

On-Line Generation of Synthetic Origin-Destination Counts for Application in Freeway Corridor Traffic Control

M. VAN AERDE, J. VOSS, AND G. NOXON

A need exists during the application of freeway corridor control models to determine the prevailing origin-destination (O-D) matrices for each time slice during the peak period to be analyzed. As it is virtually impossible to obtain these matrices directly by survey, a fully automated approach is proposed that would use Freeway Traffic Management System (FTMS) data already being collected. This approach relies on existing algorithms for formulating synthetic O-D counts from observed link flows, but uses a special relationship that exists between O-D matrices for consecutive time slices to carry out these computations more efficiently and often also with greater accuracy. The general background to the problem and the general solution approach that has been proposed are discussed. Subsequently, several different analysis runs using the proposed approach are described that were performed with data for the Burlington Skyway FTMS system in Ontario. The results of these runs illustrate the details of the technique and demonstrate the main reasons for the improved efficiencies and accuracy. The paper is concluded with a discussion of how the procedure can be further refined and implemented in both its off-line and on-line modes within existing FTMS installations.

During the past decade a number of techniques were developed for estimating synthetic origin-destination (O-D) demands from observed link flow counts. Such techniques proved to be efficient and cost-effective in generating the demand data required for transportation planning studies, when either direct survey methods were impractical or too expensive. In freeway corridor problems, all assignment-based control models require that the traffic demands are also expressed as O-D flow rates for the freeway corridor (I). However, because of the operational rather than planning character of the analysis, a sequence of O-D matrices is required to express the changes in traffic demand during the peak period that is analyzed. Consequently, a number of O-D matrices must be derived, rather than just one single matrix.

Such a sequence of O-D data is difficult and expensive to obtain for use with off-line simulation models. Furthermore, at present it is virtually impossible to obtain such O-Ds on-line for use with real-time traffic control or diversion models. We propose a technique that can efficiently generate this sequence of O-D matrices on-line using real-time data. The technique is based on a special relationship that exists between O-D matrices for consecutive time slices. The objective of

this paper is to show the feasibility of the technique, to illustrate its results and limitations, and to outline how the technique could be used in practice.

PROCEDURE FOR GENERATING AN O-D MATRIX FOR ONE TIME SLICE

The procedure for generating synthetic O-Ds was developed based on an existing algorithm by Van Zuylen and Willumsen (2).

Synthetic O-Ds in Transportation Planning

Many techniques exist for developing synthetic O-D data from link flows. Examples of these, which have been applied in a transportation planning context, include a generalized least-squares estimator (3), Bayesian statistical approach (4), constrained regression (5) and information minimization-entropy maximization (2,6).

The general procedure involved in applying these methods is illustrated in Figure 1. As shown, the inputs to the analysis consist of a network description file, a set of convergence criteria, a series of minimum path trees, a list of observed link flows, and an optional seed matrix. Within the analysis, the minimum path trees are used to determine which O-D pairs contribute to which link flows, and with the simpler algorithms only one path is allowed between each O-D pair. As there are many more variables than constraints to this problem, there are numerous different mathematical solutions possible. The derivation of a mathematical solution that closely matches the "correct" matrix is therefore assisted considerably if the algorithm is provided with a priori knowledge of the general travel pattern structure in the form of a seed matrix. This seed matrix is used to initiate the solution search and it reduces the number of required algorithm iterations. As it will also impart its general structure onto the final solution matrix, this seed matrix consistently results in a much improved final O-D matrix estimate. The quality of the generated matrix is ideally determined by measuring the deviation between the predicted O-D cell values and the actual O-D counts. However, as the technique is intended to be used

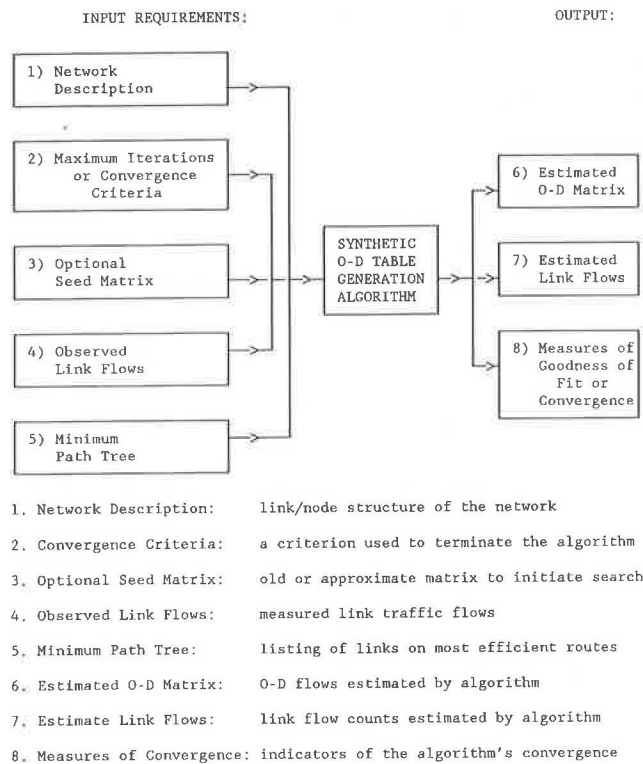


FIGURE 1 Basic procedure for generating synthetic O-Ds.

when actual O-D counts are not available, the next-best quality indicator is the ability of the matrix to reproduce the original link flows.

Selection of a Suitable Method to Generate an O-D Matrix

Of the available synthetic O-D techniques, the information minimization-entropy maximization algorithm by Van Zuylen and Willumsen (2), revised by Van Zuylen (6), was considered most suitable for the intended use. The principles and steps of this algorithm are well documented, and a version of the algorithm implemented in the ME2 model has been satisfactorily validated by Van Vliet and Willumsen (7).

The above algorithm determines the most likely O-D matrix by solving for the matrix that minimizes the information contained in the final O-D matrix. The actual solution algorithm is derived by formulating a linear equation that considers each link flow to be a result of a series of trips between all O-D pairs that have routes utilizing that particular link. For O-D cells that use multiple paths, the appropriate proportions utilizing the link along each path are expressed as probabilistic fractions. In the case of an "all-or-nothing" assignment, these probabilities end up being either zero or one, depending on whether a given link was used or not. The entire problem formulation is then a series of linear equations, including an objective function that maximizes the entropy measure of the trip matrix and a number of constraints arising from the observed link volumes.

Computer Implementation of the Selected Algorithm

The revised information-minimization algorithm (6) was implemented as a new computer program by Noxon (8) to allow model inputs that are compatible with the INTEGRATION (9) simulation model. The resulting program, called SODGE (synthetic origin-destination generator), requires three essential input files. The first is a network description file, which lists the network links. The second file contains the link traffic flows, whereas the third contains a minimum path tree matrix for the given network conditions. Two other input files are optional, namely a seed O-D matrix and the actual O-D matrix, if available. The former assists in initiating the search among the range of feasible solutions, whereas the latter, if known, allows the user to check the accuracy with which a true matrix can be recreated.

As SODGE was developed to provide O-D counts to the INTEGRATION simulation model, the network description file for both models was formulated for dual compatibility. In addition, the SODGE link volume and minimum path tree input files were configured such that they could automatically be generated using INTEGRATION. Consequently, a given network could be analyzed using INTEGRATION to determine minimum path trees and link flows, and with these SODGE could be run to retroactively determine the most likely O-D matrix governing the network's operation (Figure 2). This procedure was first used to determine the reliability and accuracy with which SODGE could reproduce a known matrix, supplied only with link flows and minimum path trees. However, in practice SODGE would be used to generate an estimate of the unknown O-D matrix for use within the INTEGRATION model, which in turn would evaluate different network control strategies.

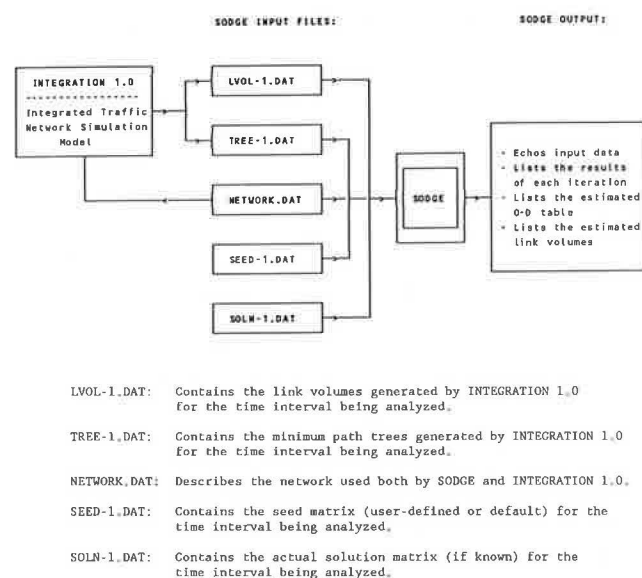


FIGURE 2 Synthetic O-D generation procedure utilized by SODGE.

SODGE Measures of Convergence

To monitor and evaluate the convergence of the SODGE algorithm, the program calculates three statistical indicators at the conclusion of each iteration. The first measure is the root mean square difference (RMSD) between the cell values of successive iterated solution tables. This value decreases as successive iterations produce more similar solution tables such that deviations between cell values for successive iterations are minimized. The second measure is the root mean square error (RMSE) between the observed link flows and the link flows that are produced by feeding the iterated trip table back into the network. These two statistical measures are produced for each iteration in all cases. The third indicator is the RMSE (in percentage form) between the cell values of the current trip table estimate and those of the actual trip table, if the latter is provided by the user.

If no solution matrix is available, convergence to a solution may be indicated by a stabilization of the trip cell RMSD figure between consecutive iterations. However, the algorithm tends to give a series of RMSD stabilizations at different levels of actual convergence. It is thus better to judge convergence using the link flow RMSE, which will consistently stabilize at the optimal convergence. Convergence of link flows indicates that the matrix, although perhaps not the exact one, can reproduce the observed link flows at a desired level of accuracy. In practice, the actual matrix is of course always unknown, as it is the object of the search. However, during the testing of SODGE, the search for a known O-D matrix was performed to determine the likely range of errors and problems associated with searches in practice where the true matrix is unknown.

APPROACH FOR SEQUENTIAL GENERATION OF ON-LINE O-D COUNTS

The previous section indicated how the SODGE implementation of Van Zuylen's (6) synthetic O-D generation technique could be used to automatically interact with INTEGRATION to derive one O-D matrix at a time. In this section we discuss how the same procedure can be used to derive a series of consecutive O-D matrices for an entire peak period.

Methodology

As the traffic demands within a peak period are not necessarily uniform, no single O-D table can accurately represent the demand pattern over the whole period. Therefore, the entire peak period to be analyzed is broken down into a series of consecutive time slices, each time slice having its own separate O-D table. As a first step, one could generate the O-D matrices for an entire peak period by simply running SODGE for each time slice by itself, without accounting for any interactions.

However, as the generation of an O-D matrix from scratch involves a large number of iterations, and as the quality of an O-D matrix generated without some reliable a priori knowledge is usually not very high, further significant performance enhancements are possible. These involve the use

of the previous time slice's O-D matrix as the seed for the derivation of the next time slice's matrix. This approach is illustrated in Figure 3 for a sample sequence of two consecutive time slices.

Consequences

If there is any relationship between the true O-D matrices of consecutive time slices, the O-D estimate of the first period will make a much better seed for the second stage than would a random or uniform seed. The first consequence of this is that fewer iterations would be required to estimate the next matrix. This is an important efficiency if these O-D estimates are to be made based on on-line traffic counts in real time. More importantly, if the O-D matrix estimated for the previous time slice was a good fit, its use as a seed should also considerably improve the accuracy of the O-D prediction for the next time slice.

If there is a consistent nontrivial relationship among a time-series of O-D matrices, this technique would efficiently retain the general structure of the O-D pattern over the entire period. However, it would also selectively scale the entire matrix or selective entries in the matrix, in view of any changes in observed link flow counts. The result would be more accurate on-line O-D estimates that are responsive to real-time traffic flow counts provided by FTMS detectors.

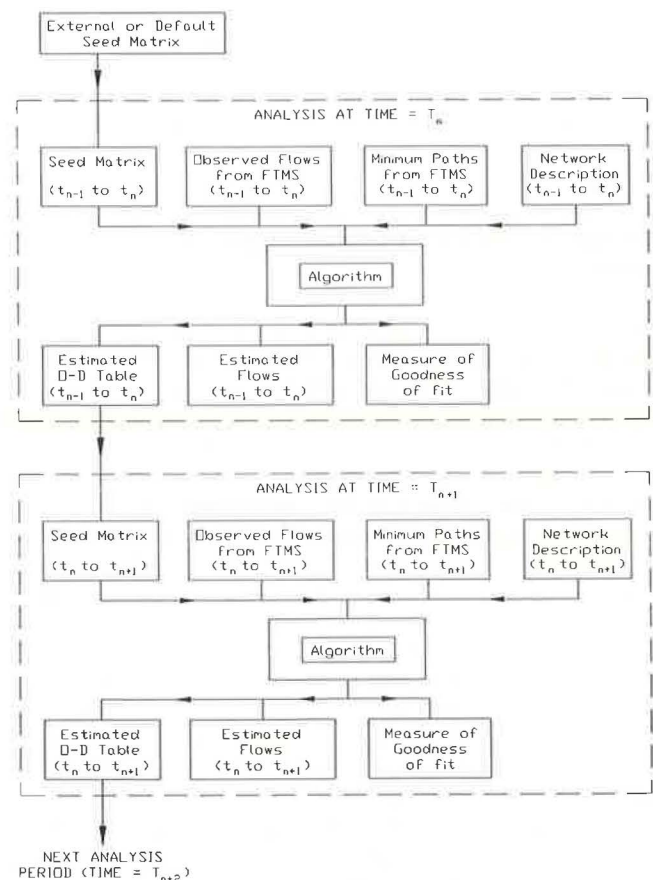


FIGURE 3 Proposed on-line synthetic O-D generation procedure.

In an off-line situation, the above features permit an efficient and economical estimation of a sequence of O-D matrices that reproduce the link flows that are observed during the peak period. In addition, when the technique is applied using on-line data, it will estimate in real time the unique O-D matrices for a particular day's peak period in view of the unique traffic flows that are observed on that particular day.

Description of the Test Network and its FTMS

To illustrate the potential of the on-line O-D generation technique, some sample test runs were performed using data for the Burlington Skyway FTMS on the Queen Elizabeth Way (QEW) between Toronto and Niagara Falls, Ontario. The general location of the Burlington FTMS system is shown in Figure 4.

The QEW is a major provincial highway between Toronto and Niagara Falls and cuts across the Hamilton Harbor at the west end of Lake Ontario. As the freeway crosses the Burlington Canal via the Burlington Skyway Bridge, its final configuration will provide three fully detectorized lanes in each direction. In addition, a four-lane arterial highway parallel to the QEW provides a second route, which acts as a diversion alternative in case of an incident on the bridge (10). This diversion route is signalized and fully detectorized.

At the time of this study, only the detectors for the southbound portion of the system were fully operational, as the northbound portion of the system was still under construction. Consequently, the test runs on the Burlington Skyway only considered the southbound traffic network and traffic demands.

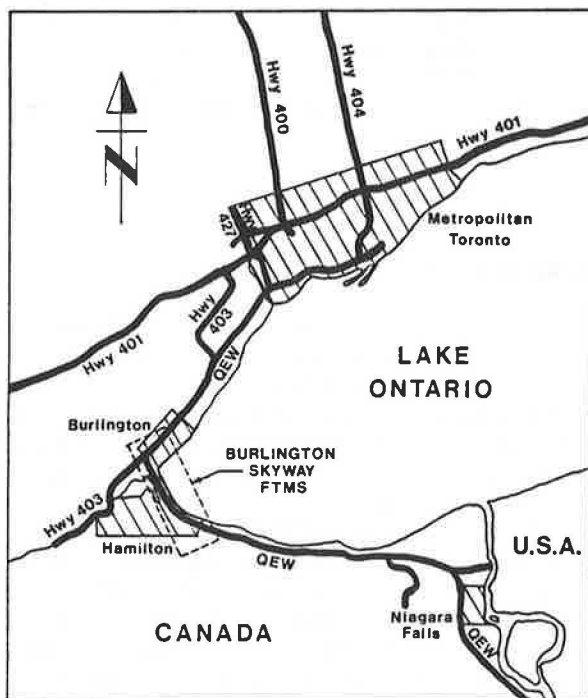


FIGURE 4 General location of the QEW and the Burlington Skyway FTMS.

The southbound Burlington Skyway network was coded and digitized in March, 1988, using 100 links and 73 nodes, of which 10 were also zone centroids (Figure 5).

Details

During the trial evaluation of this procedure, a number of details had to be resolved, such as the duration of the time slices and the updating rate of the minimum path trees.

A time slice duration of 15 min was considered to be short enough to allow the capturing of dynamic changes in the O-D pattern, while also providing sufficiently stable link flow counts to SODGE. The whole 2-hour peak period analysis was thus based on an eight-slice simulation of a typical peak period. The objective was to determine if the sequential estimation procedure could successfully back-calculate prevailing O-D patterns and their changes.

Because the current version of SODGE is set to evaluate flows for all-or-nothing route assignments, INTEGRATION was used to assign traffic flows to all-or-nothing assignments for 15 min at a time. In addition, because INTEGRATION starts its evaluations with networks that are initially empty, a state of equilibrium was allowed to develop during the first 15 min before any link summaries were computed. This time allowed all O-D patterns to fully propagate through the network, since the maximum trip length in the network was about 8 min. Finally, to provide an analysis of equilibrium conditions, all signal timings were held constant during the entire 2-hour peak period.

RESULTS OF ON-LINE O-D GENERATION TESTS

The potential of the proposed approach was assessed using a systematic evaluation of four sets of related experiments. A description of these experiments is provided below, and the results are summarized in Tables 1, 2, and 3.

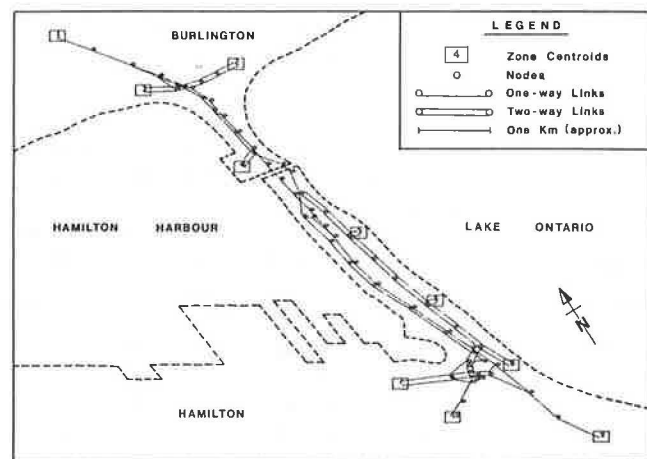


FIGURE 5 Network representation of southbound Burlington Skyway FTMS.

TABLE 1 CONSTANT O-D DEMAND PATTERNS FOR THE ENTIRE 2-HR PERIOD

TIME PERIOD	RUN A			RUN B		
	O-D Demand constant			O-D Demand constant		
	Initial seed = 100 Epsilon = 0.1			Init. seed = Act. soln. Epsilon = 0.1		
	# OF ITER	FLOW RMSE	OD TABLE RMSE %	# OF ITER	FLOW RMSE	OD TABLE RMSE %
1						
2	10	5.65	46.73	2	5.74	2.95
3	2	9.73	47.41	2	10.26	4.82
4	3	8.81	43.59	3	8.80	4.97
5	4	10.19	47.26	4	10.54	6.53
6	4	10.33	45.19	4	10.66	7.02
7	4	8.73	46.17	4	8.39	4.82
8	4	8.53	46.00	4	8.43	5.62

TABLE 2 INCREASED O-D DEMAND PATTERN FROM TIME 1.0 HRS TO 1.5 HRS

TIME PERIOD	RUN G			RUN D			RUN F			RUN H		
	O-D Demand varies			O-D Demand varies			O-D Demand varies			O-D Demand varies		
	Constant seed = 100 Epsilon = 0.1			Initial seed = 100 Epsilon = 0.1			Init. seed = Act. soln. Epsilon = 0.1			Each seed = Act. sol Epsilon = 0.1		
	# OF ITER	FLOW RMSE	OD TABLE RMSE %	# OF ITER	FLOW RMSE	OD TABLE RMSE %	# OF ITER	FLOW RMSE	OD TABLE RMSE %	# OF ITER	FLOW RMSE	OD TABLE RMSE %
1												
2	10	5.65	46.73	10	5.65	46.73	2	5.74	2.95	2	5.74	2.95
3	10	8.35	47.22	2	9.73	47.41	2	10.26	4.82	2	9.11	4.57
4	12	10.96	43.83	3	8.81	43.59	3	8.80	4.97	2	10.37	5.02
5	9	115.03	66.48	8	121.37	67.57	8	121.97	47.85	10	109.86	43.77
6	13	15.07	48.28	8	21.40	48.35	8	21.27	22.34	4	11.62	6.21
7	9	110.32	65.54	10	115.76	65.68	10	116.86	64.60	10	108.70	61.95
8	10	11.78	45.61	8	17.03	44.53	10	12.82	5.54	2	10.24	5.33

TABLE 3 INCREASED O-D DEMAND PATTERN WITH EPSILON = 0.01 RATHER THAN 0.1

TIME PERIOD	RUN E			RUN I		
	O-D Demand varies			O-D Demand varies		
	Initial seed = 100 Epsilon = 0.01			Each seed = Act. sol Epsilon = 0.01		
	# OF ITER	FLOW RMSE	OD TABLE RMSE %	# OF ITER	FLOW RMSE	OD TABLE RMSE %
1						
2	18	6.70	46.93	9	7.05	3.54
3	9	7.94	47.54	10	8.06	4.16
4	9	9.62	43.92	9	9.50	4.60
5	16	113.15	66.26	17	113.27	44.60
6	16	13.92	48.31	12	13.21	5.73
7	17	111.71	65.17	16	112.25	63.11
8	16	10.45	45.76	10	9.64	4.90

Experimental Trial I

The first experiment consisted of runs A and B, where the INTEGRATION simulation model was used to simulate traffic conditions on the Burlington Skyway for a constant demand O-D matrix for 2 hours. Link flow and minimum path tree estimates were generated by the simulation model for each time slice, after the initial 15-min start up, and these files were analyzed using SODGE.

Run A used a uniform seed O-D matrix for the first time slice, whereas run B used the actual O-D matrix as the seed. The results, which are shown in Table 1a, indicate three important facts. First, the analysis of the first time slice with a uniform seed matrix requires many more iterations (10) than any of the subsequent time slice analyses (2–4). This indicates the efficiencies that are achieved if the solution matrix for a previous time slice is used as a seed matrix for a subsequent time slice. Second, even though run B was provided with the

actual solution matrix, the O-D table it estimated was not exactly the same as the one that was used in the simulation model. The main reason for this difference is the presence of traffic signals in the network, which cause link arrival and departure rates to be nonuniform. This discrepancy is also shown by the lack of a perfect convergence of the link flows.

Finally, even though the link flows in runs A and B converged to roughly the same link flow error level, the deviation from the actual true matrix was much larger for the analysis seeded with a uniform matrix (43 to 47 percent) than for the analysis that was seeded with the true matrix (2 to 7 percent). This indicates that two solutions can have comparable link flow convergences but still differ substantially in their agreement with the actual matrix.

Experimental Trial II

Although runs A and B were based on the simulation model outputs for a constant traffic demand pattern, runs G, D, F, and H considered a traffic demand pattern that was constant for 1 hr, increased for certain O-D pairs for 30 min, and then returned to its original state for the final 30 min. The original and the changed O-D matrix are presented in Tables 4a and 5, whereas the consequent statistics for each of these runs are illustrated in Table 2.

After 1 hr, the INTEGRATION simulation model increased the vehicle departure rates at the respective origins immediately, but all relevant link flows did not increase until these vehicles reached those links downstream. Consequently, there

TABLE 4 ORIGINAL O-D MATRIX FOR TIME 0-1.0 HRS AND 1.5-2.0 HRS

Destinations across											
Orig down	1	2	3	4	5	6	7	8	9	10	SUMS
1	0	180	180	60	60	60	180	60	900	180	1860
2	0	0	180	30	30	30	90	30	90	90	570
3	0	180	0	30	30	30	30	30	90	30	450
4	0	0	0	0	60	30	30	30	30	30	210
5	0	0	0	0	0	0	60	0	60	60	180
6	0	0	0	0	0	0	60	60	60	60	240
7	0	0	0	0	0	60	0	60	180	120	420
8	0	0	0	0	0	60	60	0	0	60	180
9	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0
SUMS	0	360	360	120	180	270	510	270	1410	630	

TABLE 5 MODIFIED O-D MATRIX FOR TIME 1.0-1.5 HRS

Destinations across											
Orig down	1	2	3	4	5	6	7	8	9	10	SUMS
1	0	240	240	60	60	60	360	180	1200	300	2700
2	0	0	240	30	30	30	90	30	90	180	720
3	0	240	0	30	30	30	30	30	90	60	540
4	0	0	0	0	60	60	30	30	60	60	300
5	0	0	0	0	0	0	60	0	60	60	180
6	0	0	0	0	0	0	60	60	60	60	240
7	0	0	0	0	0	60	0	120	240	240	660
8	0	0	0	0	0	60	90	0	0	120	270
9	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0
SUMS	0	480	480	120	180	300	720	450	1800	1080	

is a lag in the response of the link flow rates, which at worst is equal to the travel time between the two most separated O-D pairs, or approximately 8 min. This lag implies that the link flows for these time slices would be a weighted average of the previous time slice's O-D rate and the new O-D flow rate. This so-called "transient" effect should disappear in the second time slice after the change.

Run G (Table 2) provides the results for an analysis where the SODGE routine was seeded with a matrix of uniform cell values (equal to 100) for each time slice. As the analysis starts from scratch at the start of each time slice, the number of iterations stays relatively high (9–13). Also, because of the presence of transients, the link flows of time slices 5 and 7 are shown to converge very poorly, and the estimates of the O-D matrix in each case are also less accurate. These results should be compared to run D, where SODGE was seeded with a uniform matrix, but was allowed to use its predicted O-D matrix from each time slice as a seed for the next time slice. Both the flow and the O-D cell errors are shown to be the same as for run G, but the number of iterations required to find this comparable solution is usually reduced.

Run F analyzes a situation where the seed provided to the first time slice is the actual solution matrix, whereas the O-D of each subsequent time slice is then calculated using the previous slice's solution as its seed. This results in a reduced number of iterations for the first time slice analysis, and a consistent number of iterations for all the subsequent time slices. Similarly, the degree of convergence of link flows is roughly the same, as is the increase in the link flow error during the transition periods. However, the agreement with the actual O-D table is much better for run F, even after the two major changes in the traffic pattern. The importance of a good seed matrix to initiate the analysis of the first time slice is emphasized in run F. The knowledge of the underlying pattern appears to be of considerable assistance, even after the matrix has undergone a change.

Finally, in run H SODGE was provided with the correct seed matrix for each time slice. The results are the best of any of the runs, but some error still remains, especially during the transient periods. When the SODGE performance in run F is compared against that in run H, one finds that relatively good results can be achieved by seeding only the first time slice with the actual matrix. An overview of the relationships among the results for runs G, D, F, and H (all in Table 2), is provided in Figure 6. The results for runs A and B (Table 1) are compared to the results for runs D and F (Table 2) in Figure 7.

Experimental Trial III

The third experiment involved an analysis of the implications of utilizing a different epsilon value for identifying the onset of convergence. Runs E and I have results very similar to runs D and H, respectively, as shown in Figure 8. Dropping the epsilon from 0.1 to 0.01 significantly increased the number of iterations, marginally increased the degree of flow convergence, and has only a negligible effect on the accuracy of the estimated O-D table.

Consequently, the use of an epsilon value of no smaller than 0.1 seemed appropriate for the tests carried out using

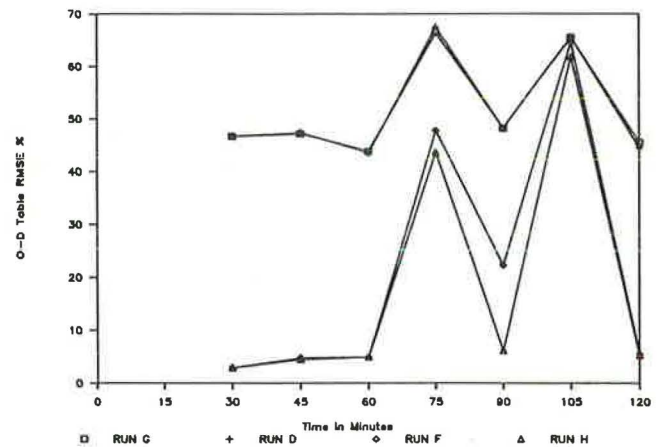


FIGURE 6 Comparison of fit for different seed matrices.

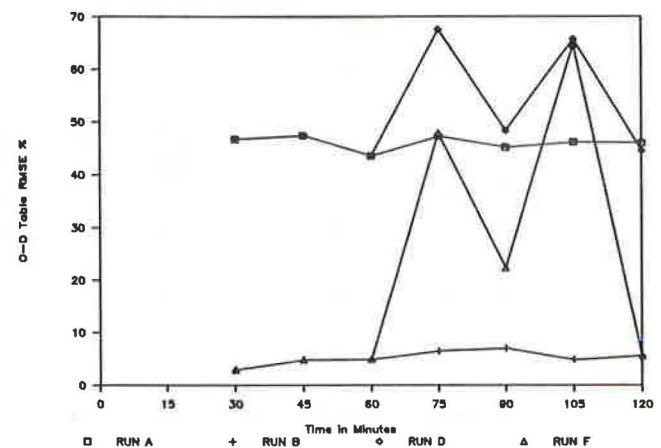


FIGURE 7 Comparison of fit for constant versus changing demands.

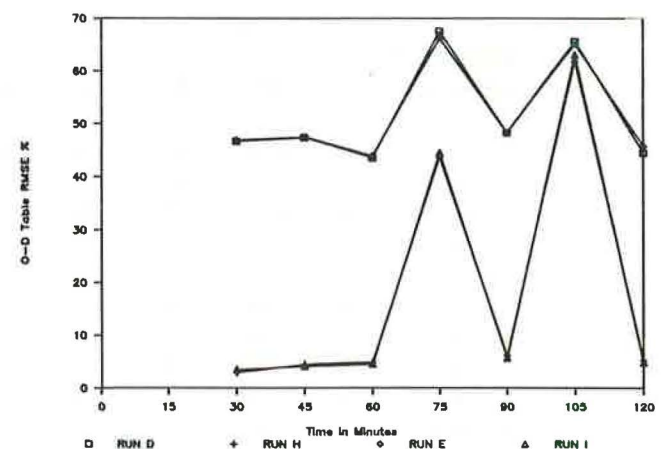


FIGURE 8 Comparison of fit for two different stopping criteria.

this network. However, this value is likely to be different for different networks and perhaps even for different traffic conditions. Epsilon should therefore be nondimensionalized and expressed in a format that is unbiased by the scale of the network and its traffic pattern.

Experimental Trial IV

The fourth and final experiment involved an analysis of the implications of using a 5-min versus a 15-min analysis interval. This analysis allowed for a more microscopic look at the dynamic behavior of the traffic within the network, and the consequent implications for the on-line generation of O-Ds. The traffic flow rates on four different links in the network are shown in Figure 9 (top).

When one compares the increase in traffic volume on the freeway links (L8 and L10), to the increases on the surface streets (L6 and L23), it is apparent that the traffic increase on the freeway is much more pronounced than on the surface streets. This is to be expected, as the change in the O-D pattern affects primarily the freeway trips.

When one compares the first freeway link (L8) to the last freeway link (L10), one can also detect the lag in the transient

effect for the downstream link (L10). This lag is approximately equal to the travel time from zone 1 to zone 9. It significantly complicates the synthetic O-D analysis, as the effect of a change in O-D pattern cannot be detected on the final downstream link until about 10 min after the O-D pattern has changed. Synthetic O-D solutions based on traffic flows during this initial 10-min transient would therefore incorrectly allocate the increased flows, on the first few links, to the same origin but a nearer destination. Of course, after a decrease in traffic flow for an O-D pair, the reverse effect would take place.

The results for the iterative SODGE application every 5 min are illustrated in Figure 9 (bottom) and Table 6. This analysis was initiated with the correct seed matrix after 20 min, and all subsequent applications of SODGE were then seeded with the O-D solution matrix from the previous 5-min period.

As shown, during the first 60 min, the number of iterations, the link flow error, and the O-D matrix error vary somewhat about a relatively stable average value. Then, after the increase in the O-D matrix at time 60 min, the dramatic transient results in a considerable error in the link flow convergence and the O-D matrix estimation during the next two 5-min time periods. Subsequently, the solutions generated by the algorithm again stabilize, until the O-D demand is dropped after 90 min.

Although the link flow error peaks for the time slice that is 5 to 10 min after the change in O-D flows occurs, the O-D matrix error has already begun to decrease significantly. Consequently, during the time slice that lasts from 10 to 15 min after the O-D flow increase or decrease, the O-D matrix provides a good fit once again.

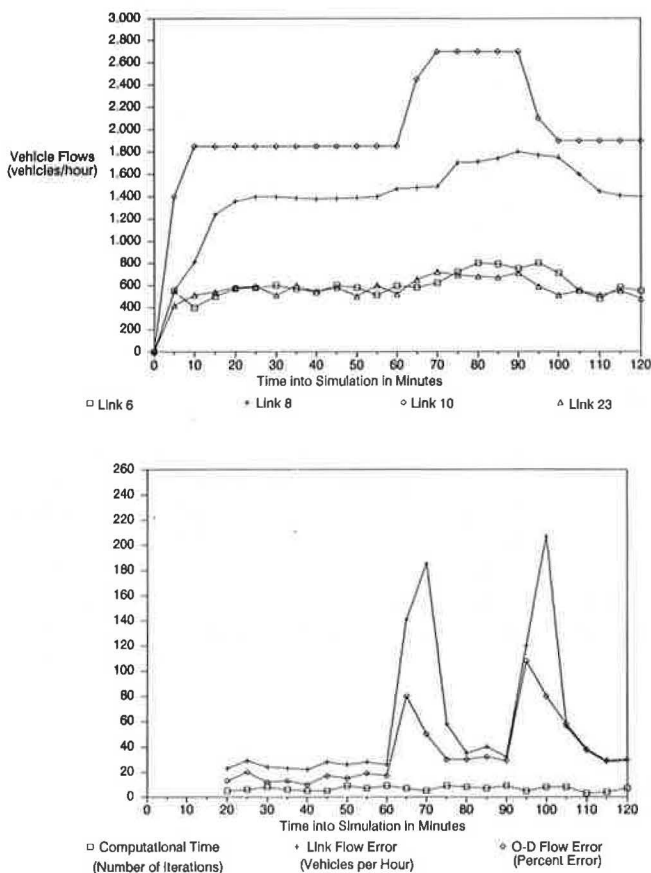


FIGURE 9 Change in 5-min flow rates on links 6, 8, 10, and 23 (top) and results for 5-min intervals and correct initial seed (bottom).

TABLE 6 RESULTS FOR 5-MIN INTERVALS AND CORRECT INITIAL SEED

TIME SLICE	TIME (Min)		NUMBER OF ITERATIONS	LINK FLOW ERRORS	O-D TABLE ERROR (%)
	FROM	TO			
1	0	5			
2	5	10			
3	10	15			
4	15	20	5	23.0	14.3
5	20	25	6	28.8	20.9
6	25	30	9	24.7	13.3
7	30	35	6	24.0	14.3
8	35	40	5	23.0	10.3
9	40	45	5	28.0	17.8
10	45	50	9	25.2	14.7
11	50	55	6	28.6	18.4
12	55	60	9	24.2	13.4
13	60	65	7	141.3	78.1
14	65	70	6	184.8	49.2
15	70	75	10	55.8	26.3
16	75	80	9	37.4	26.4
17	80	85	8	43.7	28.0
18	85	90	11	34.4	24.4
19	90	95	6	119.0	105.9
20	95	100	10	206.4	76.9
21	100	105	10	54.9	22.8
22	105	110	4	33.8	11.5
23	110	115	5	23.6	16.8
24	115	120	9	25.5	14.9

DISCUSSION OF THE RESULTS AND THEIR SIGNIFICANCE

In most network-oriented traffic management studies it is important to determine the prevailing O-D traffic demands during a peak period in order to estimate the indirect diversion impact of any proposed control strategies or to determine the direct diversion impacts of control strategies that are deliberately intended to result in a rerouting of traffic. The need to evaluate the growth and decay of traffic patterns during a peak period requires the analyst to consider the time-varying O-D demands of the network explicitly. As it is either impractical or uneconomical to obtain time-varying O-Ds by direct survey methods, it becomes necessary to use indirect methods. These synthetic O-D methods, although subject to some error and various other technical problems, provide the next-best solution, as often no alternative approach to obtaining these data is available.

Summary of Initial Findings

The results presented here indicate that it is feasible to automatically generate a sequence of O-D matrices for a series of time slices during a peak period. Such matrices can be used in conjunction with freeway control or diversion models for off-line preevaluation of different strategies using historical traffic counts or for on-line generation of diversion strategies using real-time traffic-flow measurements.

The use of a time slice's solution O-D matrix as the seed for the subsequent slice appears to reduce the number of iterations required to achieve a certain level of accuracy, as compared to using a blank or uniform seed matrix for each new time slice. This efficiency in computation time is especially useful in real time control applications.

The use of a sound initial seed matrix at the start of a control period has benefits throughout the entire control period, even if the flow rates for a number of O-D pairs may change significantly. The structure of the initial seed is usually retained throughout the analysis period and assists considerably in selecting the most appropriate O-D matrix from among the often numerous possibilities.

Problems Unique to Synthetic O-Ds for Freeway Control

Traffic demands within congested freeway networks are never in full equilibrium. Instead, they appear to be always in some state of dynamic flux or transition. Consequently, problems arise because of the transients that occur when traffic patterns change, as these changes require a finite period of time to manifest themselves on all the downstream links that will be used by the given O-D.

Similar problems may also arise when queues cause two different link flow rates along a given path, one on the upstream end of the bottleneck and one on the downstream end. In this situation, the synthetic O-D program may mistake the resulting traffic flow observations as being indicative of two short trips rather than one long one.

It is expected that in practice the transient effects discussed here may not be as drastic or dramatic as the nearly instantaneous 50 percent increase in traffic flows that we used in this report. In actual networks it is more likely that traffic demands will change gradually during a 15- to 30-min period, in which case the problems generated because of transients will be lessened, and perhaps become insignificant.

Recommended Further Work

The proposed procedure should be implemented using real data from an FTMS and urban traffic control system (UTCS) and compared to the O-Ds as estimated from a detailed driver survey. However, it is likely that in practice the true O-D matrices will never be available for use in assessing the quality of the solutions obtained. In this case, the relative magnitudes of the errors, as estimated in the sample runs discussed here, could be a guide as to the likely margin of error that would be present in situations where the true matrix is unknown.

To address some of the transient problems, it may be helpful to use the algorithm with fractional "link use" probabilities. In this case, the path that is taken by vehicles between a given O-D pair may be assigned decreasing-use probabilities along its length to reflect the decreased likelihood that the effects of the shift in that O-D demand have propagated a certain distance away from its origin. Similarly, different probabilities may be assigned to links before and after a bottleneck location to indicate the fraction of drivers from a particular O-D pair that are likely to be stuck in the queue.

Finally, it is proposed that the analysis discussed here be repeated for a wider corridor in which more alternate routes are available. Although it would be much more difficult to trace the causes and effects of any transients, this type of network application would be more representative of corridors in which one freeway can be avoided by traveling on any one of up to three or four alternate routes.

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