
7:00-9:00 A.M. 4:00-6:30 P.M.	$295,100	$47,600	6.20
7:00-9:00 A.M.* 4:00-6:00 P.M.	$328,640	$47,600	6.90
7:00-9:00 A.M. 4:30-5:30 P.M.	$338,780	$47,600	7.12

* CURRENT OPERATING TIME

lane section. The average speeds over the AM and PM peak periods are given in Table 18. During the AM peak, the average speed in the peak direction increased from 15.1 mph (6.7 m/s) to 18.7 mph (8.4 m/s); the average speed in the off-peak direction decreased from 21.7 mph (9 .7 m/s) to 19.5 mph (8.7 m/s). The change in speeds during the PM peak was much greater. In the peak direction (southbound), the average speeds increased from 13.2 mph (5.9 m/s) to 19.2 mph (8.6 m/s); however, there was a large decrease in speeds from 22.1 mph (9.9 m/s) to 13.7 mph (6.1 m/s) in the off-peak direction.

Speeds were compared to a warrant that calls for a reversible-lane system when there is a reduction in average speed of at least 25 percent in the congested time compared to normal time (1). A 25-percent reduction in the southbound, off-peak speed yielded a speed of 17.3 mph (7.3 m/s). The "before" peak-period (PM) southbound speed was 13.2 mph (5.9 m/s), which met the speed warrant. A 25-percent reduction in the northbound, off-peak speed yielded a speed of 15.9 mph (7.1 m/s). The "before" peak-period (AM) northbound speed was 15.1 mph (6.7 m/s), which just met the speed warrant.

Using speed data taken before the conversion to reversible lanes, peak and off-peak speeds were compared (Table 19). The average, northbound speed during the heaviest volumes of the AM peak (7:30-8:00 a.m.) was compared to the northbound, off-peak speed. There was about a 50-percent reduction in speed during the peak period. Also, a reduction of slightly over 50 percent was observed when the average, southbound speed during peak conditions (4:30-5:30 p.m.) was compared to the southbound, off-peak speed. Level of service has been related directly to speed (4). In both cases (northbound and southbound), the corresponding level of service was F (forced flow) during the peak period and C (stable flow, acceptable delay) during the off-peak period. Comparisons between speeds in the peak and off-peak direction during the same time period are possible from Table 20. In both AM and PM periods, the level of service was F in the peak direction and C in the off-peak direction. Also, in both cases, the speed in the peak direction was slightly under one-half the speed in the off-peak direction.

TRAFFIC CONFLICTS

A traffic conflict occurs when a driver commits a violation or makes an evasive action such as braking to avoid colliding with another vehicle or a pedestrian. Types and frequencies of traffic conflicts are measures of accident potential and operational problems. A previous research report described the traffic conflicts procedure used here (5). A summary of the conflict counts is given in Table 21. Data were collected at six of the signalized intersections.

At each intersection, counts were made on both Nicholasville Road approaches during AM and PM peak periods. The total number of conflicts and the conflict rate decreased slightly in the "after" period because of a reduction in congestion-type conflicts. Congestion conflicts accounted for the majority (69 percent). A congestion-type conflict occurs when a vehicle approaches an intersection on a green light and must slow or stop due to a queue of vehicles at the intersection. A maximum of one congestion conflict is counted per lane during the green phase. Because the number of lanes was reduced in the off-peak direction, the number of possible congestion-type conflicts, therefore, was reduced by one-half. The addition of a lane increased the number of possible congestion conflicts in the peak direction, but the improvement in traffic flow counterbalanced this increase. While the total number of congestion-type conflicts decreased in the off-peak direction, the number of conflicts per lane increased by over 40 percent. In the peak direction, the number of congestion conflicts per lane decreased by over 30 percent. There was only a small change in the number of other conflict types. The total intersection conflict rate decreased in the peak direction and increased slightly in the off-peak direction. There was only a small increase in the number of accidents after conversion to reversible lanes. Considering both peak periods, the

TABLE 18. AVERAGE SPEEDS BEFORE AND AFTER REVERSIBLE LANES

DIRECTION	AVERAGE SPEED (MPH)(M/S) AM PEAK BEFORE	AM PEAK AFTER	PM PEAK BEFORE	PM PEAK AFTER	OFF-PEAK	SPEED WARRANT*
SOUTHBOUND	21.7 (9.7)	19.5 (8.7)	13.2** (5.9)	19.2 (8.6)	23.1 (10.3)	17.3 (7.7)
NORTHBOUND	15.1** (6.7)	18.7 (8.4)	22.1 (9.9)	13.7 (6.1)	21.2 (9.5)	15.9 (7.1)

* ONE WARRANT FOR REVERSIBLE LANE SYSTEM IS A REDUCTION IN AVERAGE SPEED OF AT LEAST 25 PERCENT IN THE CONGESTED TIME PERIOD COMPARED TO NORMAL TIME PERIODS.

** PEAK DIRECTION.

TABLE 19. COMPARISON IN PEAK AND OFF-PEAK SPEEDS*

	NORTHBOUND 7:30-8:00 A.M.		NORTHBOUND OFF-PEAK		PERCENT REDUCTION IN SPEED**	SOUTHBOUND 4:30-5:30 P.M.		SOUTHBOUND OFF-PEAK		PERCENT REDUCTION IN SPEED**
	AVERAGE SPEED (MPH)(M/S)	LEVEL OF SERVICE	AVERAGE SPEED (MPH)(M/S)	LEVEL OF SERVICE		AVERAGE SPEED (MPH)(M/S)	LEVEL OF SERVICE	AVERAGE SPEED (MPH)(M/S)	LEVEL OF SERVICE	
NICHOLASVILLE ROAD	10.0 (4.5)	F	21.2 (9.5)	C	53	10.6 (4.7)	F	23.1 (10.3)	C	54
HARRODSBURG ROAD	24.0 (10.7)	C	30.1 (13.4)	A	20	21.2 (9.5)	C	31.1 (13.9)	A	32
TATES CREEK ROAD	23.6 (10.5)	C	35.8 (16.0)	A	34	26.4 (11.8)	B	37.0 (16.5)	A	29

* USING "AFTER" DATA FOR HARRODSBURG AND TATES CREEK ROADS AND "BEFORE" DATA FOR NICHOLASVILLE ROAD.

** PERCENT REDUCTION IN OFF-PEAK SPEED COMPARED TO PEAK DIRECTIONS.

TABLE 20. DIFFERENCE IN SPEEDS BY DIRECTION DURING PEAK CONDITION*

TIME PERIOD		NORTHBOUND (PEAK DIRECTION) AVERAGE SPEED (MPH)(M/S)	NORTHBOUND (PEAK DIRECTION) LEVEL OF SERVICE	SOUTHBOUND (OFF-PEAK DIRECTION) AVERAGE SPEED (MPH)(M/S)	SOUTHBOUND (OFF-PEAK DIRECTION) LEVEL OF SERVICE	PERCENT REDUCTION IN SPEED
AM	NICHOLASVILLE RD.	10.0 (4.5)	F	22.0 (9.8)	C	55
(7:30-8:00)	HARRODSBURG RD.	24.0 (10.7)	C	33.0 (14.8)	A	27
	TATES CREEK RD.	23.6 (10.5)	C	30.3 (13.5)	A	22

TIME PERIOD		SOUTHBOUND (PEAK DIRECTION) AVERAGE SPEED (MPH)(M/S)	SOUTHBOUND (PEAK DIRECTION) LEVEL OF SERVICE	NORTHBOUND (OFF-PEAK DIRECTION) AVERAGE SPEED (MPH)(M/S)	NORTHBOUND (OFF-PEAK DIRECTION) LEVEL OF SERVICE	PERCENT REDUCTION IN SPEED
PM	NICHOLASVILLE RD.	10.6 (4.7)	F	21.6 (9.6)	C	51
(4:30-5:30)	HARRODSBURG RD.	21.2 (9.5)	C	26.1 (11.7)	B	19
	TATES CREEK RD.	26.4 (11.8)	B	29.5 (13.2)	B	11

* USING "AFTER" DATA FOR HARRODSBURG AND TATES CREEK ROADS AND "BEFORE" DATA FOR NICHOLASVILLE ROAD.

TABLE 21. SUMMARY OF INTERSECTION TRAFFIC CONFLICT COUNTS

TIME PERIOD	DIRECTION	NUMBER OF CONFLICTS: CONGESTION BEFORE	CONGESTION AFTER	ALL OTHER BEFORE	ALL OTHER AFTER	TOTAL BEFORE	TOTAL AFTER	TOTAL CONFLICT RATE (CONFLICTS PER INTERSECTION PER 100 VEHICLES) BEFORE	AFTER
AM PEAK	NORTHBOUND*	351	378	97	65	448	443	5.01	3.99
	SOUTHBOUND	107	115	80	110	187	225	4.28	6.02
	BOTH	458	493	177	175	635	668	4.70	4.15
PM PEAK	NORTHBOUND	329	197	139	124	468	329	7.20	6.57
	SOUTHBOUND*	462	431	220	230	682	661	7.60	6.43
	BOTH	791	628	359	354	1150	990	7.43	6.47
BOTH PEAK PERIODS	NORTHBOUND	680	509	236	189	916	725	5.85	4.46
	SOUTHBOUND	569	546	300	340	869	886	6.51	6.32
	BOTH	1249	1121	536	529	1785	1650	6.16	5.45
BOTH PEAK PERIODS	PEAK	813	809	317	295	1130	1104	6.24	5.13
	OFF-PEAK	436	312	219	234	655	554	6.02	6.33

* PEAK DIRECTIONS

number of accidents at intersections increased from 38 in the year before to 42 in the year after. Therefore, it can be presumed that there should not be a large increase in intersection-related conflicts.

Two problem areas where special types of data were taken were at each end of the reversible-lane section where three lanes had to be reduced to two in the peak direction. The reversible-lane section stops at an intersection at both ends. A diagram of the northern end is shown in Figure 13. During AM peak operation, traffic in Lane A is required to turn right onto Rose Street. Lane B traffic must go then into Lane 1. This requires a slight merge to the right. Lane C traffic must move into Lane 2. A problem arose because some traffic in Lane A moved into Lane 1 instead of turning right as required. Also, a large percentage of traffic in Lane B went into Lane 2 rather than Lane 1, creating a problem because traffic in Lane C had to go into Lane 2. This location was a source of numerous motorist's complaints. Data taken less than a month after installation of the reversible lanes found 12 percent of the traffic in Lane A going straight instead of right and 41 percent of the traffic in Lane B going into Lane 2 instead of Lane 1. These percentages were reduced to 6 and 32 percent, respectively, less than two months later. Additional signing (Figure 14a) was installed to clarify the lane assignments. These signs were controlled so that they are visible only during AM operation. Figure 14b is a photograph of the signs in a closed position. After one year, the percentage of traffic in Lane A not turning right had dropped to 5 percent and the percentage of traffic in Lane B going into Lane 2 had dropped to 21 percent. Even though there were numerous conflicts at this location, no accidents were reported in the one-year "after" period. Apparently, drivers were familar with the location and exercised caution.

A diagram of the southern end of the section is given in Figure 15. A blank-out sign was placed above Lane A, stating that the lane ends. Data taken during one PM period a few weeks after installation showed over 200 vehicles in Lane A after going past Moore Drive, and 20 percent of those vehicles caused a traffic conflict when they merged into Lane B. Data taken one year after installation showed less than 50 vehicles trapped in Lane A.

There has been confusion among some motorists concerning proper lane use during reversible-lane conditions. Specifically, some drivers in the peak direction would turn left from the middle lane. This lane is a left-turn lane the rest of the day but a through lane for the peak direction during operation of the reversible lanes. This caused rear-end and weave conflicts and resulted in some accidents. Another potential accident problem involved a misunderstanding of the flashing yellow "x." Some motorists in the off-peak direction during reversible-lane operation would treat the left-turn lane as a through lane, as it was the remainder of the day. This creates the potential for a severe head-on collision. To alleviate these problems, ground-mounted signing was installed partially explaining the lane-use signals. A photograph of the signing is shown in Figure 16. After observation of the traffic, a decision on whether additional signing is necessary will be made.

FUEL CONSUMPTION

Multiplying fuel consumption (gallons) per vehicle from the "Runcost" program by traffic volume gave the total gallons consumed. A summary of fuel consumption before and after installation of convertible lanes is given in Table 22. There were minor changes in fuel consumption. This agreed with the finding that the reduction in cost after the reversible lanes were installed was a result of a reduction in time cost. Operating costs changed very little.

ENVIRONMENTAL FACTORS

The environmental factors considered were changes in traffic noise and air pollution. Recordings were made to evaluate changes in noise levels. Output from the "Runcost" program was used to evaluate changes in air pollution.

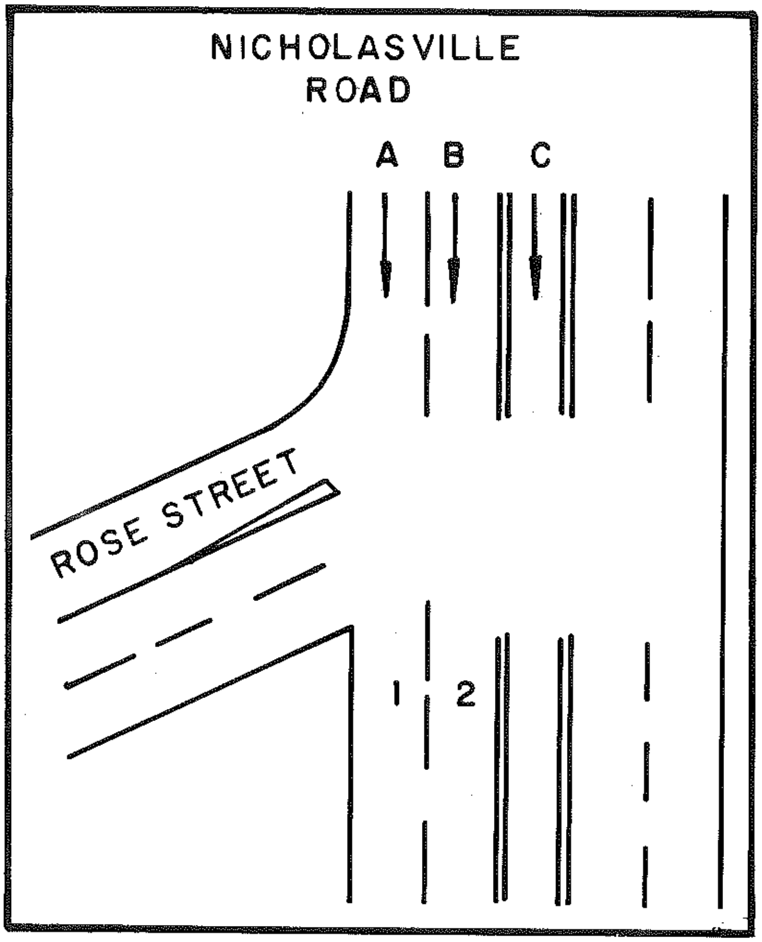

Figure 13. Diagram of North End of Reversible-Lane Section.

Figure 14a. Signing Added to North End of Reversible-Lane Section; Sign in AM Peak Position.

Figure 16. Regulatory Sign Explaining Lane-Assignment Signals.

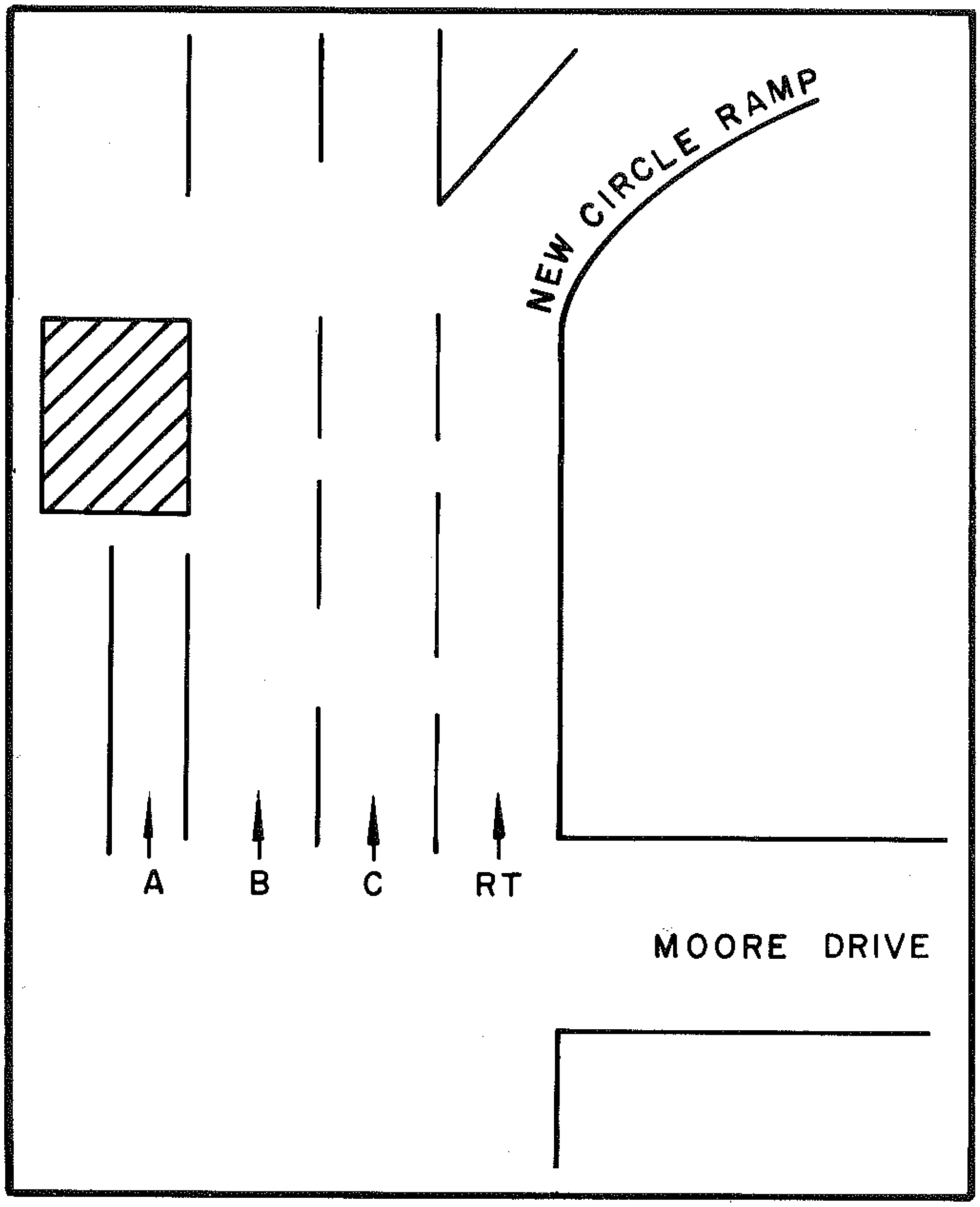

Figure 15. Diagram of South End of Reversible-Lane Section.

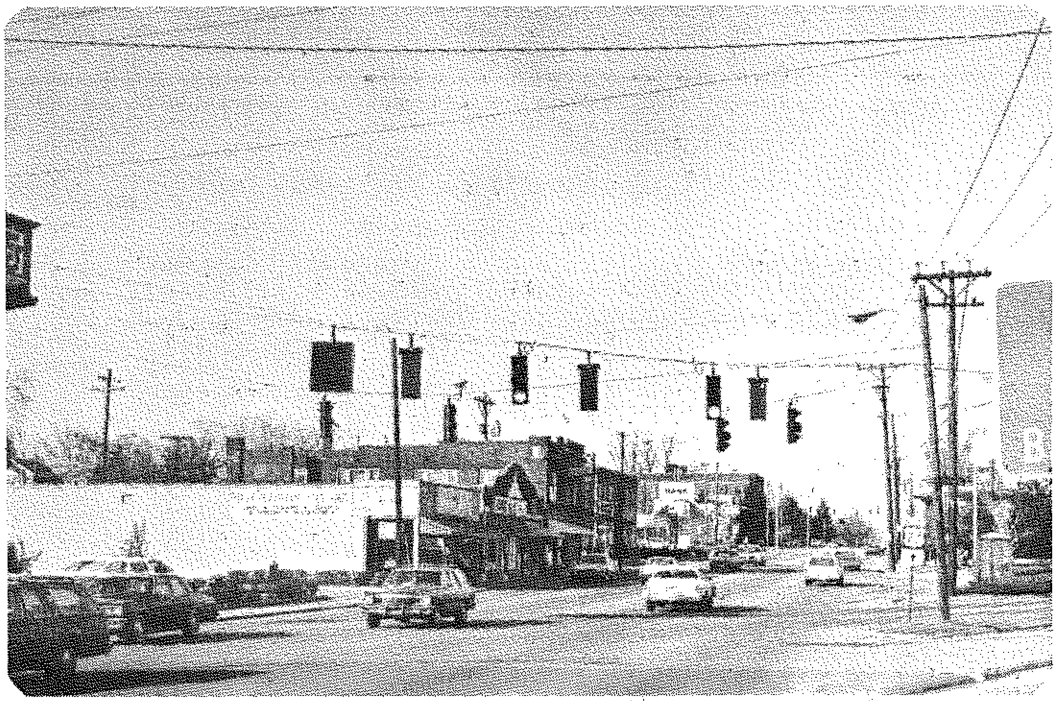

Figure 14b. Signing Added to North End of Reversible-Lane Section; Sign in Closed Position.

TABLE 22. FUEL CONSUMPTION BEFORE AND AFTER INSTALLATION OF REVERSIBLE LANES*

TIME PERIOD		FUEL CONSUMPTION (GALLONS) (LITERS) BEFORE	AFTER	CHANGE	PERCENT CHANGE
AM PEAK	7:00-9:00	267,445 (1,012,279)	270,354 (1,023,290)	+2,909 (+11,011)	+1.1
PM PEAK	4:00-5:30	240,302 (909,543)	236,245 (894,187)	-4,057 (-15,356)	-1.7
	4:00-6:00	292,268 (1,106,234)	291,450 (1,103,138)	-818 (-3,058)	-0.3
	4:00-6:30	336,192 (1,272,487)	343,953 (1,301,862)	+7,761 (+29,375)	+2.3
AM AND PM PEAK PERIODS	7:00-9:00 AM 4:00-5:30 PM	507,747 (1,921,822)	506,599 (1,917,477)	-1,148 (-4,345)	-0.2
	7:00-9:00 AM 4:00-6:00 PM	559,713 (2,118,514)	561,804 (2,126,428)	+2,091 (+7,914)	+0.4
	7:00-9:00 AM 4:00-6:30 PM	603,637 (2,284,766)	614,307 (2,325,152)	+10,670 (+40,386)	+1.8

* FUEL CONSUMPTION WAS CALCULATED FOR A ONE YEAR PERIOD BEFORE AND AFTER INSTALLATION OF THE REVERSIBLE LANES.

"Before" and "after" noise recordings were made at four locations during the AM and PM peak periods. Data were analyzed according to methods developed earlier (6). The average L10 and Leq noise levels were determined. The L10 noise level is the noise level exceeded 10 percent of the time and is the basis of federal noise standards. The term Leq refers to the noise equivalent level and is used frequently in describing traffic noise. Noise measurements were made at the same locations and times before and after the installation. Results of the noise analysis are summarized in Table 23. Each value given represents the average of eight 10-minute recordings. Both the L10 and Leq levels showed no significant change due to installation of reversible lanes.

Pollutants emitted per vehicle is an output from the "Runcost" program. A summary is given in APPENDIX B. Using these data, along with volumes, enabled a calculation of air pollutants per year based on pollutant rates. A summary of the results is given in Table 24. Total pollutants per year decreased during the after period. This resulted from the decrease in congestion. During the AM peak, total pollutants were found to have decreased by about 40,000 pounds (18,100 kg) per year. The decrease in carbon monoxide accounted for most of the decrease. There was a much smaller level of pollution from hydrocarbons. Although the percent decrease for hydrocarbons was higher than for carbon monoxide, the reduction in pounds was much less. There was no change in the nitrogen oxides. During the PM peak, there was a reduction in pollution of about 46,000 pounds (20,900 kg) for the period from 4:00 to 5:30 p.m. The reduction was less (34,000 pounds (15,400 kg)) for the period from 4:00 to 6:00 p.m. There was a very slight decrease in pollutants when the analysis period was extended to 6:30 p.m. Considering the actual time of operation during the "after" period (7:00-9:00 a.m. and 4:00-6:00 p.m.), there was a yearly decrease in pollutants of approximately 74,000 pounds (33,600 kg).

EFFECT ON OTHER STREETS

For the reversible lanes to be effective, it was necessary that traffic be diverted to and from adjacent arterials. As shown in Figure 1, there are major, parallel arterials on either side of Nicholasville Road. Tachograph data taken on both of these arterials (Harrodsburg Road and Tates Creek Pike) before and after installation of the reversible lanes are plotted in APPENDIX D. A summary of average travel times and cost per vehicle for Harrodsburg Road is shown in Table 25. The "after" data showed a large reduction in travel time in the AM peak in the peak direction. The largest decrease in delay occurred from 7:30 to 8:00 a.m. and corresponded to decreases on Nicholasville Road. There was a smaller decrease in delay during the PM peak in the peak direction. The reduction in delay and the resultant reduction in time cost on Harrodsburg Road may be attributed to the diversion of some peak-direction traffic to Nicholasville Road. Data showed an insignificant change in average travel time and cost on Tates Creek Pike (Table 26).

Average speeds on these parallel arterials were also analyzed (Tables 27 and 28). The only major change in speeds was a 6 mph (2.7 m/s) increase in average speed on Harrodsburg Road during the am peak in the peak direction (northbound). Comparison of the "after" speeds with the reversible-lanes speed warrant (a 25-percent reduction compared to the off-peak speed) showed that, generally, the speeds were close to or above the speed warrant. Tables 19 and 20 compare conditions on Nicholasville Road before the reversible lanes were installed and conditions existing on Harrodsburg Road and Tates Creek Pike after installation of the reversible lanes. Speeds during the high-volume AM and PM periods indicated a level of service F (forced flow) existed in the peak direction on Nicholasville Road. In comparison, speeds in the peak direction on Harrodsburg Road indicated level of service C (stable flow, acceptable delay). Speeds in the peak direction on Tates Creek Pike indicated levels of service C and B (stable flow,

TABLE 23. TRAFFIC STREAM NOISE LEVELS BEFORE AND AFTER INSTALLATION OF REVERSIBLE LANES

	AVERAGE NOISE LEVEL (DBA)	
	L10	LEQ
BEFORE	69.6	67.1
AFTER	69.1	66.4

TABLE 24. AIR POLLUTANTS BEFORE AND AFTER INSTALLATION OF REVERSIBLE LANES

	POLLUTANT												TOTAL POLLUTANTS			
	NITROGEN OXIDES				HYDROCARBONS				CARBON MONOXIDE							
	POUNDS (KILOGRAMS)				POUNDS (KILOGRAMS)				POUNDS (KILOGRAMS)				POUNDS (KILOGRAMS)			
TIME PERIOD	BEFORE	AFTER	DECREASE	PERCENT DECREASE	BEFORE	AFTER	DECREASE	PERCENT DECREASE	BEFORE	AFTER	DECREASE	PERCENT DECREASE	BEFORE	AFTER	DECREASE	PERCENT DECREASE
AM PEAK 7:00-9:00	30,738 (13,943)	30,738 (13,943)	0 (0)	0	4,053 (1,838)	3,535 (1,603)	518 (235)	13	401,206 (181,987)	361,843 (164,132)	39,363 (17,855)	10	435,997 (197,768)	396,116 (179,678)	39,881 (18,090)	9
PM PEAK 4:00-5:30	25,586 (11,606)	25,586 (11,606)	0 (0)	0	3,588 (1,628)	3,016 (1,368)	572 (260)	16	355,478 (161,245)	310,043 (140,636)	45,435 (20,609)	13	384,652 (174,478)	338,645 (153,609)	46,007 (20,869)	12
4:00-6:00	31,864 (14,454)	31,864 (14,454)	0 (0)	0	4,294 (1,948)	3,737 (1,695)	557 (253)	13	414,434 (187,987)	381,241 (172,931)	33,193 (15,056)	8	450,592 (204,389)	416,842 (189,080)	33,750 (15,309)	7
4:00-6:30	38,017 (17,245)	38,017 (17,245)	0 (0)	0	4,845 (2,198)	4,376 (1,985)	469 (213)	10	460,101 (208,702)	453,943 (205,909)	6,158 (2,793)	1	502,963 (228,144)	496,336 (225,138)	6,627 (3,006)	1

* AMOUNTS OF POLLUTANTS WERE CALCULATED FOR A ONE YEAR PERIOD BEFORE AND AFTER INSTALLATION OF THE REVERSIBLE LANES.

TABLE 25. AVERAGE TRAVEL TIMES AND COST PER VEHICLE ON HARRODSBURG ROAD BEFORE AND AFTER REVERSIBLE LANES

TIME PERIOD	DIRECTION*	AVERAGE TRAVEL TIME (MINUTES) BEFORE	AFTER	CHANGE	TOTAL COST PER VEHICLE (CENTS PER VEHICLE) BEFORE	AFTER	CHANGE
AM PEAK	SOUTHBOUND 7:00-9:00	5:57	6:11	+0:14	83.46	86.37	+2.91
	NORTHBOUND 7:00-9:00	9:34	6:51	-3:23	115.46	93.08	-22.38
	NORTHBOUND 7:30-8:00	13:10	7:45	-6:05	152.94	101.70	-51.24
	NORTHBOUND 8:00-8:30	7:46	6:06	-1:40	100.33	84.38	-15.95
PM PEAK	NORTHBOUND 4:00-6:00	5:57	5:33	-0:24	83.46	79.68	-3.78
	SOUTHBOUND 4:00-6:00	8:04	7:38	-1:06	103.81	94.71	-9.10
	SOUTHBOUND 4:30-5:30	8:51	8:13	-0:38	111.79	98.97	-12.82
	SOUTHBOUND 4:00-4:30 & 5:30-6:00	6:32	6:29	-0:03	87.85	86.19	-1.66

* AM PEAK DIRECTION IS NORTHBOUND AND PM PEAK DIRECTION IS SOUTHBOUND.

TABLE 26. AVERAGE TRAVEL TIMES AND COST PER VEHICLE ON TATES CREEK PIKE BEFORE AND AFTER REVERSIBLE LANES

TIME PERIOD	DIRECTION*	AVERAGE TRAVEL TIME (MINUTES) BEFORE	AFTER	CHANGE	TOTAL COST PER VEHICLE (CENTS PER VEHICLE) BEFORE	AFTER	CHANGE
AM PEAK 7:00-9:00	SOUTHBOUND	4:39	4:27	-0:12	63.36	62.38	-0.98
	NORTHBOUND	6:16	5:56	-0:20	76.56	73.57	-2.99
PM PEAK 4:00-6:00	SOUTHBOUND	5:01	5:12	+0:11	71.78	67.60	-4.16
	NORTHBOUND	4:37	4:53	+0:16	66.75	66.97	+0.22

* AM PEAK DIRECTION IS NORTHBOUND AND PM PEAK IS SOUTHBOUND.

TABLE 27. AVERAGE SPEEDS ON HARRODSBURG ROAD BEFORE AND AFTER REVERSIBLE LANES

	AVERAGE SPEED (MPH) (M/S)					SPEED
	AM PEAK		PM PEAK			WARRANT*
DIRECTION	BEFORE	AFTER	BEFORE	AFTER	OFF-PEAK	MPH(M/S)
SOUTHBOUND	29.1 (13.0)	31.1 (13.9)	22.3** (10.0)	23.1*** (10.3)	31.1 (13.9)	23.3 (10.4)
NORTHBOUND	19.1** (8.5)	25.1*** (11.2)	25.0 (11.2)	25.8 (11.5)	30.1 (13.4)	22.6 (10.1)

* ONE WARRANT FOR REVERSIBLE LANE SYSTEM IS A REDUCTION IN AVERAGE SPEED OF AT LEAST 25 PERCENT IN THE CONGESTED TIME PERIOD COMPARED TO NORMAL TIME PERIODS.

** PEAK DIRECTION

*** SPEED TO COMPARE TO SPEED WARRANT

TABLE 28. AVERAGE SPEEDS ON TATES CREEK ROAD BEFORE AND AFTER REVERSIBLE LANES

	AVERAGE SPEED (MPH) (M/S)					SPEED
	AM PEAK		PM PEAK			WARRANT*
DIRECTION	BEFORE	AFTER	BEFORE	AFTER	OFF-PEAK	MPH(M/S)
SOUTHBOUND	30.7 (13.7)	32.1 (14.3)	28.6** (12.8)	27.5*** (12.3)	37.0 (16.5)	27.8 (12.4)
NORTHBOUND	23.5** (10.5)	24.4*** (10.9)	31.0 (13.8)	29.4 (13.1)	35.8 (16.0)	26.8 (12.0)

* ONE WARRANT FOR REVERSIBLE LANE SYSTEM IS A REDUCTION IN AVERAGE SPEED OF AT LEAST 25 PERCENT IN THE CONGESTED TIME PERIOD COMPARED TO NORMAL TIME PERIODS.

** PEAK DIRECTION

*** SPEED TO COMPARE TO SPEED WARRANT

slight delay).

Other studies were made to determine if the reversible lanes changed traffic patterns on adjacent streets. Tachograph data for two major cross routes are shown in Table 29. No major changes in travel times were observed. Also, average stopped delay was determined at several sidestreet approaches at signalized intersections along Nicholasville Road (Table 30). There was a slight, but insignificant, overall increase in sidestreet delay.

SUMMARY AND CONCLUSIONS

1. The reversible-lane system has proven to be feasible and reliable during the first year of operation. The reversible lanes generated trips in the peak direction, deterred trips in the off-peak direction, and improved the directional split. During the AM peak, delays were reduced substantially in the peak direction without a large increase in delays in the off-peak direction. During PM peak operation, delays were reduced sharply in the peak direction; however, there was a large increase in delays in the off-peak direction. Total travel times were decreased during all time periods except between 5:30 to 6:30 p.m. The largest decrease occurred from 7:30 to 8:00 a.m. The largest net decrease in the PM peak occurred from 4:30 to 5:00 p.m. When all vehicles were considered in both peak periods, there was a reduction of about two minutes per vehicle in travel time and one minute in stopped time. There was only a small reduction in number of stops, which suggested additional improvements in the system could be obtained with improved signal coordination.

2. There was an overall decrease in user costs during the AM peak period. The largest decrease occurred from 7:30 to 8:00 a.m. During the PM peak, cost decreased in the 4:00-5:30 p.m. period but increased in the 5:30-6:30 period.

3. The total number of accidents during the first year of operation increased by 11 percent over the year before. The increase occurred during the PM operation. However, this increase was identical to the increase during other times. This would indicate that the reversible lanes did not generate a significant number of accidents. There was no increase in accident severity. Two types of accidents related to reversible lanes were noted. One involved drivers, desiring to make a left-turn, getting into the left-turn lane a long distance from the left-turn location. This usually occurred during PM operation in the off-peak direction in an attempt by drivers to avoid long delays. The other type involved a driver attempting to turn left into a driveway across three opposing lanes of traffic. The percentage of accidents involving non-local drivers did not increase in the "after" period.

4. Using the operating times of 7:00 to 9:00 a.m. and 4:00 to 6:00 p.m. resulted in a benefit-cost ratio of 6.90. Changing the evening cutoff to 5:30 p.m. would increase the benefit-cost ratio slightly. However, traffic volume is higher at 5:30 p.m., which probably would make the transition period more difficult.

5. Speeds increased in the peak direction during AM and PM periods. There was a large decrease in speeds in the off-peak direction during the PM period.

6. The total number of intersection conflicts was slightly less after installation of the reversible lanes, mainly due to a reduction in congestion conflicts. The total intersection conflict rate decreased in the peak direction and increased slightly in the off-peak direction. Numerous traffic conflicts were noted at each end of the reversible-lane section where one lane was dropped. However, the number of conflicts decreased with time. No accidents were reported at either end point in the one-year period after installation.

7. There were minor changes in fuel consumption due to installation of reversible lanes.

8. There was no significant change in the noise level of the traffic stream during operation of the reversible lanes.

9. Air pollutants were reduced almost 10 percent after installation of

TABLE 29. AVERAGE TIMES AND COSTS PER VEHICLE BEFORE AND AFTER REVERSIBLE LANES FOR TWO CROSS ROUTES

CROSS ROUTE	TIME PERIOD	DIRECTION	AVERAGE TRAVEL TIME (MINUTES) BEFORE	AFTER	CHANGE	TOTAL COST PER VEHICLE (CENTS PER VEHICLE) BEFORE	AFTER	CHANGE
COOPER-WALLER	AM PEAK	EASTBOUND	7:24	6:44	-0:40	84.05	72.20	-11.45
		WESTBOUND	5:57	6:06	+0:09	70.16	67.44	-2.72
	PM PEAK	EASTBOUND	6:35	7:03	+0:28	76.32	76.94	+0.62
		WESTBOUND	9:05	8:48	-0:17	98.56	91.10	-7.46
ALBANY-JESSELINE-ROSEMONT	AM PEAK	EASTBOUND	7:39	7:02	-0:37	94.41	90.03	-4.38
		WESTBOUND	9:21	8:13	-1:08	102.69	95.96	-6.73
	PM PEAK	EASTBOUND	8:34	8:15	-0:19	103.86	95.25	-8.61
		WESTBOUND	8:28	9:17	+0:49	95.40	98.59	+3.19

TABLE 30. AVERAGE SIDESTREET STOPPED DELAY AT FOUR SIGNALIZED INTERSECTIONS BEFORE AND AFTER REVERSIBLE LANES

	AVERAGE DELAY (SECONDS) BEFORE	AFTER
AM PEAK	23.1	23.6
PM PEAK	22.7	28.2

the reversible lanes. This amounted to a yearly decrease of approximately 74,000 pounds (33,600 kg).

10. An analysis of a parallel arterial (Harrodsburg Road) showed a significant reduction in travel time in the peak direction during the AM peak. Studies on another parallel arterial (Tates Creek Pike) showed no significant change in travel time. Studies on two cross routes also indicated no significant change in travel times.

11. Stopped-time delay studies on four sidestreets showed a slight, but insignificant, increase in delays after installation of the reversible lanes.

12. Data on Harrodsburg Road and Tates Creek Pike showed the level of service in the peak direction during AM and PM conditions is much higher than the level of service which existed on Nicholasville Road before installation of the reversible lanes. The volumes, delay, and speed data taken on those roads indicated reversible lanes were not warranted.

RECOMMENDATIONS

The reversible-lane system installed on Nicholasville Road has proven to be successful and merits continuation. The existing traffic control devices are performing well and have been reliable. However, data indicate an additional improvement in the system could be obtained with improved signal coordination. An effort should be made to improve public understanding of this type of signal system. Additional signing explaining the lane-use signals may be necessary. Another means of improving public awareness could be through a public information television spot sponsored by the Office of Highway Safety Programs. Consideration should be given to changing the PM peak cutoff time to 5:30 p.m. Additional efforts should be made to encourage motorists traveling the off-peak direction to use alternate routes, particularly during the PM peak.

Data from Harrodsburg Road and Tates Creek Pike taken after installation of the reversible lanes showed a higher level of service compared to Nicholasville Road before the reversible lanes were installed. Operating conditions on these routes do not warrant installation of reversible lanes. Also, these two routes provide alternate routes to Nicholasville Road in the off-peak direction during reversible lane operation.

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APPENDIX A

INSTALLATION PLANS

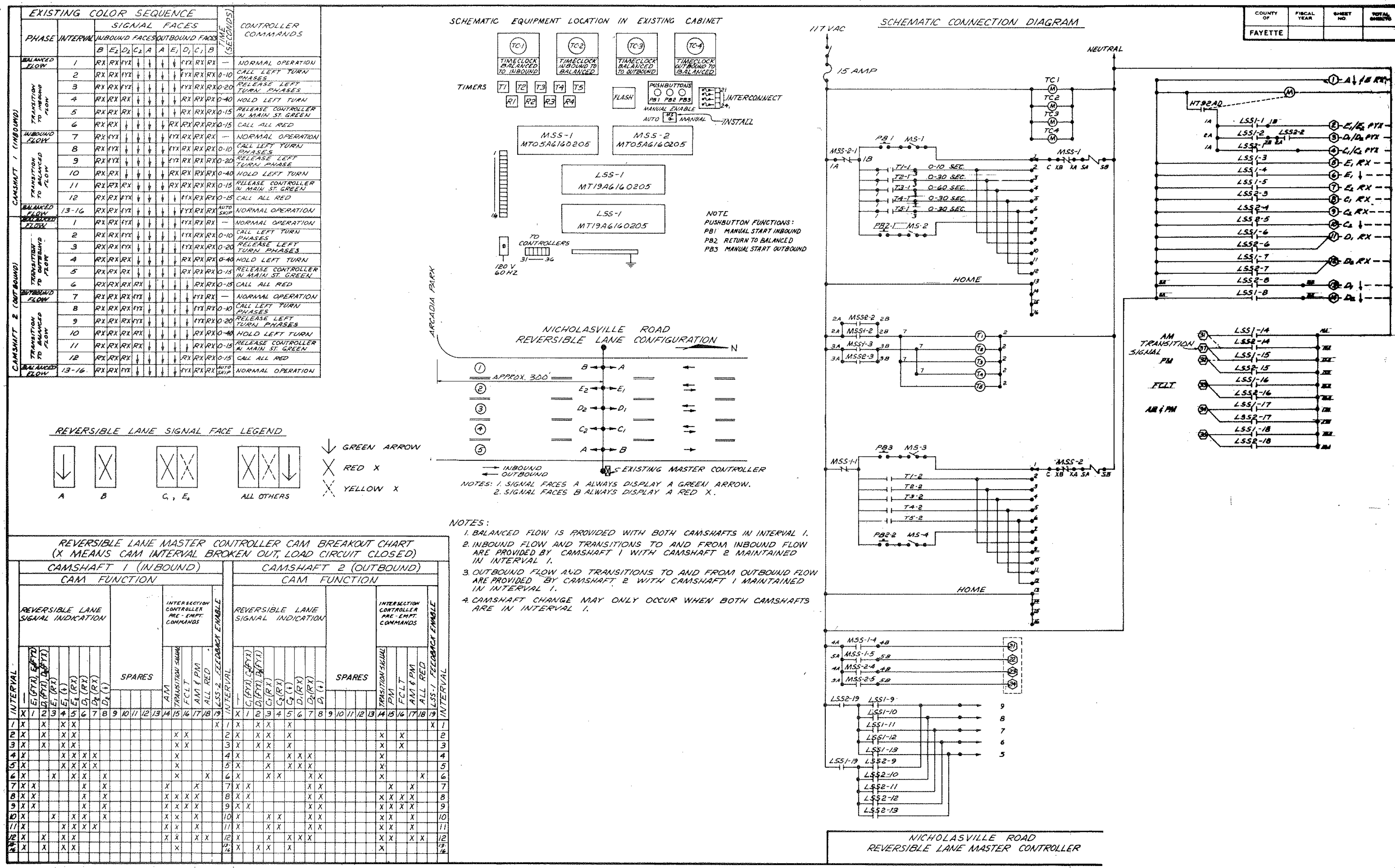


Figure A1. Nicholasville Road; Reversible-Lane Master Controller.

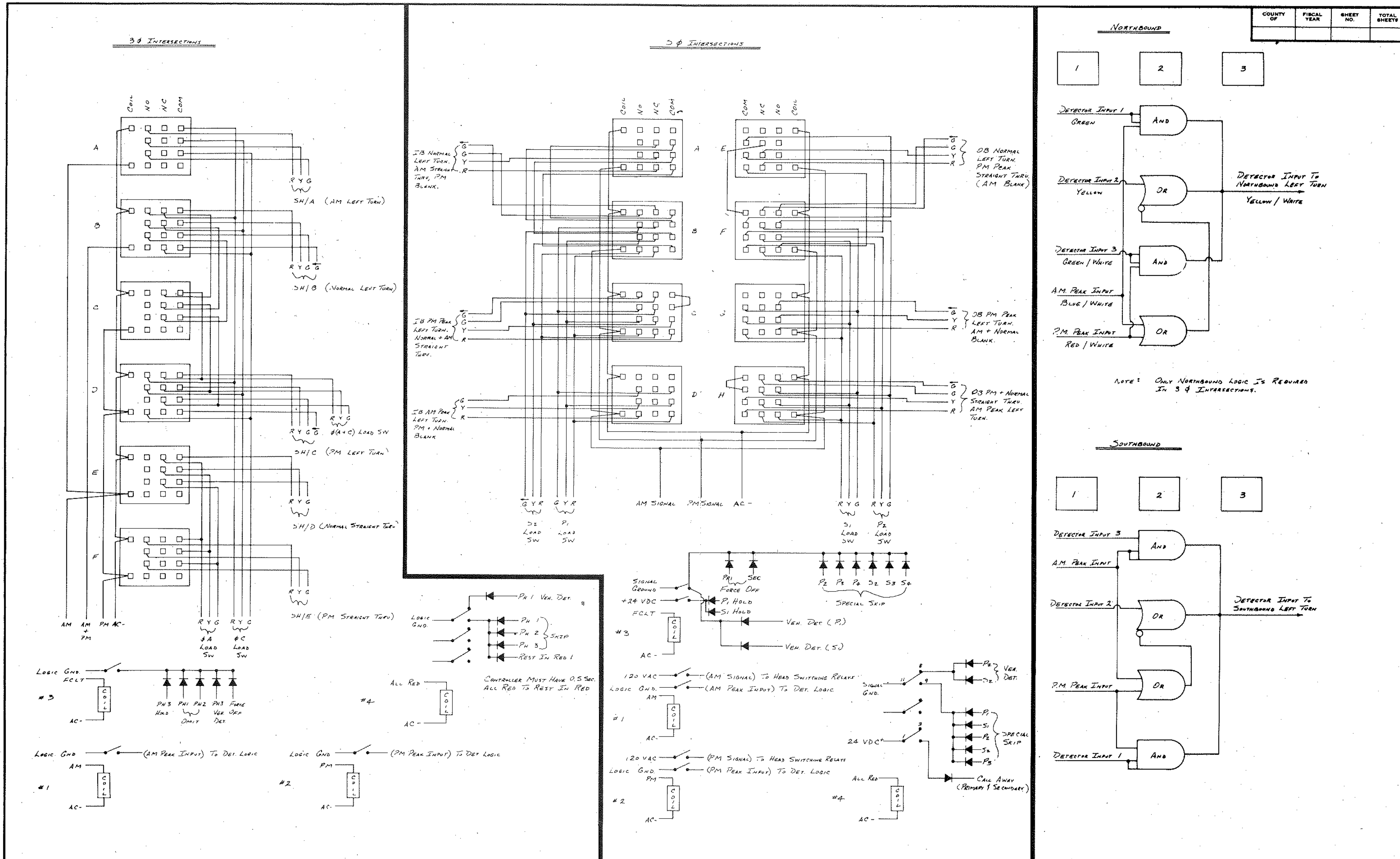


Figure A2. Traffic Signal Controller and Detection Logic.

APPENDIX B

SUMMARIES OF TACHOGRAPH DATA

AND

OUTPUTS FROM THE "RUNCOST" COMPUTER PROGRAM

TABLE B-1. SUMMARY OF TACHOGRAPH DATA, NICHOLASVILLE ROAD, AM PEAK, NORTHBOUND

AVERAGES

	TIME PERIOD	TOTAL NUMBER OF RUNS	NUMBER OF STOPS	SPEED (MPH) (M/S)	TOTAL TIME (MINUTES)	STOPPED TIME (MINUTES)	TIME COST PER VEHICLE (CENTS)	OPERATING COST PER VEHICLE (CENTS)	TOTAL COST PER VEHICLE (CENTS)	POLLUTANTS PER VEHICLE (POUNDS) (GRAMS) NITROGEN OXIDES	HYDRO-CARBONS	CARBON MONOXIDE	FUEL CONSUMPTION PER VEHICLE (GAL.)(LIT.)
BEFORE	7:00-7:30	3	7	17.3 (7.7)	10:49	3:32	87.56	34.13	121.69	.02808 (12.73)	.003279 (1.487)	.2909 (131.95)	.2362 (.894)
	7:31-8:00	3	13	10.0 (4.5)	19:10	10:04	143.51	35.39	178.89	.02808 (12.73)	.005142 (2.332)	.5885 (266.94)	.2819 (1.066)
	8:01-8:30	3	6	16.3 (7.3)	11:53	4:08	91.49	33.41	124.90	.02808 (12.73)	.003595 (1.630)	.3554 (161.20)	.2398 (.907)
	8:31-9:00	2	5	17.7 (7.9)	10:23	3:30	82.27	32.79	115.07	.02808 (12.73)	.003049 (1.383)	.2683 (121.70)	.2289 (.866)
AFTER	7:00-7:30	6	6	18.3 (8.2)	10:22	3:45	83.11	36.52	119.63	.02808 (12.73)	.003342 (1.515)	.3198 (145.06)	.2496 (.944)
	7:31-8:00	4	9	13.6 (6.1)	13:29	6:20	99.90	38.11	138.02	.02808 (12.73)	.003830 (1.737)	.4347 (197.17)	.2664 (1.008)
	8:01-8:30	4	6	23.1 (10.3)	8:21	2:19	64.33	37.36	101.69	.02808 (12.73)	.002925 (1.326)	.2842 (128.91)	.2405 (.910)
	8:31-9:00	1	5	23.8 (10.6)	7:41	2:37	52.26	39.35	91.61	.02808 (12.73)	.002786 (1.263)	.3309 (150.09)	.2298 (.869)

TABLE B-2. SUMMARY OF TACHOGRAPH DATA, NICHOLASVILLE ROAD, AM PEAK, SOUTHBOUND

AVERAGES

	TIME PERIOD	TOTAL NUMBER OF RUNS	NUMBER OF STOPS	SPEED (MPH) (M/S)	TOTAL TIME (MINUTES)	STOPPED TIME (MINUTES)	TIME COST PER VEHICLE (CENTS)	OPERATING COST PER VEHICLE (CENTS)	TOTAL COST PER VEHICLE (CENTS)	POLLUTANTS PER VEHICLE (POUNDS) (GRAMS) NITROGEN OXIDES	HYDRO-CARBONS	CARBON MONOXIDE	FUEL CONSUMPTION PER VEHICLE (GAL.)(LIT.)
BEFORE	7:00-7:30	2	3	23.2 (10.4)	6:48	1:39	58.28	28.53	86.81	.02412 (10.94)	.002393 (1.085)	.1585 (71.89)	.1931 (.73)
	7:31-8:00	1	3	22.0 (9.8)	7:09	:48	58.92	26.90	85.82	.02412 (10.94)	.002447 (1.109)	.1892 (85.82)	.1785 (.675)
	8:01-8:30	1	3	22.2 (9.9)	7:05	1:12	56.24	25.09	81.33	.02412 (10.94)	.002348 (1.065)	.1781 (80.78)	.1722 (.651)
	8:31-9:00	1	7	18.0 (8.1)	8:43	3:02	63.85	34.93	48.78	.02412 (10.94)	.002709 (1.228)	.3258 (147.7)	.2231 (.844)
AFTER	7:00-7:30	4	4	23.2 (10.4)	6:54	1:05	58.75	30.08	88.84	.02412 (10.94)	.002332 (1.057)	.1802 (81.73)	.1970 (.745)
	7:31-8:00	5	4	18.9 (8.5)	8:24	2:24	67.96	30.15	98.12	.02412 (10.94)	.002658 (1.205)	.2243 (101.7)	.2016 (.763)
	8:01-8:30	3	5	17.6 (7.9)	9:00	3:02	69.75	31.22	100.97	.02412 (10.94)	.002570 (1.165)	.2455 (111.35)	.2088 (.790)
	8:31-9:00	2	4	17.8 (8.0)	9:04	3:20	77.20	31.49	108.69	.02412 (10.94)	.002580 (1.170)	.2216 (100.5)	.2166 (.819)

TABLE B-3. SUMMARY OF TACHOGRAPH DATA, NICHOLASVILLE ROAD, PM PEAK, NORTHBOUND

AVERAGES

	TIME PERIOD	TOTAL NUMBER OF RUNS	NUMBER OF STOPS	SPEED (MPH) (M/S)	TOTAL TIME (MINUTES)	STOPPED TIME (MINUTES)	TIME COST PER VEHICLE (CENTS)	OPERATING COST PER VEHICLE (CENTS)	TOTAL COST PER VEHICLE (CENTS)	POLLUTANTS PER VEHICLE (POUNDS) (GRAMS) NITROGEN OXIDES	HYDRO-CARBONS	CARBON MONOXIDE	FUEL CONSUMPTION PER VEHICLE (GAL.)(LIT.)
BEFORE	4:00-4:30	2	6	22.0 (9.8)	8:26	2:14	69.44	35.36	104.81	.02808 (12.73)	.002819 (1.278)	.2153 (97.66)	.2359 (.892)
	4:31-5:00	1	4	21.2 (9.5)	8:38	2:10	74.74	32.17	106.91	.02808 (12.73)	.002956 (1.340)	.2071 (93.94)	.2215 (.838)
	5:01-5:30	2	3	21.9 (9.8)	8:25	1:06	70.08	33.30	103.38	.02808 (12.73)	.003088 (1.400)	.2505 (113.6)	.2226 (.842)
	5:31-6:00	1	4	22.4 (10.0)	8:09	2:22	64.25	28.85	93.10	.02808 (12.73)	.002640 (1.197)	.1840 (83.46)	.2026 (.766)
	6:01-6:30	2	4	22.5 (10.1)	8:21	2:34	62.02	30.48	92.50	.02808 (12.73)	.002614 (1.185)	.2288 (103.78)	.2032 (.769)
AFTER	4:00-4:30	2	8	13.0 (5.9)	14:10	6:26	106.64	38.31	144.95	.02808 (12.73)	.003770 (1.710)	.3963 (179.7)	.2714 (1.027)
	4:31-5:00	3	10	13.5 (6.0)	13:45	5:53	100.39	37.03	137.42	.02808 (12.73)	.003661 (1.660)	.4143 (187.9)	.2629 (.995)
	5:01-5:30	3	10	12.6 (5.6)	14:40	6:33	111.34	37.75	149.10	.02808 (12.73)	.003998 (1.813)	.4454 (202.0)	.2707 (1.024)
	5:31-6:00	4	11	13.7 (6.1)	13:22	4:59	102.08	37.76	139.84	.02808 (12.73)	.003660 (1.660)	.4024 (182.5)	.2642 (.999)
	6:01-6:30	2	7	16.4 (7.3)	11:22	4:24	85.22	38.44	123.66	.02808 (12.73)	.003091 (1.402)	.3303 (149.8)	.2537 (.960)

TABLE B-4. SUMMARY OF TACHOGRAPH DATA, NICHOLASVILLE ROAD, PM PEAK, SOUTHBOUND

AVERAGES

	TIME PERIOD	TOTAL NUMBER OF RUNS	NUMBER OF STOPS	SPEED (MPH) (M/S)	TOTAL TIME (MINUTES)	STOPPED TIME (MINUTES)	TIME COST PER VEHICLE (CENTS)	OPERATING COST PER VEHICLE (CENTS)	TOTAL COST PER VEHICLE (CENTS)	POLLUTANTS PER VEHICLE (POUNDS) (GRAMS) NITROGEN OXIDES	HYDRO- CARBONS	CARBON MONOXIDE	FUEL CONSUMPTION PER VEHICLE (GAL.)(LIT.)
BEFORE	4:00-4:30	3	9	12.8 (5.7)	12:32	5:38	99.54	33.91	133.46	.02412 (10.94)	.003463 (1.570)	.3715 (168.5)	.2407 (.911)
	4:31-5:00	3	11	10.7 (4.8)	14:42	6:59	107.50	33.28	140.33	.02412 (10.94)	.004154 (1.884)	.4837 (219.4)	.2459 (.930)
	5:01-5:30	2	7	10.5 (4.7)	15:21	8:33	134.49	31.27	165.76	.02412 (10.94)	.003886 (1.762)	.3678 (166.8)	.2450 (.927)
	5:31-6:00	2	7	15.4 (6.9)	10:15	4:10	85.19	30.82	116.00	.02412 (10.94)	.003036 (1.377)	.2758 (125.1)	.2181 (.825)
	6:01-6:30	1	3	23.3 (10.4)	6:45	0:52	53.86	25.55	79.41	.02412 (10.94)	.002087 (.946)	.1648 (74.75)	.1703 (.644)
AFTER	4:00-4:30	3	6	18.4 (8.2)	8:44	3:18	67.83	32.79	100.62	.02412 (10.94)	.002657 (1.205)	.2599 (117.8)	.2167 (.820)
	4:31-5:00	4	6	19.0 (8.5)	8:26	2:33	67.08	32.28	99.36	.02412 (10.94)	.002466 (1.118)	.2255 (102.28)	.2141 (.810)
	5:01-5:30	3	7	16.2 (7.3)	9:41	3:16	74.24	33.86	108.11	.02412 (10.94)	.002736 (1.241)	.2890 (131.09)	.2264 (.856)
	5:31-6:00	4	5	19.5 (8.7)	8:04	2:30	64.18	29.63	93.81	.02412 (10.94)	.002498 (1.133)	.2216 (100.51)	.2014 (.762)
	6:01-6:30	2	5	24.4 (10.9)	6:29	1:59	50.71	30.91	81.62	.02412 (10.94)	.002383 (1.080)	.2357 106.91)	.1960 (.741)

TABLE B-5. SUMMARY OF TACHOGRAPH DATA, HARRODSBURG ROAD, AM PEAK

AVERAGES

TIME PERIOD	TOTAL NUMBER OF RUNS	SPEED (MPH) (M/S)	TOTAL TIME (MINUTES)	STOPPED TIME (MINUTES)	TIME COST PER VEHICLE (MINUTES)	OPERATING COST PER VEHICLE (MINUTES)	TOTAL COST PER VEHICLE (CENTS)	POLLUTANTS PER VEHICLE (POUNDS) (GRAMS) NITROGEN OXIDES	HYDRO- CARBONS	CARBON MONOXIDE	CONSUMPTION PER VEHICLE (GAL.)(LIT.)
SOUTHBOUND BEFORE	8	29.1 (13.0)	5:57	1:25	51.57	31.88	83.46	.02642 (11.98)	.002463 (1.117)	.1571 (71.26)	.2114 (.800)
(7:00-9:00)AFTER	7	29.5 (13.2)	6:11	4:94	52.06	34.31	86.37	.02642 (11.98)	.002477 (1.123)	.1597 (72.44)	.2213 (.837)
NORTHBOUND BEFORE	9	19.1 (8.5)	9:47	3:51	81.54	33.91	115.45	.02642 (11.98)	.003118 (1.414)	.2742 (124.37)	.2345 (.887)
(7:00-9:00)AFTER	8	25.9 (11.6)	6:51	1:15	58.76	34.32	43.08	.02642 (11.98)	.002589 (1.174)	.1859 (84.32)	.2233 (.845)
(7:30-8:00)BEFORE	2	13.1 (5.9)	13:11	6:16	118.33	34.60	152.94	.02642 (11.98)	.003949 (1.791)	.3802 (172.45)	.2318 (.877)
AFTER	3	22.6 (10.1)	7:45	1:17	68.47	33.23	101.70	.02642 (11.98)	.002820 (1.279)	.2066 (93.71)	.2204 (.834)
(7:00-7:29 BEFORE 8:01-9:00)	7	22.2 (9.9)	8:06	2:10	64.97	35.36	100.34	.02642 (11.98)	.002746 (1.245)	.2311 (104.82)	.2265 (.857)
AFTER	5	29.1 (13.0)	6:09	1:07	51.00	33.38	84.38	.02642 (11.98)	.002431 (1.102)	.1647 (74.70)	.2142 (.810)

TABLE B-6. SUMMARY OF TACHOGRAPH DATA, HARRODSBURG ROAD, PM PEAK

AVERAGES

TIME PERIOD	TOTAL NUMBER OF RUNS	SPEED (MPH) (M/S)	TOTAL TIME (MINUTES)	STOPPED TIME (MINUTES)	TIME COST PER VEHICLE (MINUTES)	OPERATING COST PER VEHICLE (MINUTES)	TOTAL COST PER VEHICLE (CENTS)	POLLUTANTS PER VEHICLE (POUNDS) (GRAMS) NITROGEN OXIDES	HYDRO- CARBONS	CARBON MONOXIDE	CONSUMPTION PER VEHICLE (GAL.)(LIT.)
SOUTHBOUND BEFORE	9	22.3 (10.0)	8:04	2:07	67.95	35.86	103.81	.02642 (11.98)	.002731 (1.238)	.2183 (99.02)	.2329 (.881)
(4:00-6:00)AFTER	9	23.1 (10.3)	7:38	1:43	63.32	31.39	94.71	.02642 (11.98)	.002623 (1.189)	.1956 (88.72)	.2091 (.791)
(4:30-5:30)BEFORE	6	20.1 (9.0)	8:51	2:25	74.06	37.72	111.79	.02642 (11.98)	.002851 (1.293)	.2478 (112.4)	.2431 (.920)
AFTER	6	21.2 (9.5)	8:13	2:02	66.59	32.38	98.97	.02642 (11.98)	.002705 (1.226)	.2215 (100.4)	.2139 (.809)
(4:00-4:29 BEFORE 5:31-6:00)	3	26.7 (11.9)	6:32	1:30	55.71	32.14	87.85	.02642 (11.98)	.002490 (1.129)	.1592 (72.2)	.2125 (.804)
AFTER	3	26.8 (12.0)	6:29	1:06	56.79	29.40	86.19	.02642 (11.98)	.002458 (1.114)	.1438 (65.2)	.1994 (.754)
NORTHBOUND BEFORE	7	25.0 (11.2)	6:56	1:25	58.22	33.80	92.02	.02642 (11.98)	.002481 (1.125)	.1847 (83.77)	.2197 (.831)
(4:00-6:00)AFTER	8	25.8 (11.5)	6:44	1:18	53.85	32.54	86.39	.02642 (11.98)	.002413 (1.094)	.1789 (81.1)	.2081 (.787)

TABLE B-7. SUMMARY OF TACHOGRAPH DATA, TATES CREEK ROAD

TIME PERIOD		TOTAL NUMBER OF RUNS	AVERAGES SPEED (MPH) (M/S)	TOTAL TIME (MINUTES)	STOPPED TIME (MINUTES)	TIME COST PER VEHICLE (MINUTES)	OPERATING COST PER VEHICLE (MINUTES)	TOTAL COST PER VEHICLE (CENTS)	POLLUTANTS PER VEHICLE (POUNDS) (GRAMS) NITROGEN OXIDES	HYDRO-CARBONS	CARBON MONOXIDE	CONSUMPTION PER VEHICLE (GAL.)(LIT.)
AM PEAK SOUTHBOUND 7:00-9:00	BEFORE	4	30.7 (13.7)	4:39	0:41	39.23	24.13	63.36	.02182 (9.897)	.001975 (.895)	.1395 (63.27)	.1623 (.614)
	AFTER	5	32.1 (14.4)	4:27	0:24	37.46	24.92	62.38	.02182 (9.897)	.001875 (.850)	.1122 (50.88)	.1630 (.616)
AM PEAK NORTHBOUND 7:00-9:00	BEFORE	5	23.5 (10.5)	6:16	1:21	51.92	24.84	76.56	.02182 (9.897)	.002302 (1.044)	.1806 (81.92)	.1712 (.647)
	AFTER	6	24.4 (10.9)	5:56	1:35	49.18	24.40	73.57	.02182 (9.897)	.002126 (.964)	.1690 (76.65)	.1663 (.629)
PM PEAK SOUTHBOUND 4:00-6:00	BEFORE	4	28.6 (12.8)	5:01	0:59	43.62	28.16	71.78	.02182 (9.897)	.007215 (3.272)	.1592 (72.2)	.1848 (.699)
	AFTER	5	27.4 (12.3)	5:12	0:46	43.01	24.59	67.60	.02182 (9.897)	.001996 (.905)	.1422 (64.50)	.1648 (.623)
PM PEAK NORTHBOUND 4:00-6:00	BEFORE	4	31.0 (13.9)	4:37	0:45	39.70	27.06	66.75	.02182 (9.897)	.001973 (.894)	.1230 (55.79)	.1772 (.670)
	AFTER	4	29.4 (13.1)	4:53	0:36	40.74	26.23	66.97	.02182 (9.897)	.001898 (.860)	.1302 (59.05)	.1693 (.640)

TABLE B-8. SUMMARY OF TACHOGRAPH DATA, COOPER-WALLER

TIME PERIOD		TOTAL NUMBER OF RUNS	AVERAGES SPEED (MPH) (M/S)	TOTAL TIME (MINUTES)	STOPPED TIME (MINUTES)	TIME COST PER VEHICLE (MINUTES)	OPERATING COST PER VEHICLE (MINUTES)	TOTAL COST PER VEHICLE (CENTS)	POLLUTANTS PER VEHICLE (POUNDS) (GRAMS) NITROGEN OXIDES	HYDRO-CARBONS	CARBON MONOXIDE	CONSUMPTION PER VEHICLE (GAL.)(LIT.)
AM PEAK EASTBOUND 7:00-9:00	BEFORE	4	15.7 (7.0)	7:24	1:57	64.41	19.65	84.05	.01749 (7.93)	.002395 (1.08)	.2222 (100.78)	.1430 (.54)
	AFTER	5	17.5 (7.8)	6:44	2:07	52.31	19.89	72.20	.01749 (7.93)	.001962 (.88)	.1839 (83.41)	.1399 (.52)
AM PEAK WESTBOUND 7:00-9:00	BEFORE	4	19.4 (8.7)	5:57	1:53	50.20	19.96	70.16	.01749 (7.93)	.001861 (.84)	.1509 (68.44)	.1406 (.53)
	AFTER	5	18.9 (8.4)	6:06	1:52	47.97	19.47	67.44	.01749 (7.93)	.001751 (.79)	.1521 (68.99)	.1355 (.51)
PM PEAK EASTBOUND 4:00-6:00	BEFORE	4	17.5 (7.8)	6:35	1:58	53.54	22.78	76.32	.01749 (7.93)	.002075 (.94)	.1900 (86.18)	.1557 (.59)
	AFTER	5	16.4 (7.3)	7:03	2:28	55.21	21.73	76.94	.01749 (7.93)	.002130 (.96)	.2200 (99.79)	.1519 (.57)
PM PEAK WESTBOUND 4:00-6:00	BEFORE	4	12.7 (5.7)	9:05	3:53	72.81	25.74	98.56	.01749 (7.93)	.002545 (1.15)	.2759 (125.14)	.1830 (.69)
	AFTER	5	13.3 (5.9)	8:48	4:02	67.06	24.04	91.10	.01749 (7.93)	.002361 (1.07)	.2611 (118.43)	.1714 (.64)

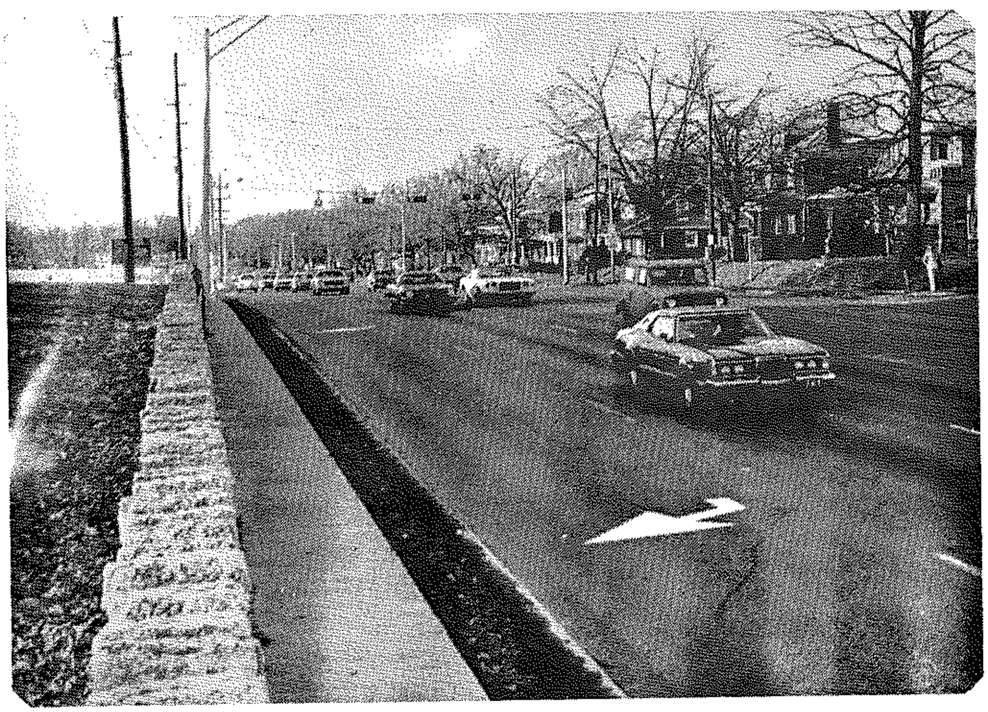
TABLE B-9. SUMMARY OF TACHOGRAPH DATA, ALBANY-JESSELIN-ROSEMONT

TIME PERIOD		TOTAL NUMBER OF RUNS	AVERAGES SPEED (MPH) (M/S)	TOTAL TIME (MINUTES)	STOPPED TIME (MINUTES)	TIME COST PER VEHICLE (MINUTES)	OPERATING COST PER VEHICLE (MINUTES)	TOTAL COST PER VEHICLE (CENTS)	POLLUTANTS PER VEHICLE (POUNDS) (GRAMS) NITROGEN OXIDES	HYDRO-CARBONS	CARBON MONOXIDE	CONSUMPTION PER VEHICLE (GAL.)(LIT.)
AM PEAK EASTBOUND 7:00-9:00	BEFORE	4	21.8 (9.7)	7:39	1:55	63.24	31.18	94.41	.02532 (11.48)	.002365 (1.07)	.1796 (81.4)	.2045 (.77)
	AFTER	3	23.8 (10.6)	7:02	1:26	57.31	32.72	90.03	.02532 (11.48)	.002329 (1.05)	.1792 (81.28)	.2060 (.77)
AM PEAK WESTBOUND 7:00-9:00	BEFORE	4	19.9 (8.9)	9:21	1:34	70.82	31.87	102.69	.02532 (11.48)	.002519 (1.14)	.2140 (97.07)	.2111 (.79)
	AFTER	3	20.2 (9.0)	8:13	2:09	61.37	34.59	95.96	.02532 (11.48)	.002399 (1.08)	.2155 (97.75)	.2185 (.82)
PM PEAK EASTBOUND 4:00-6:00	BEFORE	3	20.5 (9.1)	8:34	1:55	70.64	33.21	103.86	.02532 (11.48)	.002455 (1.11)	.2005 (90.94)	.2157 (.81)
	AFTER	4	20.1 (9.0)	8:15	1:15	64.23	31.02	95.25	.02532 (11.48)	.002363 (1.07)	.1983 (89.94)	.2053 (.77)
PM PEAK WESTBOUND 4:00-6:00	BEFORE	4	19.7 (8.8)	8:28	2:02	63.47	31.92	95.40	.02532 (11.48)	.002561 (1.16)	.2372 (107.59)	.2108 (.79)
	AFTER	4	18.1 (8.1)	9:17	3:12	66.62	31.97	98.59	.02532 (11.48)	.002524 (1.14)	.2366 (107.32)	.2141 (.81)

APPENDIX C

PHOTOGRAPHS BEFORE AND AFTER INSTALLATION OF REVERSIBLE LANES

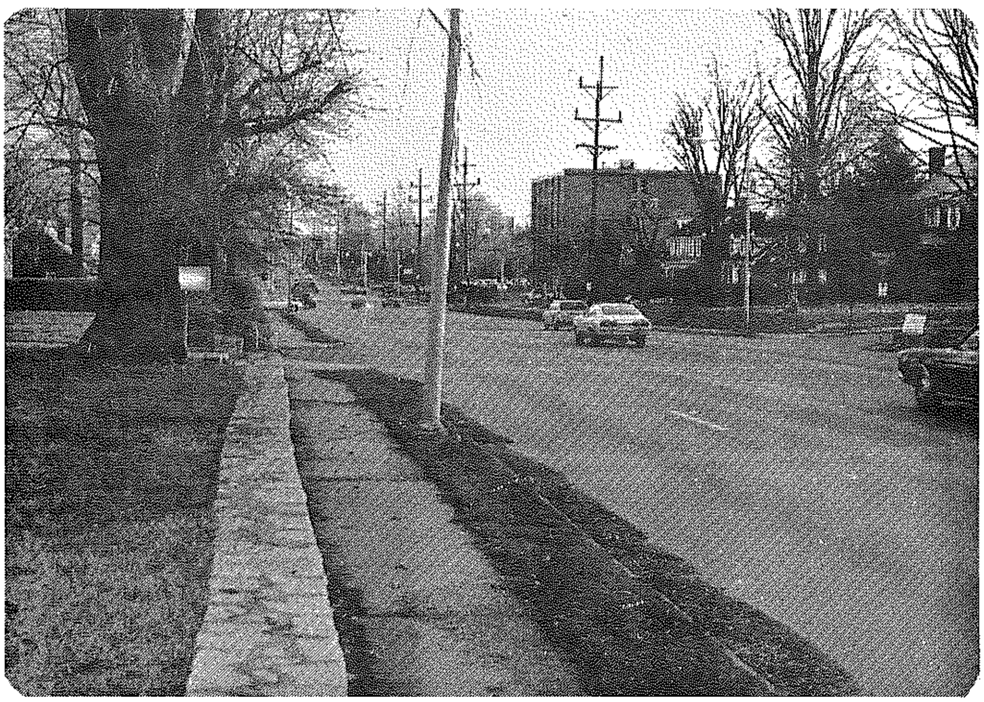
Before



After

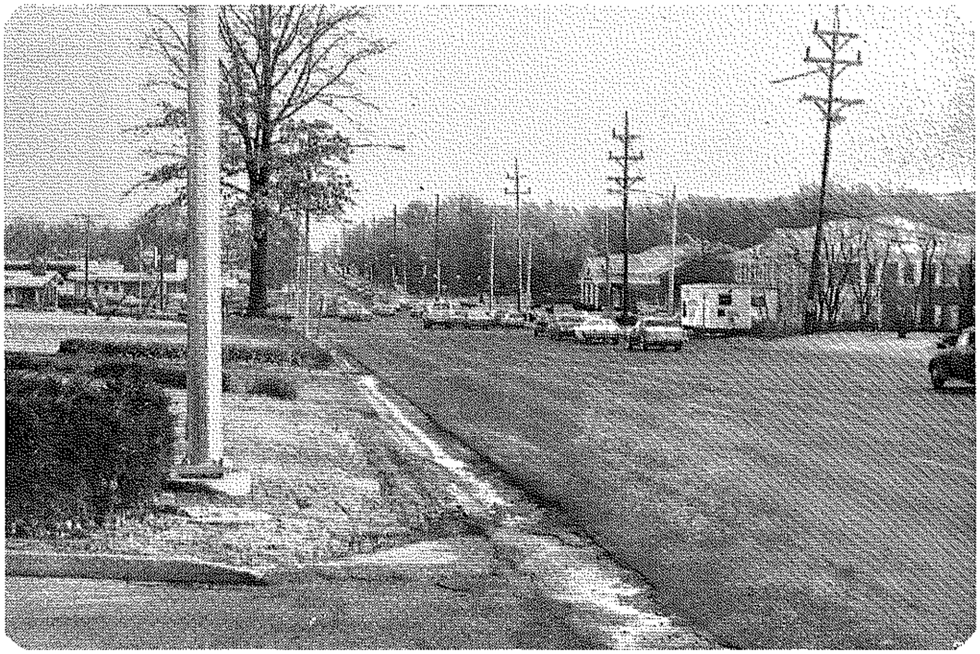
Figure CI. Before-and-After Photographs of AM Peak Conditions (Northbound) between Cooper Drive and Arcadia Park.

Before



After

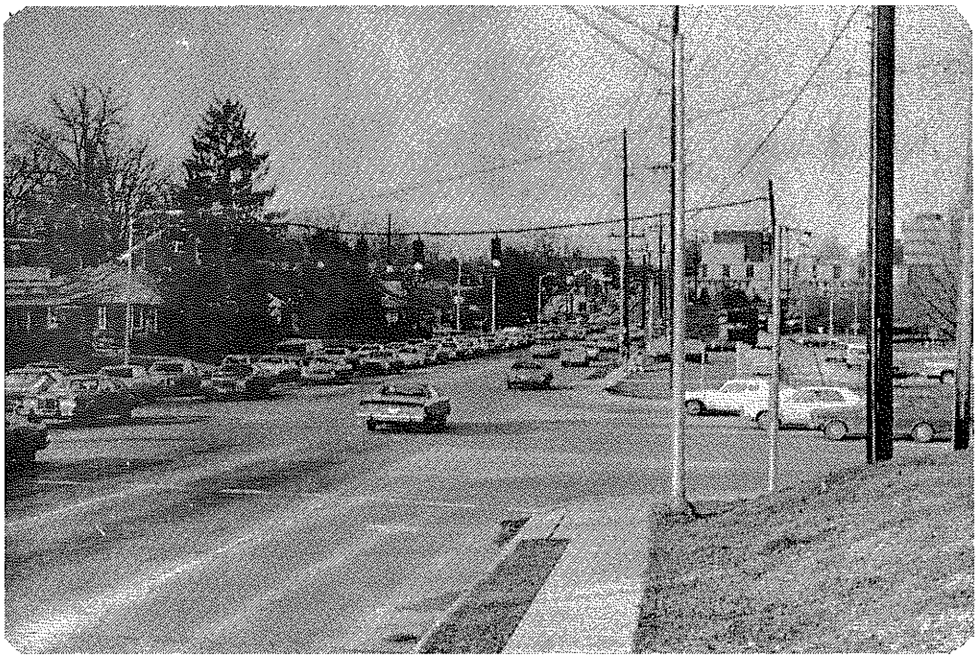
Figure C2. Before-and-After Photographs of AM Peak Conditions (Northbound) at Rosemont Garden.



Before

After

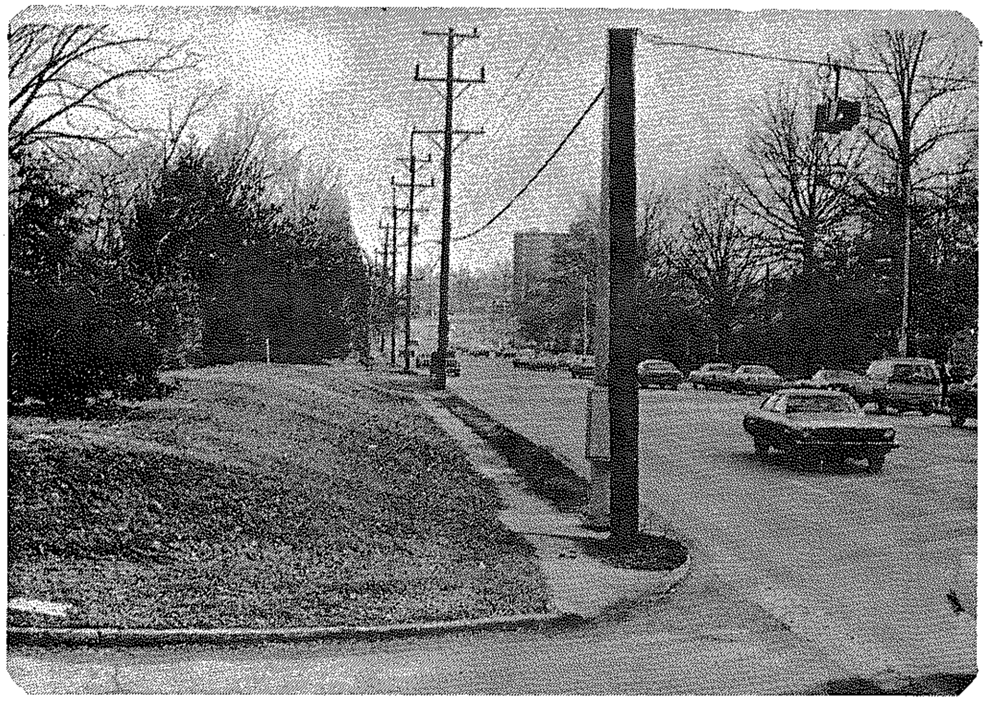
Figure C3. Before-and-After Photographs of AM Peak Conditions (Northbound) at Southland Drive.



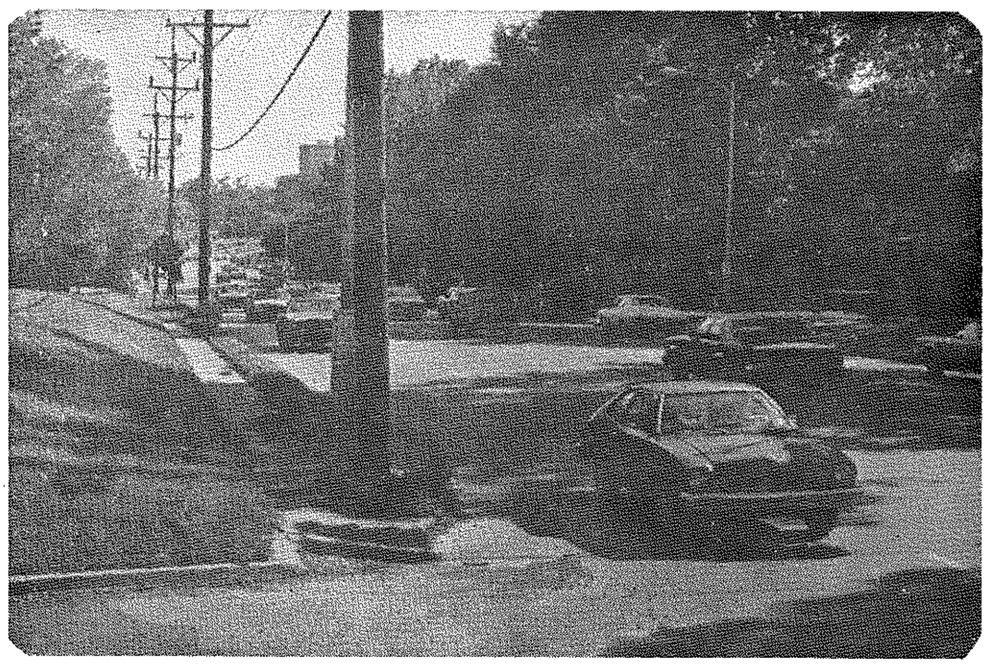
Before

After

Figure C4. Before-and-After Photographs of PM Peak Conditions (Southbound) at Cooper Drive.

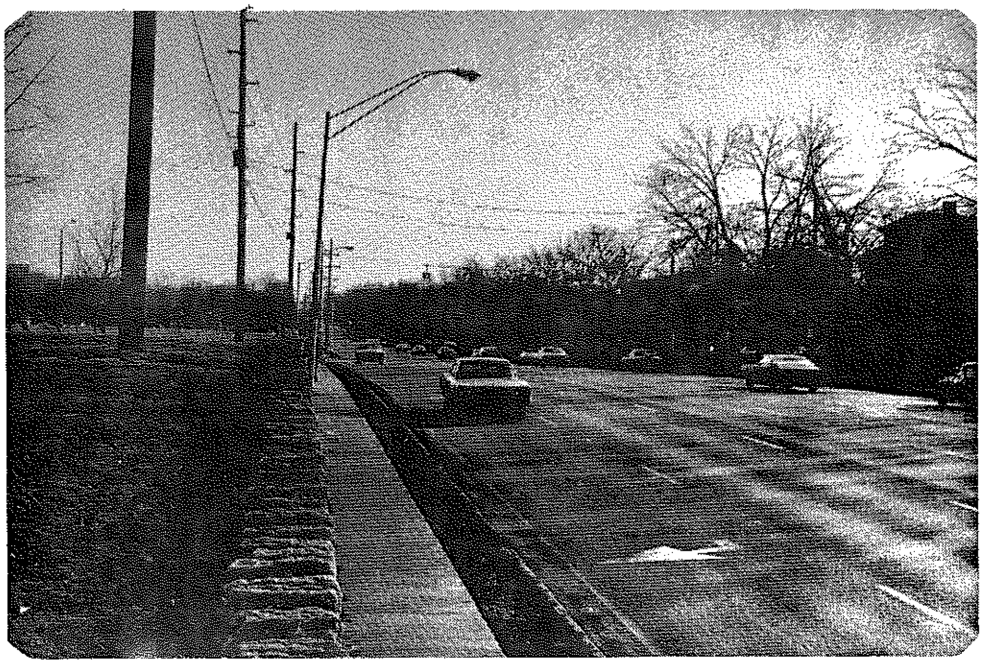


Before

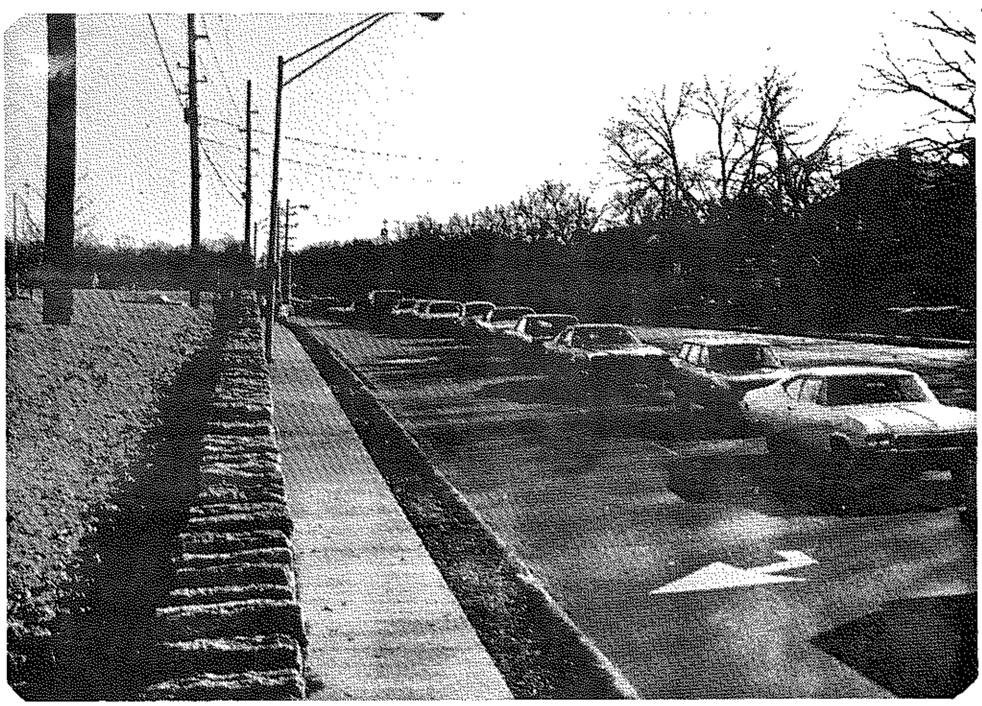


After

Figure C5. Before-and-After Photographs of PM Peak Conditions (Southbound) between Rosemont Garden and Southland Drive.



Before



After

Figure C6. Before-and-After Photographs of PM Peak Conditions (Northbound) between Cooper Drive and Arcadia Park.

APPENDIX D

TIME-DELAY RUNS

(HARRODSBURG ROAD AND TATES CREEK PIKE)

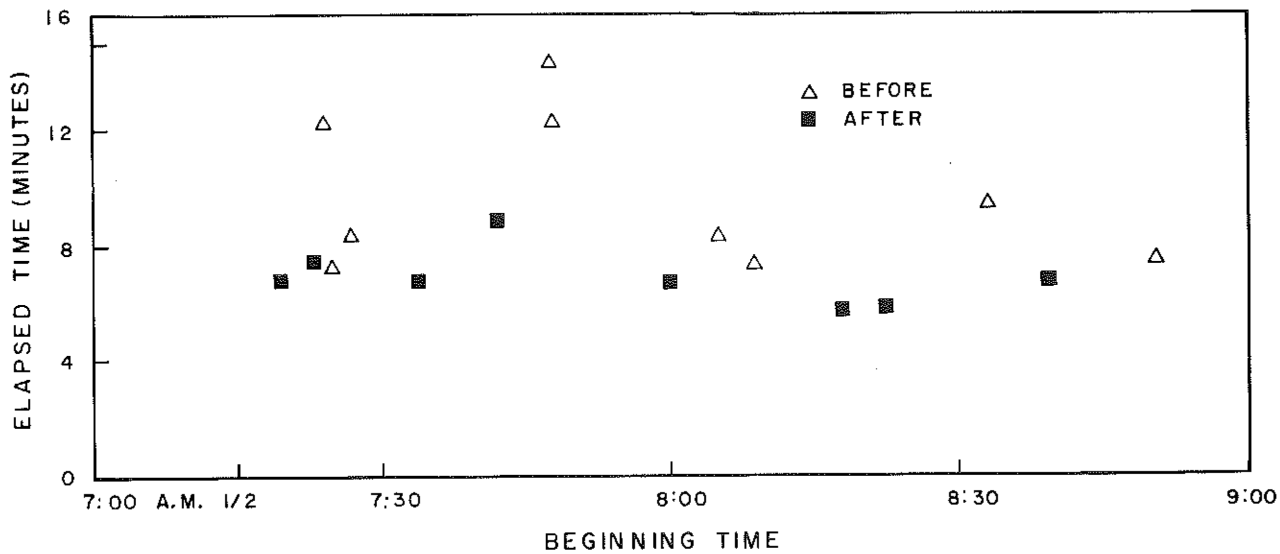


Figure D1. Harrodsburg Road Time-Delay Runs, Am Peak, Northbound.

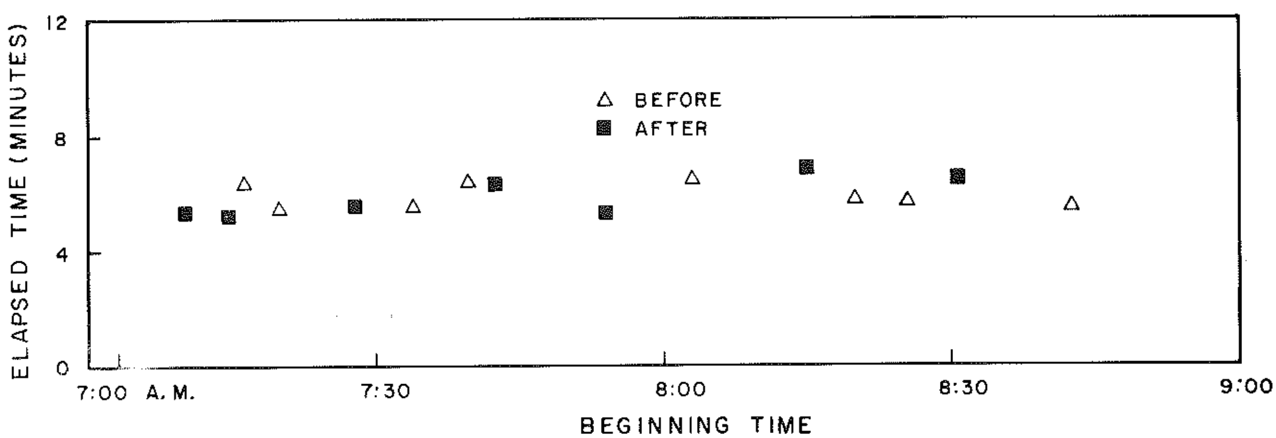


Figure D2. Harrodsburg Road Time-Delay Runs, AM Peak, Southbound.

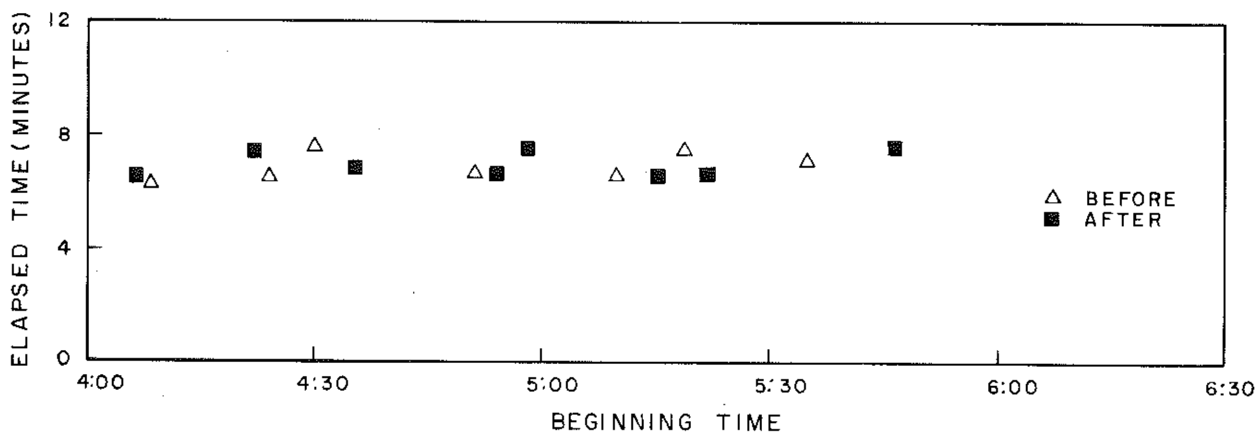


Figure D3. Harrodsburg Road Time-Delay Runs, PM Peak, Northbound.

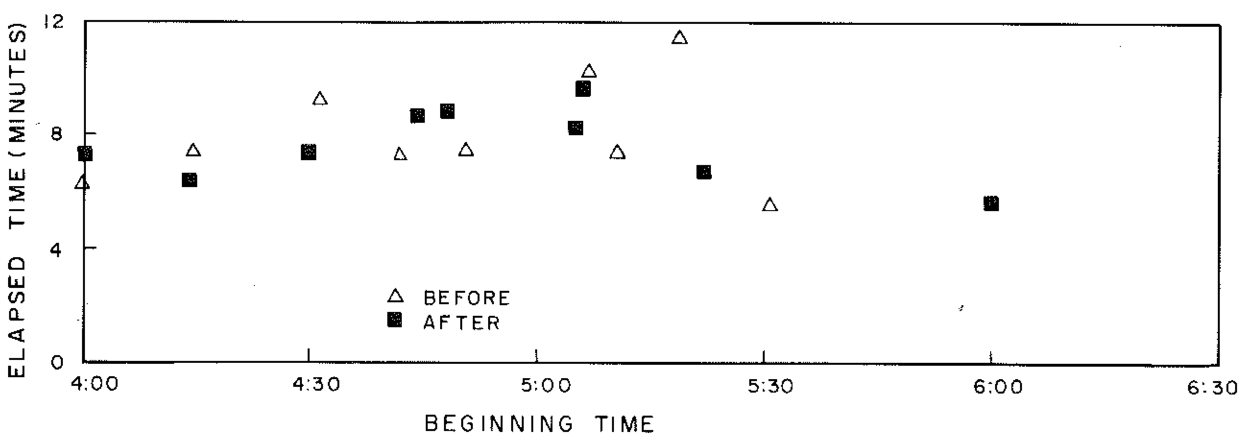


Figure D4. Harrodsburg Road Time-Delay Runs, PM Peak, Southbound.

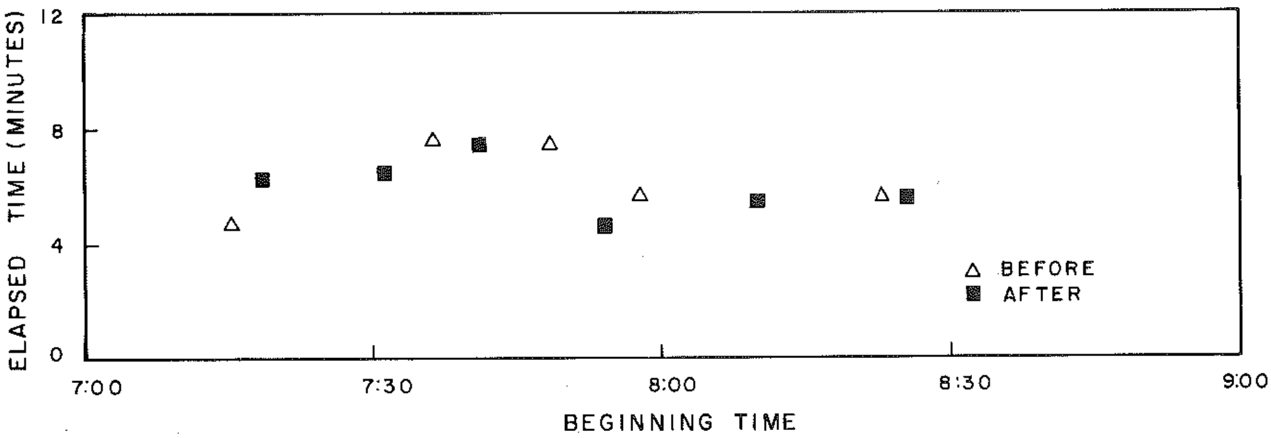


Figure D5. Tates Creek Road Time-Delay Runs, AM Peak, Northbound.

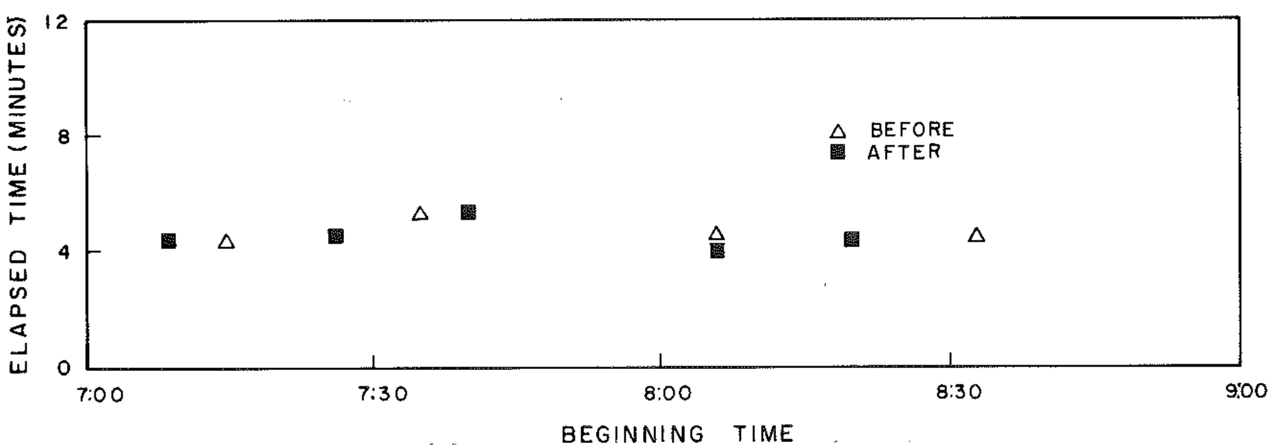


Figure D6. Tates Creek Road Time-Delay Runs, AM Peak, Southbound.

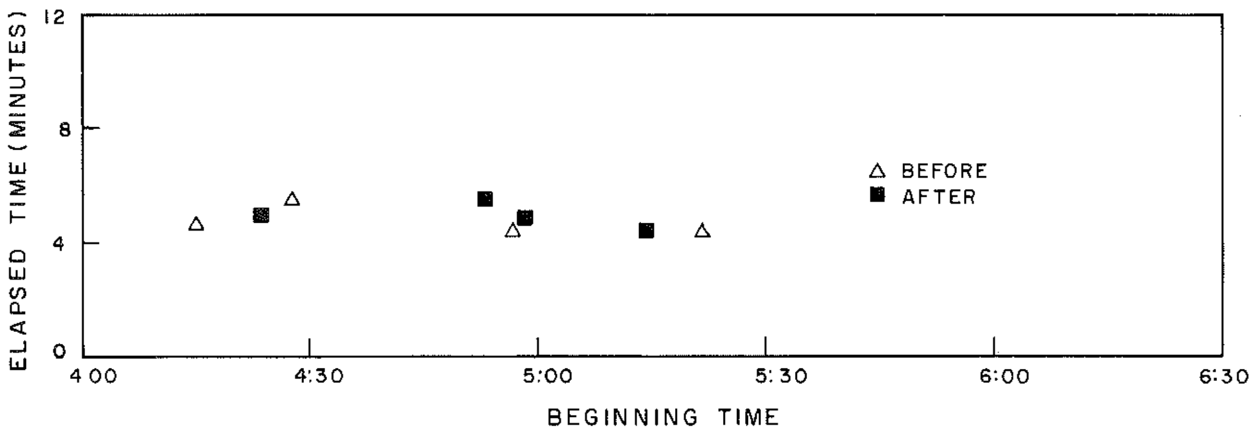


Figure D7. Tates Creek Road Time-Delay Runs, PM Peak, Northbound.

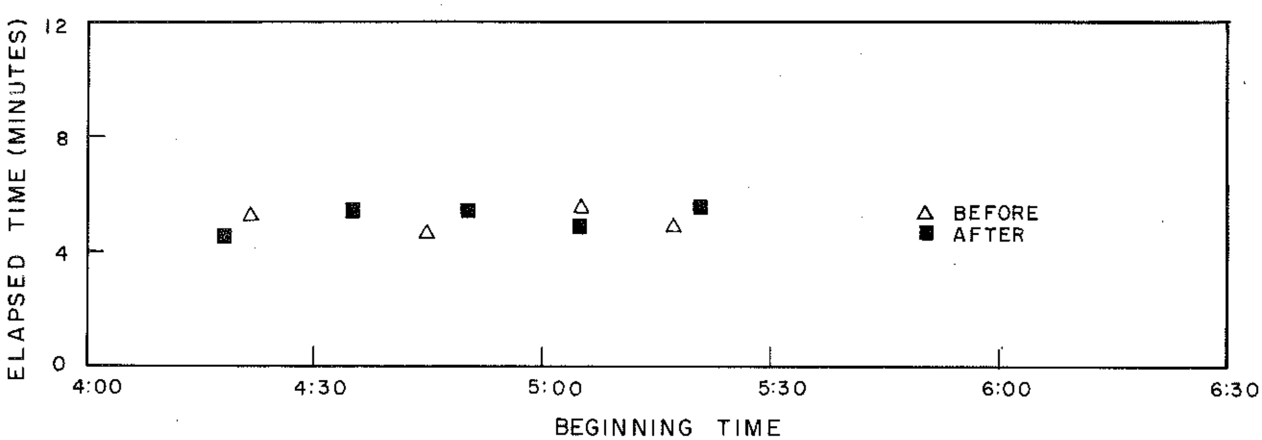


Figure D8. Tates Creek Road Time-Delay Runs, PM Peak, Southbound.