Micro-Assignment: A New Tool for Small-Area Planning

GEOFFREY J. H. BROWN and ROBERT S. SCOTT, Creighton, Hamburg, Inc.

EARLY in the past decade, the main impetus for the development of traffic assignment techniques was the need to prepare link volume estimates for region-wide networks, with emphasis on the accurate estimation of expressway volumes.

Around the middle of the decade, the first operational techniques appeared that dealt simultaneously with mixed transit/highway networks; and in at least one large metropolitan region (a region much too vast to be digested by existing assignment methods), a technique for directly estimating link volumes was developed that made it unnecessary to treat the entire region as a single indivisible entity.

In parallel with the growth in sophistication of assignment methods, an enormous increase has occurred in the last 10 years in both the number and quality of techniques for studying the behavior of vehicles at what might be called the microscopic scale—wending their way through intersections, forming queues at traffic lights and toll booths, or merging onto expressways. The models that have arisen from these studies have proven invaluable in the solution of problems ranging in complexity from fixing the green time ratio for a traffic light, to the geometric design of freeway interchanges.

These two classes of techniques, however, have been inadequate for the purposes of planners and traffic engineers with problems intermediate in scope between the region-wide network and the individual intersection. Typical of these "grey" areas are the study of detailed traffic movements within central business districts under peak-hour and off-peak conditions and within institutions such as airports and universities.

In such areas, region-wide assignments neither treat trip patterns or network geometry in sufficiently fine detail to give useful answers, nor do they attempt to respond to such factors as intersection control, parking regulations, or delays caused by congestion at intersections. On the other hand, the "behavioristic" models consider neither the impact of region-wide travel patterns on the study area nor the changes in vehicle routings through the study area caused by the buildup of congestion on certain links.

It was with a view to narrowing this gap in the technology of transportation planning that the Bureau of Public Roads (BPR) in 1967 retained the firm of Creighton, Hamburg, Inc., to develop a model designed specifically for traffic studies in small areas. Under the terms of the contract, the model was required to give an explicit treatment of all traffic movements in an area equivalent to approximately 200 city blocks and to provide data on link volumes, congestion delay, and travel costs for given time periods throughout the day. Such a "micro-assignment" model has been developed and is in operational use. It is implemented by a set of computer programs for the IBM System/360 which are now part of the Bureau of Public Roads Urban Transportation Program System.

The current version of the micro-assignment model permits simulation within a study area (micro-area) of up to 1,000 city blocks. Within the micro-area, every segment of highway network and each traffic movement through an intersection may be represented by a separate link. Furthermore, any network node (usually representing a block front) may be used as an origin or destination for trips.

For purposes of simulation, the user may divide the day into a number of time periods in any way he chooses. For each period, the model assigns to the micro-

Paper sponsored by Committee on Origin and Destination.

area network the proportion of the average total daily trips that occur during that period. During the assignment, the flow of traffic is allowed to increase gradually on the network. At regular intervals (usually after each minimum-path tree is built and loaded), the model computes the delay at each intersection caused by this buildup of traffic. The computed delays are then used to update the link travel time, which in turn influences subsequent minimum-path routings.

At the end of each time period, the program writes out a table of link volume and delays from which operating costs and network travel statistics can later be derived.

DESCRIBING THE MICRO-AREA

Size of the Micro-Area

The model places limitations neither on the shape of the area to be simulated nor on the configuration of the highway network within it. The present version of the model is designed to accommodate a network of up to 4,000 nodes and 12,000 links, equivalent to an area of approximately 1,000 city blocks. In the interest of economy in computer running time, however, and because of the computer memory requirements of the model, a more practical size for the micro-area seems to be from 200 to 300 blocks.

Network Layout

The main requirements of the micro-area network description are, first, that it accurately portray all the movements possible through each intersection (and only those movements), and second, that it contain all the data necessary to compute delays at each intersection.

To meet these needs it was found desirable to depart from the conventional method of representing networks as a collection of nodes (intersections) connected by links (road segments) to one in which each movement through an intersection is represented by a separate (one-way) link, with the road segment leading to the intersection treated as an integral part of the movement. Under this conception a link shares certain characteristics (such as speed, length, and parking restrictions) with the other links on the same approach leg, whereas other characteristics (such as number of lanes) are peculiar to the movement involved. A diagram of a typical four-way intersection, illustrating this concept of network layout, is shown in Figure 1.

Although this method of network layout requires more links than conventional representation, it overcomes two of the latter's major drawbacks. First, U-turns and other prohibited movements are automatically prevented from occurring during the minimum-path algorithm without recourse to "turn prohibitors"; and second, the need to compute turning volumes disappears.

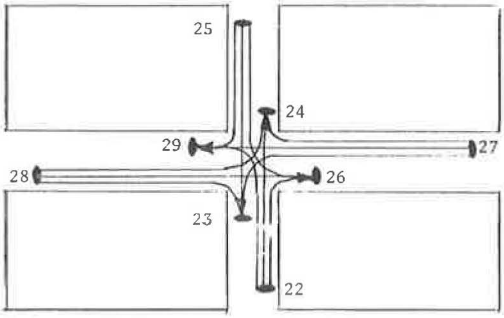

Figure 1. Conceptual layout of a typical intersection.

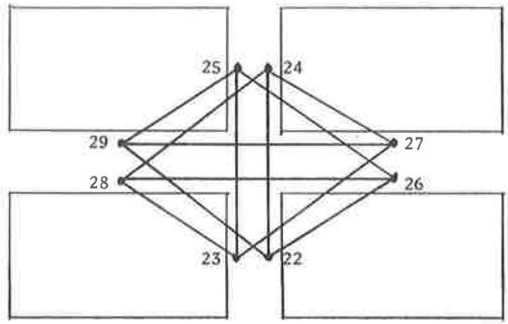

Figure 2. Intersection layout used for mapping.

Although the layout shown in Figure 1 is correct from a conceptual point of view, it has been found to be more convenient for purposes of mapping and node numbering to locate the network nodes at midblock, resulting in the intersection layout shown in Figure 2.

Because of the complexity of the intersection delay algorithm, it has been necessary to limit the number of movements leading out of a node to three—left, right, and through. An intersection at which more than three distinct movements are possible from any one approach leg represents a special coding problem. A method of dealing with this problem is explained in detail in the Creighton, Hamburg, Inc., final report (1).

DETERMINING TRAVEL IN THE MICRO-AREA

One of the principal inputs to the model is a file of trip interchanges that use the road network within the micro-area. Except in such applications of the model as uni-

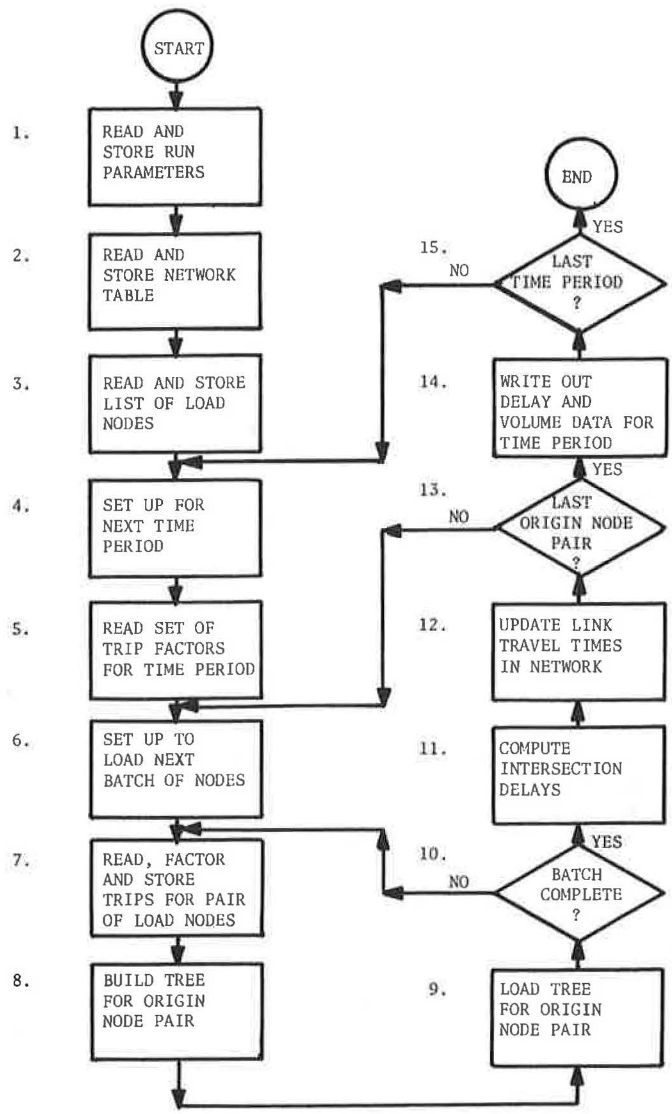

Figure 3. The micro-assignment process.

versities or airports where special travel surveys may be necessary, it is assumed that this trip file will be derived from existing region-wide origin-destination (O-D) tables.

This is done by use of a modified version of the BPR network loading program. One of the inputs to this program is a list giving every link in the region-wide network that crosses the micro-area boundary. The program then keeps a record of every O-D pair that uses the micro-area network for some portion of its minimun-path length, and notes the point(s), if any, at which these movements cross the boundary.

The output of this program may be used to select from a file of region-wide trip survey records all those that contribute to the micro-area trip population and to recode their origins and destinations to conform to the micro-area node numbering scheme. A further program step uses these selected survey records to create trip tables for use in the micro-assignment. This same program also prepares frequency distribution tables of travel purpose, which give the percentage of average daily traffic (ADT) trips entering the micro-area network during each 6-minute interval throughout the day. These tables are used to specify the percentage of trips of each purpose to be assigned during each time period selected for micro-assignment simulation.

THE MICRO-ASSIGNMENT PROCESS

The process described in this section involves a set of computer routines which, functioning as a single program, read the micro-area network description and trip tables and produce tables of link volumes and other network operating characteristics for selected time periods throughout the day. A flow diagram of this process (Fig. 3) is provided to supplement the text.

1. The first step in the micro-assignment process is to read in the parameters for the particular run. These are used to determine the amount of core storage needed for certain tables and to specify program user options. They include the highest node number, the number of network links, the number of time periods, and the number of travel purposes to be used.
2. The link data for the micro-area is read in and edited, and the internal network table is built. The program indicates any links containing errors.
3. A list of the nodes to be used as trip origins (load nodes) is read in and stored. The network loading routine causes minimum-path trees to be built and trips to be loaded only for those origin load nodes in this list, regardless of the constitution of the trip file being used. In this context, a load node implies an even/odd pair of network nodes, usually designated by the even node number (Fig. 2).
4. In preparation for the assignment of trips for the current time period, the link volume accumulation area is cleared and the travel time in each link of the network is set to its zero-volume value (i.e., to the value it would have for a solitary vehicle using the link). The program then is initialized to process the first node in the load node list.
5. Next, the program reads the set of trip factors (one for each purpose of travel) that determines the proportion of trips to be loaded during the current time period.
6. The user is given the option of building and loading a given number (batch) of trees before the program computes intersection delays and updates the link travel times. In this step the batch count is initialized to the value specified by the user.
7. The program now locates on the input tape the set of trip tables for the current load node and reads it into core storage. Tables for travel purposes not specified by the user are ignored. The trips for each node-to-node pair in the selected trip tables are multiplied by the appropriate factor and are accumulated into a single table for the current load node. If separate tables exist on the input tape for each of the nodes of the current even/odd pair, they are combined at this step.
8. A minimum-path tree is built for the current load node. Both nodes of the even/odd pair (if both exist) are regarded by the algorithm as though they were a single origin point.
9. In this step the trips from the current load node to all other pairs of nodes in the network are loaded onto the links of the minimum paths connecting them. Because

the completed tree always contains a different minimum path to each node of a destination pair (one approaching from each direction on the block) and because it is assumed that both sides of the street are equally accessible from either node of the pair, the trips are loaded onto the shorter of the two routes.

10. At this point the program tallies the number of trees loaded in the current batch. If the batch is not yet complete, the program returns to process the next load node (step 7). Otherwise it proceeds to step 11.

11. Using the duration time of the current time period, the program now converts the traffic volume on each link into the rate of arrival at the intersection (in vehicles per second) for that link. If the volume on a link was not changed during the loading of the current batch, an indicator is set for that link because it may not be necessary to recompute its delay.

The network is scanned to find those links with delays that must be recomputed. For each such link the program examines its characteristics (movement type, control device, etc.) to determine which form of delay computation is to be used.

12. As the intersection delay is computed for each link, the link travel time in the network is augmented by the amount of the delay.

13. When every link in the network has been examined and (if necessary) its delay computed, the program determines if the last origin node pair has been processed. If not, the program returns to step 6. Otherwise, the assignment for the current time period is complete, and the program proceeds to step 14.

14. The loaded network table (link volume) and the set of link delays in effect at the end of the time period are now written onto the output tape for later processing.

15. If the last time period of the run has been processed, the micro-assignment process is complete. Otherwise, the program returns to step 4 to set up for the next time period.

MICRO-ASSIGNMENT OUTPUT

The principal output of the micro-assignment model is a table for each selected time period giving for each link in the network a complete description of the link characteristics (used as input to the model) plus selected items computed during the assignment. These include computed delay, vehicle arrival rate and volume, operating speed and cost, and vehicle-miles and vehicle-minutes of travel. Additional tables for each time period summarize these data by type of intersection control, direction of movement (left, right, or through), and by number of lanes. Other tabular outputs from the model include listings of link data and tabulations of minimum-path trees and trip tables.

Graphic output from the model in the form of CalComp plots includes plots of trees, networks, and link volumes.

DELAYS AT INTERSECTIONS

A key feature of the micro-assignment model is a set of delay calculations detailed enough to be sensitive to such items as parking restrictions, number of lanes, signal timing, left-turn movements, and volume congestion and yet is simple enough to permit the simulation of traffic flow over an entire network. A collection of travel time and delay formulas were developed that met these conditions. A brief description of these equations and the methods of derivation are given in this section.

As a first step in analysis, travel time is decomposed into three parts: free travel time, zero-volume delay, and volume delay.

Free Travel Time

Free travel time is the time required to traverse a straight segment of roadway equal in length to the link length when traveling at the speed limit. Hence, this time is the link length divided by the speed limit. Travel time is computed once for each link and is not altered during the program.

TABLE 2

DELAYS FOR UNIMPEDED THROUGH TRAFFIC

Demand (number of vehicles)	Expected Delay
1	L_1 (1)
2	L_1 (2)
⋮	⋮
K_1	L_1 (K_1)
$K_1 + 1$	$L_1 (K_1) + [1/(K_1 + 1)] [R + A_1 + d (1) - L_1 (K_1)]$
$K_1 + 2$	$L_1 (K_1) + [2/(K_1 + 2)] [R + A_1 + d (2) - L_1 (K_1)]$
⋮	⋮
$2K_1$	$L_1 (K_1) + [K_1/(K_1 + K_1)] [R + A_1 + d (K_1) - L\ (K_1)]$
$2K_1 + 1$	$L_1 (2K_1) + [1/(2K_1 + 1)] [C + R + A_1 + d (1) - L_1 (2K_1)]$
$2K_1 + 2$	$L_1 (2K_1) + [2/(2K_1 + 2)] [C + R + A_1 + d (2) - L_1 (2K_1)]$
⋮	⋮
$3K_1$	$L_1 (2K_1) + [K_1/(2K_1 + K_1)] [C + R + A_1 + d (K_1) - L_1 (2K_1)]$
$3K_1 + 1$	$L_1 (3K_1) + [1/(3K_1 + 1)] [2C + R + A_1 + d (1) - L_1 (3K_1)]$
$3K_1 + 2$	$L_1 (3K_1) + [2/(3K_1 + 2)] [2C + R + A_1 + d (2) - L_1 (3K_1)]$
⋮	⋮
$4K_1$	$L_1 (3K_1) + [K_1/(3K_1 + K_1)] [2C + R + A_1 + d (K_1) - L_1 (3K_1)]$
$4K_1 + 1$	$L_1 (4K_1) + [1/(4K_1 + 1)] [3C + R + A_1 + d (1) - L_1 (4K_1)]$
⋮	⋮

Although the computed expected delay yields satisfactory results, its use in an assignment program where hundreds or even thousands of such calculations must be made would result in long, expensive programs. To avoid this contingency an empirical equation was developed that approximates the previous results and is capable of rapid evaluation.

Volume Delays at a Stop Sign, Cross Facility Not Controlled

This delay is composed of two parts: Time waiting at the stop sign for a suitable gap in the cross traffic, and time waiting in a queue to reach the intersection when a queue exists.

To account for the delay of waiting for a suitable gap in the cross stream of traffic, heavy reliance was placed on the work of others. Gazis et al. (2) have developed expressions for the expected waiting time at a stop sign by a vehicle that is trying to cross a road with n lanes, given the vehicles' gap acceptance characteristics (acceptable gaps for each of the n lanes) and the mean arrival rates of the n lanes. An approximation formula is also developed that uses the sum of the mean arrival rates and a single weighted gap acceptance value. Because this formulation is more in keeping with data bases for an entire area, it has been retained for use in the micro-assignment program. Let

$F(i)$ = mean arrival rate on the i th lane;
$T(i)$ = gap acceptance time for the i th lane; and
b = expected delay time.

If

$$F = \sum_i F(i); \text{ and}$$

$$T = \left[\sum_i F(i)\, T(i)\right] \Big/ \sum_i F(i);$$

then the required expression is

$$b = (1/F)\,[\exp(FT) - 1] - T$$

This same expression has been developed under different assumptions by other researchers (3, 4).

To find the time lost in queues, the service time γ is defined as the reciprocal of gap time b; the service time thus is exponential in form. Because the vehicle arrivals are assumed to be Poisson distributed, we may turn to queuing models for a single lane to find an expected delay of $V/(\gamma^2 - \gamma V)$.

Because this service is based on arrival rates persisting indefinitely, it gives unbounded delays as V approaches γ in value. We are interested, however, in shorter time intervals, and therefore it seems logical to bound this expression by a delay that would result from the demand persisting for 10 minutes: $\Phi + 600\,(V - \gamma)/(2\gamma)$, where Φ is chosen to make a smooth tangent with $V/(\gamma^2 - V)$. The point of tangency v can be found by equating slopes:

$$\frac{300}{\gamma} = [1/(\gamma^2 - \gamma v)] + [\gamma v/(\gamma^2 - \gamma v)]$$

making

$$v = \gamma - (\sqrt{3\gamma}/30)$$

This implies that

$$\Phi = [(20\sqrt{3\gamma})/\sqrt{\gamma}] - (1/\gamma)$$

Hence, the expected delay L_5 is equal to

$$b + [V/(\gamma^2 - \gamma V)] \text{ for } V \leq v$$

and

$$b + \Phi + \{[300\,(V - \gamma)]/\gamma\} \text{ for } V > v$$

Volume Delays on Local Streets, No Intersection Control

The computation of these delays can get somewhat involved because of the various movements sharing lanes and because of frictions arising from high densities on the lanes. The latter effect is difficult to deal with and is not dominant in systems where priority links are coupled with links having some other intersection control. Because this is true in most systems of interest, the volume delays discussed are limited to those arising from lane sharing.

Through vehicles with their own lane experience no delay whereas those that share a lane with a turning movement do experience some delay. To simplify the delay calculation for those movements, through vehicles are assumed to suffer delays in accordance with the least hampered of the through lanes.

For the through movement with its fastest lane shared with a right turn movement or a left turn movement without interference, this delay is just A_2.

For a left turn movement with interference (the usual case because the opposing traffic commonly is also a priority movement), the delay is the same as for the burdened leg except that a full stop is required only as dictated by opposing traffic. Ignoring this small difference, we may use L_5 to represent this delay.

The values of L_6 are summarized as

A_2, for through movement when this fastest lane is shared with right turn or left turn with no interference;

L_5, for left volume; i.e., for left turn with interference or for other movement sharing its lane with left turn with interference; and

0, for through movement (at least one lane unshared), for right turn with no interference, or for left turn with no interference.

Volume Delays at a Stop Sign, Cross Street Also Controlled by a Stop Sign

The calculation of this volume delay could get quite involved. Because there are typically 12 movements at a four-legged intersection, random arrivals give rise to many vehicular arrangements and the various possibilities cannot be ordered as neatly as in the case of signal-controlled intersections. To find the probability of all possible arrangements, the 12 mean arrival rates and the associated average delay for the 12 movements must be given and then the sum of the products of probability times delay for all movements must be found for all possibilities. This task is not feasible for network analysis.

To reduce the problem, assume for the moment that all the vehicles on the various legs form a single serving line with a mean service time (capacity K_7) equal to the reciprocal of usage time (which we assume to be exponentially distributed). We may then apply the Poisson single-channel-arrivals queuing model to find the expected delay per vehicle at the intersection. By bounding this expression to the delay that would result after the demand persisted for 10 minutes and by prorating the resulting delay among the various links using the intersection, we find the following expected delay on the i th approach leg:

$$D(i) = [V(i) \Sigma V(i) L_7] / \Sigma [V(i)]^2$$

The summation is taken over all of the approach legs to the intersection and

$$L_7 = \Sigma V(i)/[K_7^2 - K_7 \Sigma V(i)] \quad \text{for } \Sigma V(i) \leq v$$

and

$$L_7 = \Phi + [300 (\Sigma V(i) - K_7)/K_7] \quad \text{for } \Sigma V(i) > v$$

where

$$\Phi = (20\sqrt{3}/\sqrt{K_7}) - (1/K_7)$$

Volume Delay at a Yield Sign

The zero-volume delay for links with this control device is somewhat less than that of the stop-sign facilities (Table 1) because the vehicle need only slow down when no other vehicles are present. The delays caused by other vehicles are those of waiting in queues and waiting for a suitable gap in the cross traffic. Because these are the same elements that occur on facilities controlled by stop signs, the volume delay for a link controlled by a yield sign is the same as that of a stop-sign-controlled link.

Volume Delays on Expressways

The volume delay developed for expressways is quite simple and does not involve the problem of unstable flow. There may be questions, however, about the method of handling demand in excess of capacity. On the other hand, the treatment of delays for demands not exceeding the capacity are in line with the studies and observations of previous researchers. Also, for the case of demand in excess of capacity, the volume delay increases rapidly; this is certainly the correct behavior even if there is some question about the absolute magnitude of these large delays.

The delays are derived as follows. Speeds are reduced linearly from the speed limit at zero demand to one-half the speed limit at a demand equal to the capacity. For demands exceeding the capacity, the speed continues to decrease linearly with the amount the demand exceeds the capacity. This implies that queues form on the entrance ramps. The existance of these queues increases drastically the average delay. Also implied by this assumption is a flow rate of zero when the demand is twice the capacity. This of course implies an infinite average delay per vehicle. Although there actually might be some small nonzero flow at this demand, it would not be much greater than zero and the authors are not unduly alarmed at the asymptotical behavior of the derived delay function. The translation of this into mathematical equations is not particularly difficult. The results are

$$L_{10} = [\ell V_{10}]/[v\,(2K_{10} - V_{10})] \text{ for } V_{10} \leq 2K_{10}$$

$$L_{10} = \infty \text{ for } V > 2K_{10}$$

where
- v = speed limit,
- ℓ = length of expressway link,
- K_{10} = capacity of a lane of expressway, and
- V_{10} = demand volume on the expressway link.

Applications of the Volume Delay Formulas to Specific Intersection Configurations

To correctly apply the delay functions, the number of lanes available to a link must be known. This determination is complicated by the presence of parked vehicles, turn bays, and various intersection movements sharing one or more lanes. From the link description on one approach leg and the internal clock (parking restrictions, turn prohibitions, and number of lanes vary by time of day), a subroutine called "intersection switching" determines the number of lanes available for each movement and the number of these lanes that must be shared with other movements. This information, together with certain assumptions as to vehicular arrangement on shared lanes, enables the computer to select a final expected delay for the link that is a weighted average of the expected delays discussed previously. Space does not permit a development of these final expected delays in this paper, but Figure 4 shows a diagram of each approach-leg configuration that can be handled by the program at this time.

TESTING THE MODEL

When the programs written to implement the model were considered operational, two sets of tests were made to evaluate the performance of the model. The first of these was designed to assess the behavior of the delay computations for various intersection configurations and under various traffic loadings. The second set of tests involved making assignments over an actual downtown area (Buffalo, New York) so that certain results of the model might be compared with observed data.

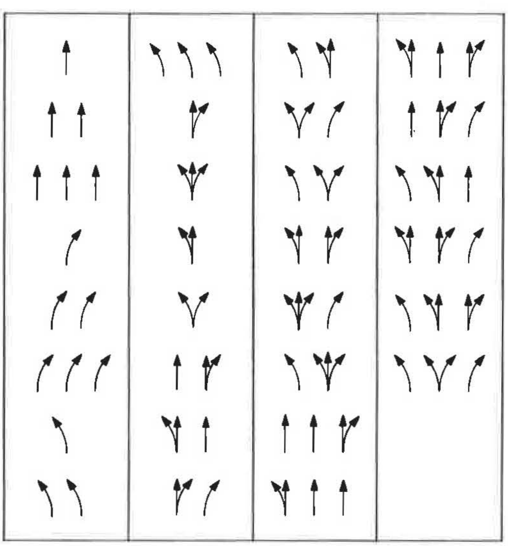

Figure 4. Possible approach-leg configurations for signalized intersections.

The first set of tests was run using a hypothetical network consisting of a string of 19 intersections; 15 of which were controlled by traffic lights; two, by four-way stop signs; and the remaining two were through streets, with stop signs controlling the intersecting streets.

The number of lanes, the total cycle time, the green cycle time, and the arrival rates were varied in a systematic manner for each of five time periods, during which various parking and movement restrictions were imposed.

A complete tabulation of the results of these test is included in the study's final report (1), and a few of them are discussed here for illustrative purposes.

Table 3 gives the arrival rates and parking restrictions in effect during four of the test periods; Table 4 gives the delays computed for the through movements at each of six intersections for each time period. Delay times and cycle times are both in seconds. It should be noted that these delays are in addition to the zero-volume delays, which are generally on the order of one-half the duration of red time for each link.

TABLE 3

CONDITIONS PREVAILING DURING THE TEST TIME PERIODS

Time Period	Parking	Arrival Rates (vehicles/min)		
		Through	Left	Right
1	Yes	12.0	1.2	1.2
2	No	12.0	1.2	1.2
3	No	24.0	2.4	2.4
4	No	0.6	0.3	0.3

The effect of allowing parking can be seen by comparing the delays for period 1 with those for period 2 (Table 4). In particular, links 1 and 3 exhibit marked increases in delay when lanes were effectively reduced to one. Link 5, with its greater green time ratio, is much less affected by the loss of a lane; and movements that shift from three to two lanes because of parking do not experience much increase in delay in the process.

The arrival rates used for period 4 were apparently too small to cause any significant delay (over and above zero-volume delay).

A comparison of the delays for periods 2 and 3 shows the effect of doubling the arrival rates on each link. Although links 2, 4, 5, and 6 still remain well below capacity in period 3, the volume on link 1 has exceeded the discharge capacity of the intersection, resulting in an average delay of nearly two full signal cycles. Link 3, under these conditions, shows an average delay of only half a signal cycle, reflecting the greater capacity obtained by using this signal setting.

TABLE 4

DELAYS ON THROUGH LINKS FOR EACH TIME PERIOD

Link	Lanes	Total Cycle	Green Cycle	Congestion Delay Time (sec) for Time Period Number			
				1	2	3	4
1	2	60	30	150	3	104	0
2	3	60	30	3	2	4	0
3	2	120	60	118	6	60	0
4	3	120	60	6	4	8	0
5	2	120	90	7	3	5	0
6	3	120	90	3	1	4	0

TABLE 5

SUMMARY OF RESULTS FOR BUFFALO, NEW YORK, MICRO-AREA

Time Period	Trip Length		Average Speed (mph)	Percent Vehicles Turning		
	Vehicle-Hours	Vehicle-Miles		Left	Through	Right
5:00-6:30 a.m.	329	3,304	14.4	12.9	70.4	16.7
6:30-7:30 a.m.	564	8,608	15.2	11.9	72.4	15.7
7:30-9:00 a.m.	2,409	26,891	11.1	12.2	72.0	15.8
9:00-10:00 a.m.	712	10,272	14.4	11.9	71.9	16.2

For the second series of tests, a micro-area network was prepared for a portion of downtown Buffalo, New York. In the absence of much of the detailed data needed to complete the network, many link and intersection characteristics had to be estimated. The trip files in these tests were derived from the 1962 O-D survey conducted by the Niagara Frontier Transportation Study (NFTS).

The main purpose of this series of tests was to study the behavior of the model in a real downtown area. Although no traffic flow data were available by time-of-day with which the model's results might be compared, it was hoped to find agreement on some of the broader parameters of network performance.

The results obtained from four time periods, which included the morning peak period, are given in Table 5.

The average speeds obtained in this run are substantially in agreement with those obtained in the NFTS driving time survey (16 mph during off-peak hours), and exhibit the decrease expected during the height of the morning peak period. The percentages of turning vehicles also agree very well with those obtained in other studies.

Although the number of tests made so far on the micro-assignment model is insufficient to be the basis for any dramatic claim on its behalf, the results must be regarded as an encouraging indication of its potential.

REFERENCES

1. Creighton, Hamburg, Inc. Micro Assignment—Final Report. Bureau of Public Roads Contract FH 11-6755, Washington, D.C., 1969.
2. Gazis, D. C., et al. The Delay Problem for Crossing an n-Lane Highway. Proc. Third Internat. Symp. on the Theory of Traffic Flow, 1965. Elsevier, New York, 1967.
3. Greenshields, Bruce D., and Weida, F. M. Statistics—With Applications to Highway Traffic Analysis. Eno Foundation for Traffic Control, Saugatuck, Conn., 1952.
4. Adams, W. F. Road Traffic Considered as a Random Series. Jour. Inst. Civil Engineers (London), Vol. 4, 1936.