# Signal Timing Optimization and Evaluation: Route M-53 (Van Dyke), Macomb County

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In August 1980, FHWA solicited a proposal for an advanced project entitled "Local Agencies Signal Optimization Project". This is a summary of the final project report.

The major objectives of the program were to evaluate the effectiveness of optimizing timing plans, to train local agencies in the use of TRANSYT, and to evaluate the level of effort required for, and payoff of, signal timing optimization. We subsequently entered into a contract with FHWA to optimize a 10-mile, 26-signal network on highway M-53 (Van Dyke). Revised timing was implemented through the cooperation of the Macomb County Road Commission.

The contract called for an evaluation of the cost and effectiveness of new timing plans with documentation in an evaluation report. More specifically, the Michigan Department of Transportation staff was to collect traffic and street network data, code the data and run the TRANSYT program, retime the signals in the field, fine tune the system, obtain "after" evaluation data, and prepare an evaluation report for FHWA.

The short-term goal was to optimize splits and offsets for the 80-s a.m. and p.m. dials (two offsets) and the normal 60-s dial. Flasher schedules were also adjusted. Also, the lengths of vehicular and pedestrian clearance intervals were also checked. The study section is a 10-mile length of state trunkline M-53, a major north-south arterial with average daily traffic of more than 60 000 vehicles. Peak-hour flows are directional in some areas but not consistent throughout the section, reflecting origins and destinations other than home-central business district (Detroit). There are several major factories as well as commercial establishments bordering the M-53 right-of-way affecting traffic patterns. Several major east-west county roads and I-696 further influence traffic in the Van Dyke corridor.

M-53 retains a constant seven-lane cross section (two-way left-turn lane) from Eight Mile to Fifteen Mile Road with right-turn lanes at some intersections. Further north, the through approach laneage varies from two to three lanes. The side street approaches vary widely from one lane in some areas to as many as four in others. Speed limits increase from 35 mph in the southern end to 45 mph in the north.

While the basic trunkline cross section is fairly constant, many special geometric features have been implemented to facilitate turning traffic. These include "New Jersey left-turn lanes", directional crossovers, at-grade loops, and free flow ramps. Since most of these movements have little effect on the signalized portion of the intersection, we have not tried to simulate them but have eliminated them from the study, adjusting volumes accordingly. The network simulated is simpler than that in the field, but we feel that little reliability is lost.

Though we were treating M-53 as an arterial, it is, in fact, a segment of a larger network of county roads and city streets. We were constrained by the existing cycle lengths, the time of day, and we were also concerned about significant offset changes. System hardware limitations precluded an addition of a third dial unit as part of this study.

## DATA COLLECTION

In order to conduct this study and provide input to the TRANSYT 6C, 7, and NETSIM models, it was necessary to collect a large amount of data on current traffic volumes and turning movements. Manual turning movement counts and pedestrian counts were conducted at all signalized intersections on Van Dyke within the study limits during the peak eight hours.

The existing signal system is limited to two dials, including a 60-s normal dial, operating at times other than the morning and afternoon peaks, when an 80-s dial is used. Though different offsets can be used between morning and afternoon, the splits are the same. The telephone interconnect is unreliable in wet weather. Generally the controllers are in good condition. Several intersections revert to flashing mode during very-low-volume hours. Travel time data were obtained before and after the timing changes by using a "floating car" equipped with the Greenshield's Traffic Analyzer. In addition, data relating to lineage, intesection spacing, special geometrics, and signal plans were gathered. No parking is permitted within the Van Dyke right-of-way.

Three runs were made in each direction during each of three periods studied. In summary, the average travel time decreased 2 percent while stop time decreased by an average of 50 percent. The number of stops decreased 13 percent on the average. Results are given in Table 1.

## SIMULATION RESULTS

The system was optimized by using TRANSYT 7 as requested in the contract. TRANSYT 6C was used to obtain fuel consumption data. We also ran the NETSIM model to evaluate the splits and offsets and to compare results. The turning movements and flow data are summarized on the link-node diagram, a portion of which is shown in Figure 1.

A caveat is in order before evaluation of output data. The network simulated was the mainline only without adjacent nontrunkline signals. In TRANSYT, side street data were measured. Fuel consumption on the side street approaches due to idling only is included in the TRANSYT data. No fuel consumption data or delay information were gathered on the side street with NETSIM. Intersections with one-sided signals were not simulated so the number of nodes was 22 rather than 26.

## TRANSYT RESULTS

By using volume data for the appropriate hour, signals were optimized and evaluated for three periods: a.m. peak, p.m. peak, and off peak. Results are shown in Table 2. The data indicate savings of more than 140 000 gal of fuel per year. This is the difference between the fuel consumption with the existing signal settings and those implemented, multiplied by the hours of operation of that dial, and adjusted for traffic volumes.

The implemented settings differ from the optimized only in splits. This is because some of the splits were readjusted after manual calculations of capacity were performed by using the critical lane volume method. Compromise splits were used in some cases since the existing equipment restricts us to one split on the 80-s dial for both a.m. and p.m. periods.

Some of the results in Table 2 appear difficult to explain. Looking closely at only the a.m. peak, the delay more than doubles between optimized settings and implemented settings though the only difference is a small percentage split at a few intersections. Speed is also reduced greatly. Review of the link-by-link output not included in this report showed that almost all of the increased delay could be attributed to four side street links that were oversaturated. Yet the splits were set by critical-lane capacity analysis. This points to the importance of inputting proper saturation flow values to TRANSYT.

**Table 1. Travel time and delay studies.**

| | P.M. Peak | | A.M. Peak | | Off Peak | |
|---|---|---|---|---|---|---|
| Item | SB | NB | SB | NB | SB | NB |
| **Before** | | | | | | |
| Avg travel time (s) | 1209.0 | 1371.0 | 1096.4 | 1135.6 | 1025.1 | 1133.8 |
| Avg stop time (s) | 230.9 | 299.4 | 151.4 | 174.5 | 93.4 | 119.3 |
| Distance (0.01 mile) | 945 | 977 | 945 | 977 | 945 | 977 |
| Avg running speed[a] (mph) | 34.8 | 32.8 | 36.0 | 36.6 | 36.5 | 34.7 |
| Avg travel speed[b] (mph) | 28.1 | 25.7 | 31.0 | 31.0 | 33.2 | 31.0 |
| Avg stops/run | 10.3 | 12.0 | 9.3 | 9.0 | 7.3 | 9.7 |
| Avg time/stop (s) | 22.42 | 24.95 | 16.28 | 19.39 | 12.79 | 12.30 |
| **After** | | | | | | |
| Avg travel time (s) | 1167.6 | 1315.3 | 1103.9 | 1120.2 | 1025.0 | 1105.9 |
| Avg stop time (s) | 69.7 | 181.5 | 103.4 | 81.3 | 41.3 | 58.3 |
| Distance (0.01 mile) | 945 | 977 | 945 | 977 | 945 | 977 |
| Avg running speed[a] (mph) | 31.0 | 31.0 | 34.0 | 33.9 | 34.6 | 33.6 |
| Avg travel speed[b] (mph) | 29.1 | 26.7 | 30.8 | 31.4 | 33.2 | 31.8 |
| Avg stops/run | 8.7 | 11.3 | 5.7 | 7.7 | 6.7 | 7.0 |
| Avg time/stop (s) | 8.01 | 16.06 | 18.14 | 10.56 | 6.16 | 8.33 |
| **Change Before to After (%)** | | | | | | |
| Avg travel time | -3.42 | -4.06 | +0.68 | -1.36 | -0.01 | -2.46 |
| Avg stop time | -69.81 | -39.38 | -31.70 | -53.41 | -55.78 | -51.13 |
| Distance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Avg running speed[a] | -10.92 | -5.49 | -5.56 | -7.38 | -5.21 | -3.17 |
| Avg travel speed[b] | +3.56 | +3.89 | -0.65 | +1.29 | 0.00 | +2.58 |
| Avg stops/run | -15.53 | -5.83 | -38.71 | -14.44 | -8.22 | -27.84 |
| Avg time/stop | -64.27 | -35.63 | +11.43 | -45.54 | -51.84 | -32.28 |

Note: NB = northbound, SB = southbound.
[a]Running speed = distance x 3600/travel time – stop time.
[b]Travel speed = distance x 3600/travel time.

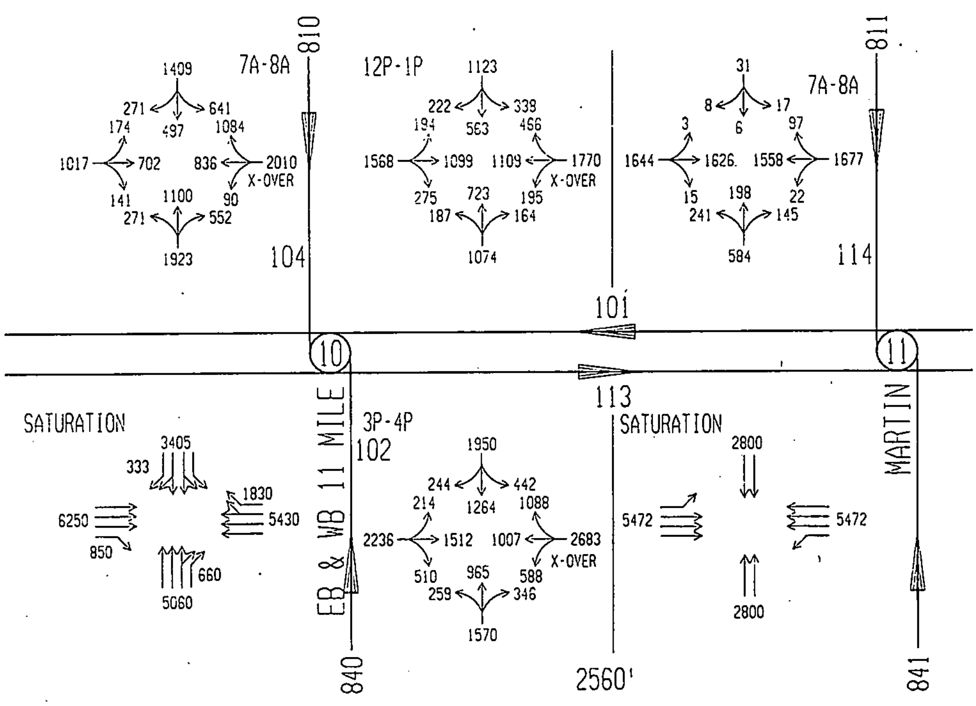


**Figure 1. Link-node diagram of turning movements and flow data.**

Table 2. TRANSYT optimization output.

| Period | Delay (vehicle-h/h) | Gasoline (gal/h) | Hydro/carbon (kg/h) | Carbon Monoxide (kg/h) | Nitrous Oxides (kg/h) | Performance Index | Speed (mph) | Time (vehicle-h/h) |
|---|---|---|---|---|---|---|---|---|
| A.M. Peak | | | | | | | | |
| Existing settings | 627 | 1813 | 153 | 1647 | 108 | 627 | 22.1 | 1346 |
| Optimized settings | 320 | 1776 | 125 | 1319 | 106 | 320 | 28.6 | 1039 |
| Implemented settings | 717 | 1775 | 161 | 1728 | 109 | 717 | 20.7 | 1436 |
| P.M. Peak | | | | | | | | |
| Existing settings | 906 | 2405 | 207 | 2227 | 140 | 906 | 20.9 | 1857 |
| Optimized settings | 578 | 2342 | 177 | 1887 | 138 | 578 | 25.4 | 1529 |
| Implemented settings | 892 | 2338 | 206 | 2207 | 140 | 892 | 21.1 | 1843 |
| Off Peak | | | | | | | | |
| Existing settings | 201 | 1669 | 112 | 1182 | 98.9 | 201 | 31.5 | 893 |
| Optimized settings | 178 | 1651 | 110 | 1154 | 98.2 | 178 | 32.3 | 870 |
| Implemented settings | 181 | 1650 | 110 | 1160 | 98.5 | 181 | 32.2 | 873 |

Table 3. NETSIM simulation output.

| Period | Delay (vehicle-h/h) | Gasoline (gal/h) | Hydrocarbon (g/mile) | Carbon Monoxide (g/mile) | Nitrous Oxides (g/mile) | Speed (mph) | Time (vehicle-h/h) |
|---|---|---|---|---|---|---|---|
| A.M. Peak | | | | | | | |
| Existing settings | 627 | 2668 | 2.53 | 37.55 | 5.07 | 23.5 | 1495 |
| Implemented settings | 490 | 2562 | 2.36 | 33.97 | 5.04 | 26.0 | 1370 |
| P.M. Peak | | | | | | | |
| Existing settings | 607 | 2796 | 2.49 | 36.21 | 5.10 | 24.1 | 1549 |
| Implemented settings | 509 | 2741 | 2.37 | 33.75 | 5.06 | 26.0 | 1463 |
| Off Peak | | | | | | | |
| Existing settings | 268 | 1988 | 2.20 | 30.68 | 5.01 | 28.9 | 995 |
| Implemented settings | 278 | 1993 | 2.20 | 30.74 | 4.99 | 28.6 | 1005 |

At volumes near or exceeding saturation flows, the increases in calculated delay are large with just minor changes in split due to the nature of the delay model used. Since the side street delay is included in the network speed calculation, this value is also affected.

NETSIM RESULTS

The NETSIM evaluations (Table 3) were run to see how closely they correlated with the TRANSYT output. Traffic volumes, turning movements, splits, and offsets were the same for both.

It is interesting and perhaps coincidental that the existing delay in the a.m. peak was the same in both simulations, 627 vehicle/h. This is remarkable since NETSIM does not include side street delay. The remaining values on the chart follow the same relative changes as the TRANSYT output with a few exceptions. The off-peak implemented settings gave slightly poorer values for the measures of effectiveness than existing settings. Total fuel savings based on the NETSIM output was 93 000 gal/year. Though this value was not corrected for current vehicle fleet, the saving of 4200 gal/intersection is a close value to that used for estimating fuel savings for the 11 demonstration cities selected in the FHWA study.

COMMENTS ON TRANSYT

Detailed comments regarding the use of TRANSYT 6C and 7 will not be discussed. Version 7F, now being implemented, promises to alleviate many of the problems we have encountered in using the previous two models. Generally, we have found that the offsets given by the models appear good when shown graphically on time-space diagrams. For arterials, offsets may be obtained by simpler models or by manual computation that may be just as accurate. We chose this simple system to better understand how TRANSYT works.

The TRANSYT model is not too complex and with some training the coding is readily mastered. However, there is a need for guidelines on the effect of the various weighting factors. We ran 45 optimizations by using different weighting factors and saturation flows. TRANSYT 7F documentation should provide the necessary guidance.

Further system optimizations should require considerably less personnel and computer time. TRANSYT 7F is a much faster model and is easier to code and interpret.

RECOMMENDATIONS FOR M-53 (VAN DYKE)

In addition to optimization of splits and offsets, several other aspects of the signal system were reviewed as part of this study. These include condition of control equipment and reliability of telephone interconnect. Length of vehicular and pedestrian intervals, and flasher schedules, signal head visibility, need for pedestrian indications, and need for geometric revision were also evaluated. All of these cannot be discussed here. But some comments are appropriate concerning implemented or planned changes that will further increase capacity and safety while reducing delay, fuel consumption, and emissions.

Lack of telephone interconnect reliability has consistently been a major problem in our system's optimization reviews. We plan to replace the Van Dyke interconnect with time-base coordinators that will ensure proper offset and also allow more flexibility in timing plans. Flasher schedules at some intersections were lengthened. Yellow intervals were lengthened at several intersections. We are pursuing extended flasher operation or possible removal of two poorly spaced signals on the south end of the section.

It is safe to conclude that motorists will save at least 100 000 gal of fuel yearly on Van Dyke and more if the plans are implemented. Considering only fuel savings, the cost of this project, completed in February 1981, was returned to the taxpayers by the end of April in the same year.

# System Timing Optimization and Evaluation of US-12, Detroit

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This report is a summary of the analysis that led to the recent publication of the final report entitled "Michigan Avenue Traffic Flow Study" by Ross Roy, Inc., and the Traffic Safety Association of Detroit. One of the original purposes of this study was to evaluate improvements to a traffic signal system that would save fuel and travel time and reduce accidents. The study was modified to identify other energy-saving improvements. The results could be used for project selection and improvement.

The corridor selected for review consists of a 4.8-mile section of Michigan Avenue (US-12) within the city of Detroit. This portion of Michigan Avenue extends from the fringe of the central business district (CBD) at 6th Street to the city limits at Wyoming Avenue. It is a principal link in the street network and serves as an alternate route to Interstate 94. The adjacent land use is commercial-industrial.

Michigan Avenue average daily traffic (ADT) varies from approximately 20 000 vehicles near the CBD to 33 000 vehicles near Wyoming Avenue. Typical directional peak-hour volumes are about 1500 vehicles/h. See Figures 1 and 2 for directional flow by hour. The existing laneage on Michigan Avenue can adequately serve this volume. In the section from 6th Street to Livernois, seven lanes are provided including a center lane for left turns. From Livernois to Wyoming the cross section is five lanes. In addition, parking is provided on both sides with a peak-hour prohibition that theoretically should provide another travel lane for each direction. There are 64 intersections in this section of Michigan Avenue of which 25 are signalized. The posted speed limit is 35 mph.

## DATA COLLECTION

In order to conduct this study and provide input to the NETSIM model, it was necessary to collect a vast amount of data relevant to current traffic on Michigan Avenue. The following briefly describes the data collection, sources, and reliability.

Traffic volumes in the form of 8-h manual turning movement counts were obtained at 16 signalized intersections. Pedestrian counts were conducted at the major intersections. Traffic estimates were prepared for those intersections where manual counts could not be taken due to staff limitations.

The existing signal system on Michigan Avenue throughout the study area is a two-dial hardwire interconnected system. The average life of the 25 intersectional controllers is 24 years, with the operating time ranging from 6 to 31. At the present time these controllers receive little or no preventive maintenance.

In addition to the equipment data, it was necessary to obtain a physical description of Michigan Avenue. These data included the distances between intersections, laneage, existing traffic signal timing plans, and parking control. The average peak-hour speeds on Michigan Avenue are 20-23 mph, and stops averaged 1.2/mile.

The speeds obtained from the NETSIM runs are weighted average speeds (bidirectional) for the entire system and are figured by total distance of travel (all vehicles) divided by total travel time. These speeds would not agree with the speeds obtained from test vehicles in the field.

## NETSIM BACKGROUND

The practicing traffic engineer has long needed a problem-solving aid to evaluate the cost and benefits of alternative methods of traffic control. Simulation modeling has evolved as a tool with the advent of the high-speed computer. By approximating real-world conditions, modeling gives the engineer the ability to inexpensively choose the best alternatives before actually committing financial resources.

NETSIM is one such tool developed by FHWA for traffic engineers. The NETSIM model has been formally validated against field data. The model has been used successfully by the Michigan Department of Transportation and throughout the country for the last few years.

The first step taken in the use of the model is construction of a link-node diagram that represents the actual street network. Links are stretches of roadway-connecting nodes. They are directional and may be either entry or exit type or internal to the system under study. Nodes are points at which vehicles enter, exit, or are controlled, such as signalized intersections.

The next step is to gather the input data. These include entering counts, turning movements, road and intersection geometrics, channelization, types of control, operational signal timing desired, and detector placement if used. The network is then coded onto a 80-column FORTRAN card and the network is ready for simulation.

The NETSIM output shows the following:

1. Listing of input card deck,
2. Link and network statistics,
3. Number of stops per vehicle,
4. Stopped delay,