Application of Dynamic Assignment in Washington, D.C., Metropolitan Area

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A study in which the dynamic assignment model 3DAS was used as a planning tool is described. The Virginia part of the Washington, D.C., metropolitan area was chosen for the study. This area offers a heavily congested urban network with several rerouting possibilities. On the basis of available data it was decided to calculate a morning peak hour from 5:00 until 11:00 a.m. in 24 periods of 15 min each. The results show that the use of dynamic assignment for planning purposes can be very helpful. Dynamic assignment gives more detailed information than static assignment methods about the occurrences of traffic jams, and a more precise location and cause of congestion can be identified. Advanced traffic management system measures, introduced to alleviate the congestion, can be simulated, and all kinds of evaluations are possible, such as influences on travel time and jam length and effects of ramp metering and rerouting. Dynamic assignment, however, requires more accurate data and more computing time. Also very important is the ability to visualize the results. A dynamic assignment model gives flows in time. The best way to analyze the results is to present them in a movielike fashion. This requires a computer with a powerful graphics capability. For advanced traffic management systems to be successful more data and better (three-dimensional) origin-destination matrices are needed. New methods for origin-destination estimation and data from more induction loops and probe vehicles will improve the reliability of the results.

This paper describes a study in which the dynamic assignment model 3DAS is used as a planning tool. The study has two objectives. The primary objective is to find answers to the following three questions:

1. Can dynamic assignment be used for planning purposes?
2. Does dynamic assignment have an advantage above static assignment?
3. Is dynamic assignment a useful tool for investigating the effects of advanced traffic management systems (ATMSs)?

The secondary objective is to gain insight into the possibilities and problems associated with the application of 3DAS on large networks.

The model is applied to the southwestern part of the Washington, D.C., metropolitan area in the United States. This area was chosen because it offers a heavily congested urban network with several rerouting possibilities. Several ramp metering installations are in operation, and parts of the freeways are monitored. The data used for this research were obtained from the Virginia Department of Transportation (VDOT) and the Metropolitan Washington Council of Governments (COG). A small portion of the study area is monitored by induction loops. One-minute data from these induction loops were used to derive the departure time functions and to validate the calculation results.

The research was conducted during a 4-month visit to the Center for Transportation Research at Virginia Polytechnic Institute and State University (Virginia Tech). In accordance with the objectives the study is meant only as an example of the use of dynamic assignment as a planning tool. Because of the lack of data and the short study time the calculated results are not suitable for use in making serious planning decisions. The results, however, do permit one to determine the usefulness of dynamic assignment for planning purposes.

Briefly discussed are the 3DAS model, the research approach, and how the data were derived. Apart from a static assignment, three different scenarios are calculated: a morning peak hour scenario, a scenario with several ramp metering installations, and a scenario with an incident. The results of the model for these scenarios are reported.

3DAS MODEL

The 3DAS model is based on the work carried out by Hamerslag and Opstal (*1*) and Hamerslag (*2,3*). The basic feature of a dynamic assignment model is the partitioning of time into small slices, usually referred to as *periods*. Over the last 2 years the model has been improved, in particular its dynamic aspects. The 3DAS model has been described by de Romph et al. (*4,5*) and by van Grol (*6*).

The model determines the flow distribution in the network with an iterative process. In each iteration the shortest paths in the network are calculated for all origin-destination (OD) pairs and for every departure period. The link parameters are defined separately for each period. The properties of the network and the travel demand are presumed to be given.

The basic iteration scheme in Figure 1 is essentially the same as that for static assignment models. The difference lies in the all-or-nothing-in-time module. In this module an extra iteration over the departure period is needed, and the shortest path must be found and the assignment must be performed in time.

The paths are defined by using the travel time on a link in the period in which the traffic actually traverses the link; that is, the trajectory that the traffic follows in time is calculated. The network is loaded on the basis of these trajectories. During the assignment the contribution of a traveler to the traffic load on a link in a certain period is determined by calculating the duration of the

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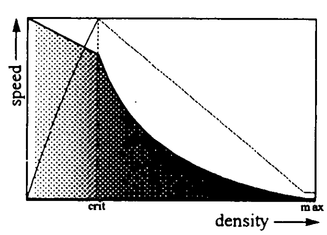
traveler's presence on that link in that period. If one focuses on one traveler, two situations can occur:

1. Several links are covered in one period. In this case the traveler is present on the link for only a part of the period, and therefore should be assigned to the link for only this part of the period.
2. One link is covered in several periods. The traveler is present on the link during multiple periods and should be assigned to the entire link for each individual period.

At the start of each iteration the travel times on the links are derived from the load of the previous iteration. For each link the travel time is calculated with a speed-density function. A relation between speed and density instead of the traditional relation between travel time and flow is used. This allows modeling of a decreasing flow in the case of congestion. The conservation of traffic and the continuity of flow are maintained. In case of overflow the overflow is assigned to the preceding link on the path in the same period. The stop criterion is reached when there is no difference in the resulting flows between two successive iterations.

The 3DAS model has been tested on several small networks (*4*). Several parameters of the model were calibrated by using these networks. The initial settings of these parameters followed from these tests and were not changed for the study described here. A speed-density function of the following form is used:

$$v(\rho) = \begin{cases} v^{max} \cdot \left(1 - \dfrac{\rho}{\rho^{max}}\right) & 0 < \rho < \rho^{crit} \\ v^{max}\, \rho^{crit} \cdot \left(\dfrac{1}{\rho} - \dfrac{1}{\rho^{max}}\right) & \rho^{crit} < \rho < \rho^{max} \end{cases} \tag{1}$$



where

v^{max} = free-flow speed,
ρ^{crit} = critical density, and
ρ^{max} = maximum density.

The maximum density represents a no-motion traffic jam.

RESEARCH APPROACH

In accordance with the objectives of the study, the following research approach was set up. The first objective consists of the following three questions:

1. Can dynamic assignment be used for planning? Dynamic assignment can be used for planning if, given a network and a traffic demand, it can predict a correct distribution of traffic flow. Since for long-term purposes the traffic demand will represent the average demand, the expected traffic distribution will also be average. This is in contrast to real-time applications, when the results should be based on the actual situation at that moment. To validate the model the average traffic demand and a measured traffic distribution averaged over a longer period are required.
2. Does dynamic assignment have an advantage above static assignment? There are several (well-known) problems with static assignment models. A static assignment model

- Can give wrong results when congestion occurs. Because traffic is assigned along the complete route, a car can contribute to more than one congestion at the same time.
- Cannot correctly show the effects of a variable traffic demand.
- Cannot correctly show the effects of temporal disturbances such as roadworks or accidents.
- Cannot predict queue lengths and cannot show how a growing queue can limit the capacity of upstream junctions.

The authors determined whether dynamic assignment can solve these inconsistencies and how it will improve the decision making for planning.

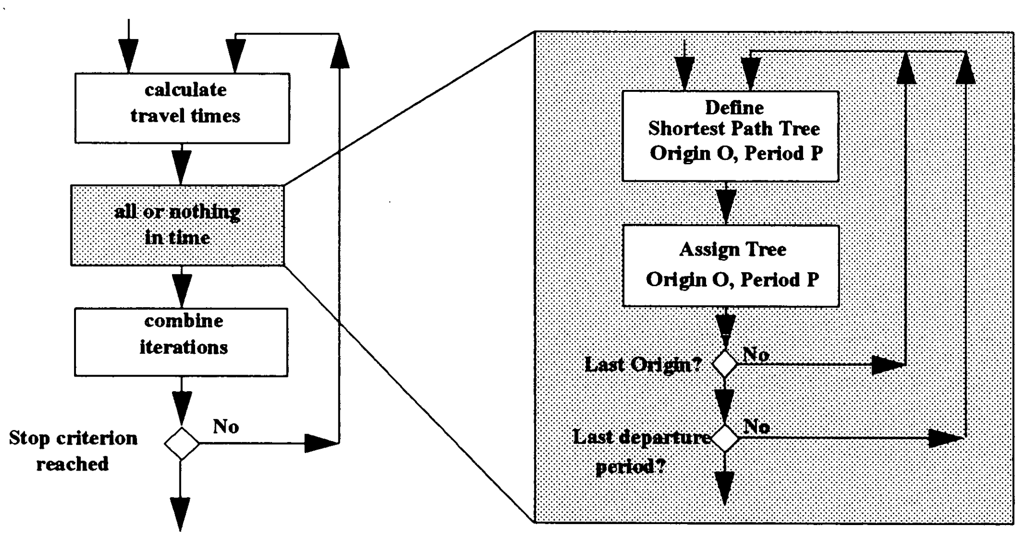


FIGURE 1 Iteration scheme.

3. Is dynamic assignment a useful tool for investigating the effects of ATMSs? The model has been extended to model several ATMS instruments, such as ramp metering, rerouting, and tidal flow. To answer the question two tests were executed. The first scenario considered several ramp metering installations, and the second scenario considered an accident at one of the freeways. For the second scenario the effects of diversion measures are reported.

Since the network used for the study is fairly large the secondary objective of this research, to gain insight into the possibilities of and the problems associated with dynamic assignment applied on larger networks, is also satisfied by the research approach described above.

DATA

The study area covered the eastern part (Virginia part) of the Capital Beltway around Washington, D.C. The major Interstates are I-95, I-395, I-66, and I-495; a large part of the arterial network was also included.

Network

Figure 2 represents the network used for the study. The network consists of 857 nodes and 2,086 links. There are 180 zones. Most freeway intersections are represented in a fairly detailed way. Examples of two of these intersections and their detailed representatives are given in Figure 2. Each line in Figure 2 shows a separate one-directional road consisting of from one to four lanes.

The 2,086 links are divided into 13 types, each representing a certain road type. All of the links in one type have the same attributes. The attribute for the capacity is not given but is derived from the maximum density, the maximum speed, and the speed-density function.

OD Matrix

The network is not accompanied by a matching dynamic OD matrix. This OD matrix must be constructed from other data sources.

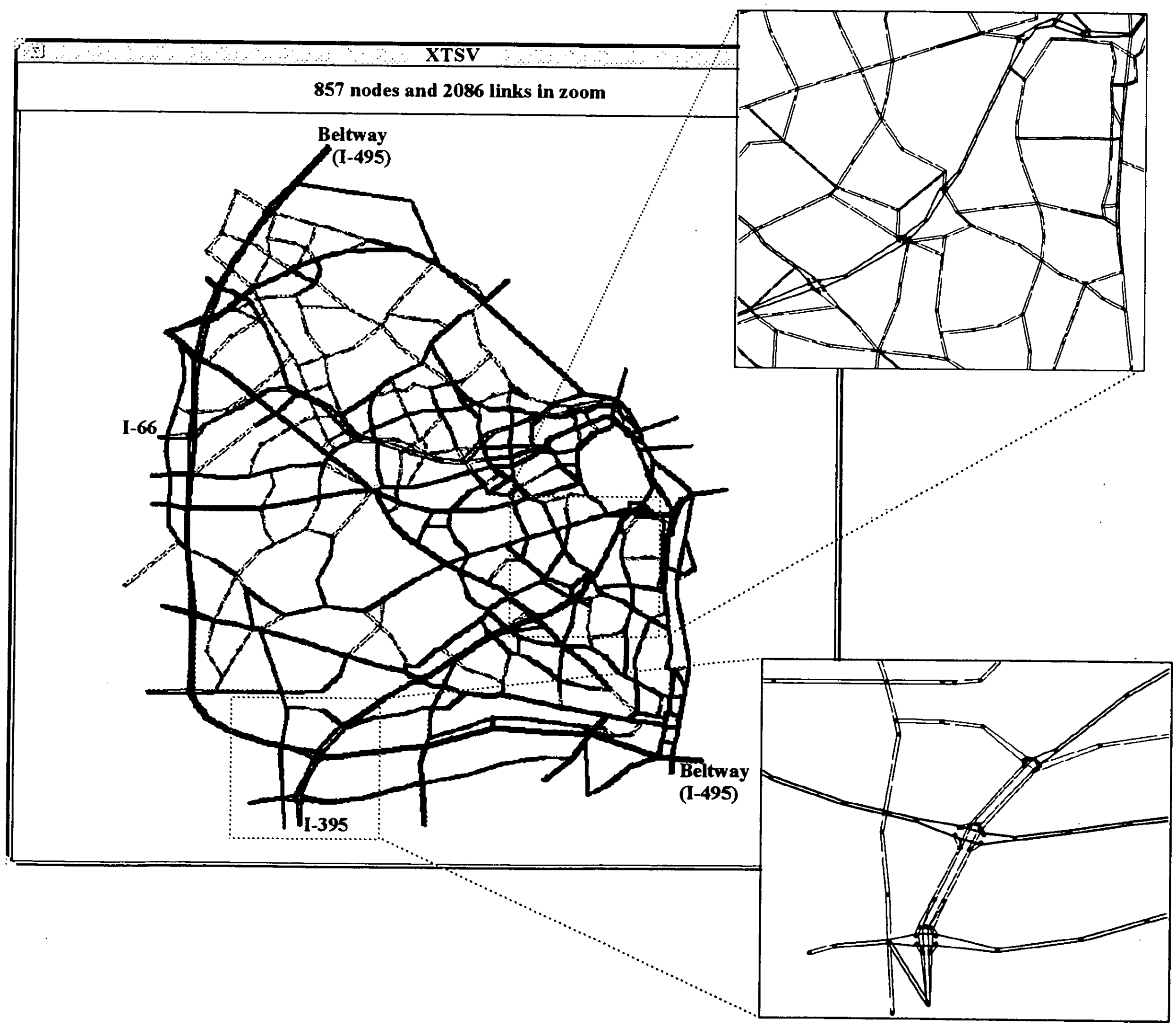


FIGURE 2 Study network.

The best OD matrix available was a (static) 24-hr matrix that covers a much larger area. This OD matrix resulted from a study by COG. The OD matrix for the study area had to be extracted from this OD matrix. To make the OD matrix dynamic, departure time functions were used. A departure time function describes for each OD pair the portions of the amount of traffic departing in each period. These departure time functions can be estimated and calibrated with link volume data.

The COG study (7) was done with 1990 as the base year and comprised 293 districts (1,478 zones), which covers the entire area of Washington, D.C., and several surrounding jurisdictions in Virginia and Maryland. The network covered 5,983 nodes and 18,104 links.

The model used by COG for the trip generation, distribution, and mode choice was a gravity model and was calculated at the distict level. The districts were then split into zones via land use factors. For production these land use factors were based on household and groups-quarter population. For attraction they were based on office, retail, industrial, and other employment. The resulting OD matrix had 1,478 zones.

The network used for the study (Figure 2) is only a part of the COG network, so the OD matrix for the smaller network (180 zones) had to be derived from the large OD matrix (1,478 zones). All trips made within the study network are easily derived. All trips entering, leaving, or passing through the study network were derived by a selected link analysis. To perform the selected link analysis the OD matrix is assigned to the network with a static all-or-nothing assignment. The shortest path is found by using the actual speeds in the network. These actual speeds were derived from the static assignment done by COG. For all OD pairs crossing the selected links the origin and the destination are stored. The entering and exiting links become new origins and destinations, and the trips are summed. By using this method all entering and exiting traffic is aggregated to the links in which it exits or enters the subnetwork.

Derivation of an OD matrix for the subnetwork by this method has one major drawback. Because an all-or-nothing assignment is used no alternative routes are chosen for OD pairs. To minimize the effects of this problem some links are added to the subnetwork to allow a diversion for some origins to different links to enter the network.

Induction Loop Data

The Northern Virginia Traffic Control Center controls a part of the freeway system in northern Virginia. The freeways covered are I-66 and I-395. These freeways are equipped with several hundred induction loops. One minute of data for fixed portion of these induction loops can be downloaded on a data tape. Unfortunately, the Traffic Control Center is not yet fully equipped, and the downloading of data from induction loops is therefore not easy. Only one tape (1-day) was available for the present research. Although the traffic patterns of this 1 day were not sufficient to derive any statistical information, they were the best data available. The tape used for the study contained data measured on Monday, December 7, 1992, from 4:00 p.m. until 11:00 a.m. the next day. The number of vehicles that passed was registered and downloaded every minute.

Figure 3 gives an impression of the traffic patterns at several locations on I-66. The x-axis shows the time in hours. The registration started at 4:00 p.m. and lasted until 11:00 a.m. the next day. The y-axis shows the flow in vehicles per hour. For each direction two graphs are shown. The first graph is located at the beginning of the freeway, and the second graph is located near the end of the freeway. The locations of the induction loops are displayed in Figure 4.

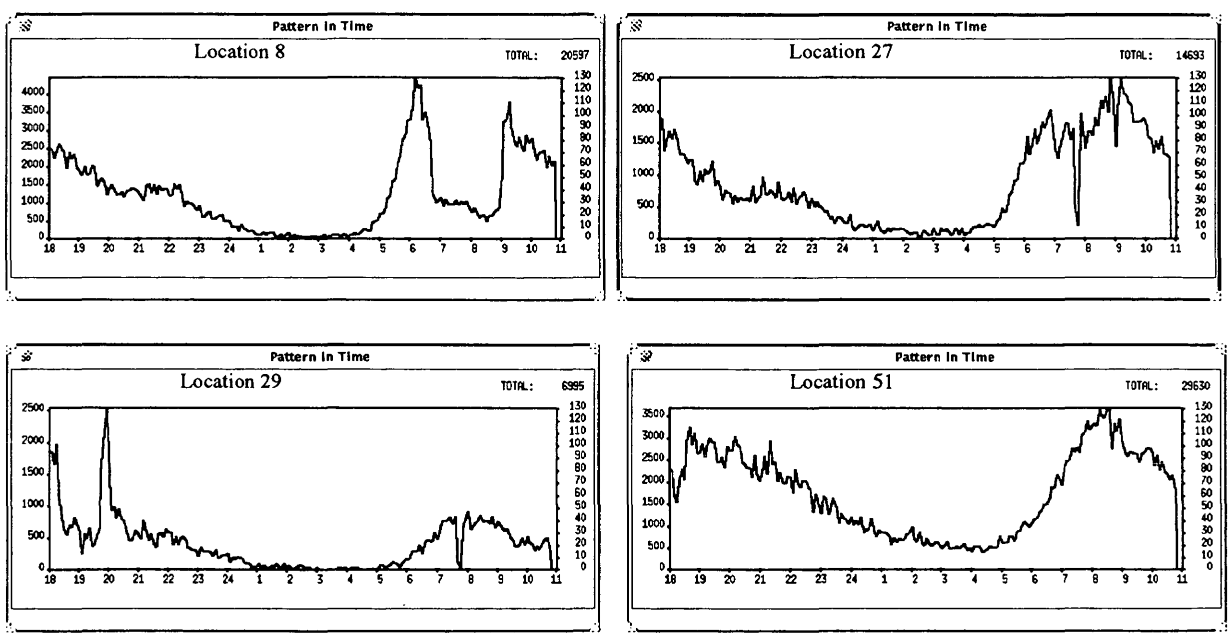


FIGURE 3 Traffic flow from 4:00 p.m. to 11:00 a.m. (next day) for locations 8 and 27 on I-66 eastbound and locations 29 and 51 on I-66 westbound.

Figure 3 shows that the peak hour starts at ±5.00 a.m. At location 8 the flow increases in approximately 1 hr to 4,500 vehicles/hr. At ±6:00 a.m. some kind of congestion occurs and the flow drops rapidly (possibly an incident). After ±9:00 a.m. the flow increases again. The end of the peak hour is at approximately 11:00 a.m. At location 27, which is farther downstream I-66, the flow increases to ±2,500 vehicles/hr. The two graphs for locations 29 and 51 show that the flow on I-66 westbound is lower and that no congestion occurs in this direction. At location 29 the flow increases to ±2,000 vehicles/hr. At location 51 the flow increases to ±3,500 vehicles/hr

On the basis of the induction loop data it was decided to calculate a morning peak hour from 5:00 to 11 a.m. This time period captures the total morning peak hour, and the graphs show that before 5:00 a.m. the network is still reasonably empty. This has the advantage that the calculations can be started with an empty network.

Departure Time Functions

To use a static OD matrix as a substitute for a dynamic OD matrix departure time functions are required. A departure time function is a discrete function that determines for each period the percentage of the OD value that departs during that period. To derive these departure time functions induction loop data can be used.

One departure time function for all OD pairs will not give a realistic representation of the dynamic OD matrix for the peak hour. The departure time functions of individual OD pairs can be quite different. Figure 3 shows that the volume of traffic on I-66 traveling westward is lower in the morning peak hour and higher in the evening peak hour and that traffic departs according to a different departure time function. The same observation ws made for I-395. This requires at least different departure time functions for traffic entering Washington and traffic leaving Washington. For this reason the OD matrix is split into four major trip types. For each type a different departure time function is used.

Use of only four different departure time functions will give a rather rough reproduction of the traffic patterns. This choice was made because of the lack of data that could be used to derive more departure time functions and the lack of data that could be used to evaluate the results. For estimation of departure time patterns more data and maybe some new approaches are desirable.

MODELING AND CALIBRATION

On the basis of the available data it was decided to calculate a morning peak hour from 5:00 until 11:00 a.m. in 24 periods of 15 min each. The total time span of 6 hr captures the total morning peak hour. The period length of 15 min was chosen for practical reasons, that is, to keep the calculation time in bounds. A period length shorter than 5 min is not recommended because it suggests a level of detail that cannot be reached with the available data. A period length longer than 20 min dissipates the dynamics in the traffic assignment too much.

The following four scenarios were considered:

1. The first scenario is meant to achieve a reasonable reproduction of the morning peak hour. The departure time functions are calibrated with induction loop data, and the resulting flows are compared with the induction loop data. By adapting the departure time functions it is possible to reproduce the induction loop data at the beginning of a route. When the flow pattern farther downstream on that route still matches the induction loop data, this is considered a good result. The flow pattern can be tested at several locations on the following time-varying form, the average height of the flow, and the moments of sudden changes in the flow. Since only day of induction loop data was available and no information about weather or incidents was available, these data do not represent an average flow pattern. Only a rough reproduction of volume patterns can be expected.
2. The second scenario is a static equilibrium assignment comparing the results with those of a dynamic assignment. The advantages and disadvantages of time variation are studied.
3. The third scenario introduces ramp metering at all ramps on I-66 eastbound and at all ramps on I-395 northbound. The influences on queue length, travel time, and diversion behavior are investigated.
4. The fourth scenario introduces an accident at one of the freeways (I-66). For this scenario two different situations are calculated. In the first situation the drivers are unaware of the accident. This is simulated by using initial travel times for the section with the accident. In the second situation the drivers are assumed to be fully informed. Here an equilibrium assignment is used.

The third and the fourth scenarios investigate the possibilities of dynamic assignment for ATMSs. The input data used for these scenarios are the same as those used for the morning peak hour scenario (scenario 1). The departure time functions and the OD matrix remain unchanged.

HARDWARE AND SOFTWARE

The model is implemented as an *X*-window program for the UNIX operating system. Several different computers were used to run the program. We used a Silicon Graphics 320VGX or INDIGO, an International Business Machines RS6000, or SUN Sparc2, whichever computer was available at the Laboratory for Scientific Visualization at Virginia Tech.

On the Silicon Graphics 320VGX computer one iteration took approximately 5 min. In one iteration all of the OD pairs are assigned to their time-dependent shortest paths. For this study with 180 zones and 24 departure periods, this resulted in 692,040 OD relations per iteration.

Large arrays of numbers on paper are difficult to interpret, so the visualization of the results is very important. The 3DAS software displays several results in graphic form. For each link the pattern in time can be investigated, and to get an overall impression of the traffic flows, the build-up of traffic jams, and so on, the results are displayed in a movielike fashion. Errors in the input or other anomalities are easily detected by using a good visualization system.

RESULTS

Morning Peak Hour Scenario

On the basis of the OD matrix, the departure time functions, and the network attributes a dynamic assignment was done. Heavy congestion was found on I-66 and I-395 going into Washington, D.C.; low levels of congestion were found at several locations on the beltway and on certain arterials. The movielike representation showed quite clearly where congestion started and how it evolved. To give an impression of the results, the flow patterns at two locations along I-66 (Figure 4) are shown.

Figure 4 shows the flow (intensity) at four different locations on I-66. The x-axis represents the time, and the y-axis shows the flow. Each bar represents a time period of 15 min. The heights of the bars measure the flow, whereas the colors of the bars show the density. Light grey represents a low density, and dark grey represents a high density. By using this representation the difference between a low flow caused by a high density (dark grey) and a low flow caused by a low density (light grey) can be discriminated.

Figure 4 represents the same locations on I-66 as the induction loop graphs in Figure 3.

Comparing the graphs in Figure 4 with the induction loop graphs in Figure 3, a reasonable reproduction of the traffic distribution was found to be possible. On I-66 eastbound, however, the induction loop data show heavy congestion with a low flow (almost zero). On the basis of the low flow downstream, one may assume that there was probably some kind of incident during that day. In the simulation a higher flow downstream was found. If there really was an incident the differences between the model and the induction loop data are explainable. To validate the result the flow pattern on the freeways were compared with the induction loop data at several places along I-66 and I-395. In general a fairly good match at I-66 and I-395 was achieved.

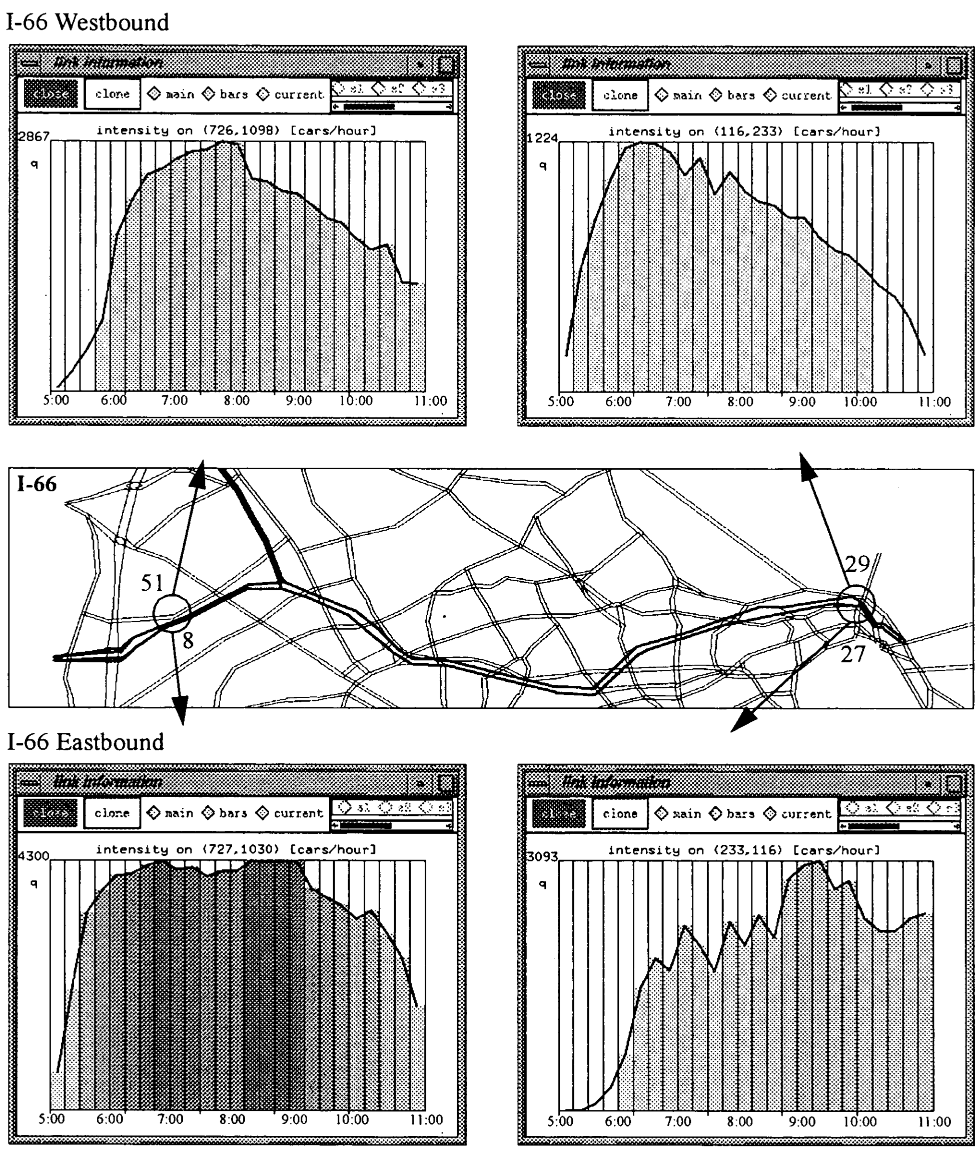


FIGURE 4 Flow calculated by 3DAS for peak hour from 5:00 to 11:00 a.m. at four locations (51, 8, 29, 27) on I-66.

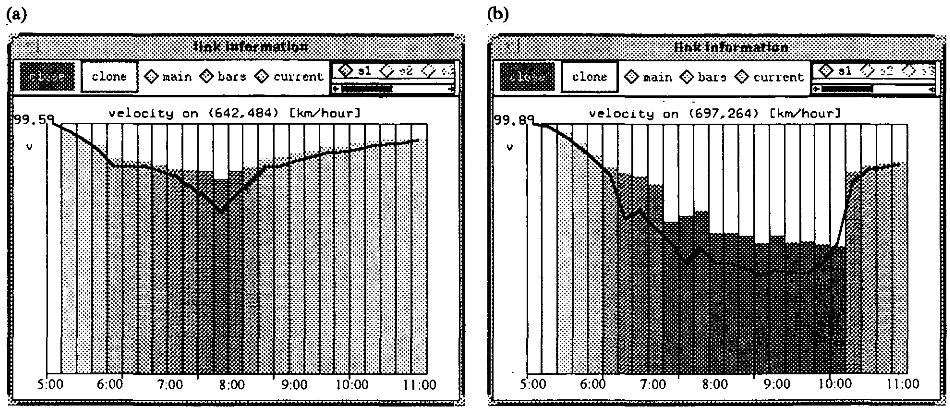


FIGURE 5 Velocity (km/hr) calculated by 3DAS at two locations on I-395. In bars, the ramp metering scenario is displayed. The solid line displays the velocity during normal peak hour.

Since no induction loop data for the arterial system were available, no validation for these sections is possible.

Static Assignment Scenario

The 3DAS model was compared with a static user equilibrium assignment. For the static assignment the results show heavy overload on the entire I-66 and I-395. The results do not point out where the congestion starts, that is, where the bottleneck is located. In particular the downstream occurrences of overflow do not exist because of upstream congestion. For example, on I-66 the dynamic assignment shows congestion on half of this freeway; downstream a free-flow situation exists. The static assignment shows an (incorrect) congestion situation downstream as well. This might result in incorrect planning decision making.

The static assignment did not give any insight into the development of the peak hour as it evolved, and it did not give any information on the lengths of traffic jams or how they evolved. On the other hand the results of a static assignment were much easier to interpret. Many fewer data were produced by the static assignment, and it took a shorter period of time to evaluate the results of the static assignment.

Advanced Traffic Management Scenario

To test whether ATMS strategies can be investigated with 3DAS, a scenario with ramp metering was created. Ramp metering is introduced on all on-ramps on I-66 eastbound and all on-ramps on I-395 northbound. Ramp metering is implemented as a simple maximum flow limit for all on-ramps. Since the shape of the speed-density functions dictates the maximum flow (i.e., capacity), the maximum flow limit is achieved by using different speed-density functions.

Figure 5 compares the ramp metering scenario with the normal scenario. The graphs show speed as the heights of the bars and density as the colors of the bars for the ramp metering scenario.

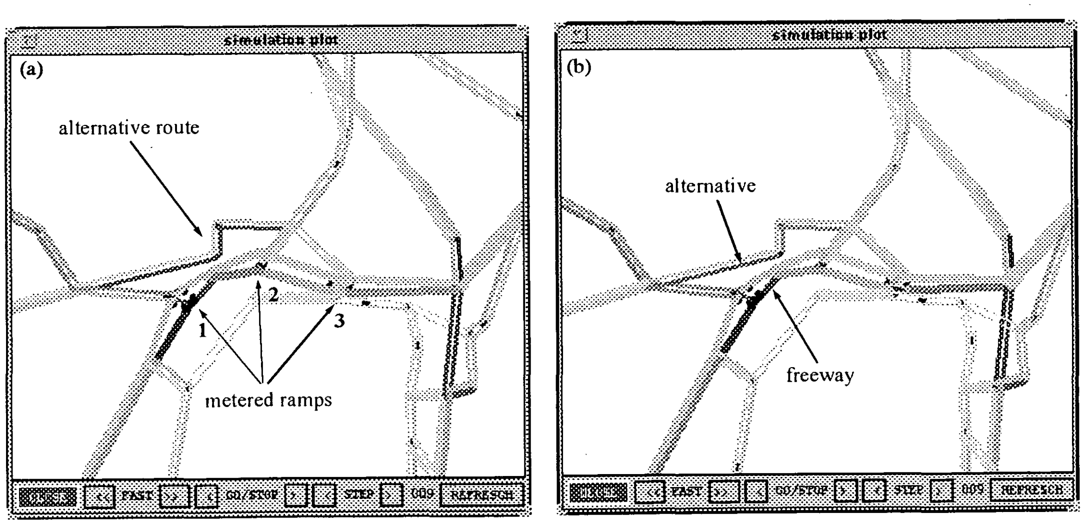


FIGURE 6 Rerouting behavior. Density in 9th period (7:00 to 7:15): (*a*) ramp metering scenario; (*b*) normal peak hour scenario.

The speed results for the normal peak hour scenario are displayed as a solid line in the same graph. The *x*-axis represents time.

Figure 5 shows a location halfway on I-395 and one downstream on I-395. The two graphs demonstrate that there was a noticeable impact. Both locations show slight improvements in speed. In Figure 5(*a*) the temporal decrease in speed at 8:00 a.m. in the normal peak hour (solid line) is no longer there. At the other location [Figure 5(*b*)] there is an improvement in speed almost over the total duration.

Figure 6 shows the impact that ramp metering has on the arterial network. Figure 6 displays a location at the end of I-395.

Figure 6 was chosen to illustrate that because of ramp-metering alternative routes parallel to the freeway could be chosen. Figure 6(*a*) shows a slightly darker grey (higher density) than Figure 6(*b*) on the alternative route. On the freeway a slightly lower flow is detected. The values show that traffic is avoiding Ramp 1 and that a higher density is found on the alternative route.

Accident Scenario

To test whether the effects of incidents can be investigated with 3DAS, an accident was simulated on I-66. The accident was introduced by decreasing the capacity for a link by 60 percent. The OD matrix and the departure time functions were unchanged.

Two different route choice strategies were used. One strategy used the same routes that were chosen during a normal morning peak hour; the other route choice strategy was according to an equilibrium assignment. The first scenario represents a situation in which the accident is unknown to the travelers, whereas the second scenario is one in which each traveler is optimally diverted.

In the first scenario (no diversion) there is a traffic jam at I-66 that grows farther upsteam than in the normal morning peak hour. The average speed of the congested links is very low. Figure 7 shows the situation on I-66. The graphs show the middle section of I-66. The density for each link is represented in grey. The darker the grey, the higher the density and the lower the speed. Figure 7(*a*) shows the situation in the 5th period, and Figure 7(*b*) shows the situation in the 10th period.

In the first scenario the drivers did not divert to a different route because they were not aware of the accident. In the second scenario an equilibrium assignment was used. This means that all travelers were informed about the accident and chose their routes accordingly.

The equilibrium assignment gave some remarkable results. The total length of the traffic jam that started because of the incident did not grow farther upstream than in the normal morning peak hour. Comparison with the normal peak hour shows that the length of the queue is in fact shorter but the average speed is much lower. Arterials around the location of the accident all have heavier loads. Figure 7(*c*) shows I-66 at the 10th period for this scenario.

When the travel times to traverse the entire length of I-66 are compared there is a significant difference between the two accident scenarios. In Figure 8 the normal peak hour travel time is compared with the travel times in the accident scenario and the accident with diversion scenario.

The free-flow travel time on I-66 is 11.5 min. For the normal morning peak hour it takes approximately 18 min to traverse I-66 for traffic that departs at 7:30 a.m. In the case of the accident, when the traffic is rerouted, the travel time increases significantly, although the total length of time of the traffic jam is the same. When the traffic is not rerouted the travel time to traverse I-66 increases to almost an hour for traffic that departs at 7:45 a.m.

Figure 8 shows that the travel time is shortest during a normal peak hour. The scenario with the accident gives a travel time approximately three times as long. When diversion is allowed the travel times are approximately 1.5 times as long. This case shows an improvement of travel time by approximately 50 percent. Of course, this is an extreme case. The worse case is compared with the optimal one, and there seems to be enough capacity on the arterial network, which could not be validated.

CONCLUSION

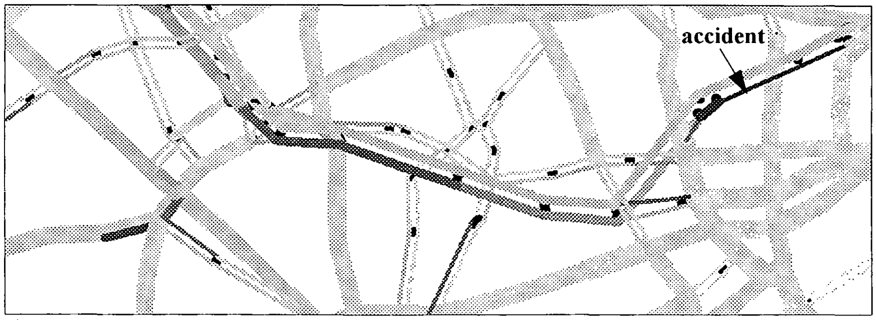
The present study shows that a dynamic assignment model can be very useful for planning applications. A number of clear advantages from using 3DAS instead of static assignment are given. The results give more detailed information about the occurrences of traffic jams, and the location or the cause of congestion can be identified more precisely. To alleviate congestion ATMS measures can be simulated, and all kinds of evaluations are possible, such as the influence on travel time and jam length and the effects of ramp metering and rerouting.

Dynamic assignment also has the advantage that all kinds of temporary disturbances, such as accidents or roadwork, can be simulated and the duration of delays can be derived. The study also showed that 3DAS can be used with larger networks.

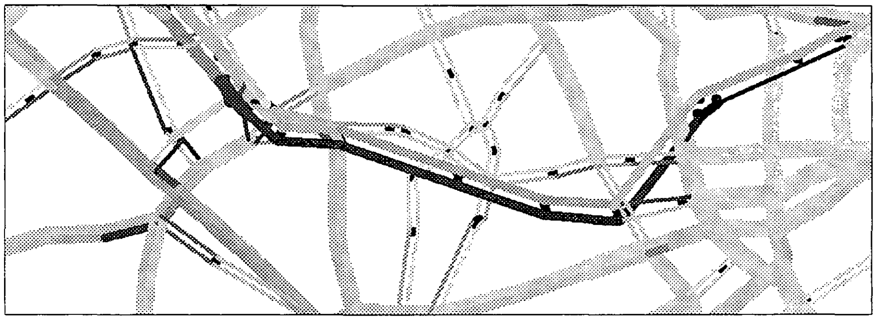
It must be stressed, however, that data requirements are much more stringent. Since by using 3DAS the level of detail is higher, the data must also support this level of detail. The accuracy of the time variance is directly dependent on the accuracy of the time variance of the OD matrix. For the amount of data that 3DAS requires and produces it is essential that a good system of organizing and maintaining this large amount of data be found. In the beginning this may require a great effort, but with increasing experience with 3DAS this disadvantage will probably disappear.

The calculation time required for 3DAS is longer than that required for static assignment. For planning purposes, however, calculation time is not the main concern. Much more important is the visualization of the results. Dynamic assignment gives flows in time. The best way to analyze the results is in a movielike fashion. To do that, a workstation with powerful graphics capability can be used. This is one of the main reasons workstations were used for the research described here. When the model is used for traffic control and real-time management, a faster computation time is needed. This can be achieved by reducing the problem size (smaller network). When this is not possible, a faster computer could be used. The research described by van Grol (*6*) toward the development of special-purpose hardware for assignment calculations provides a cost-effective solution.

In the present specific study the amount and the quality of the data were very poor, and there wre limited possibilities for verifying the data. Since the authors had no insight into the local traffic patterns they could not judge the quality of the OD matrix. The time spent on this research was too short to make any serious planning decisions. The study is therefore primarily meant to investigate the usefulness of dynamic assignment for planning purposes. For real planning decisions a more elaborate study is required.



a)



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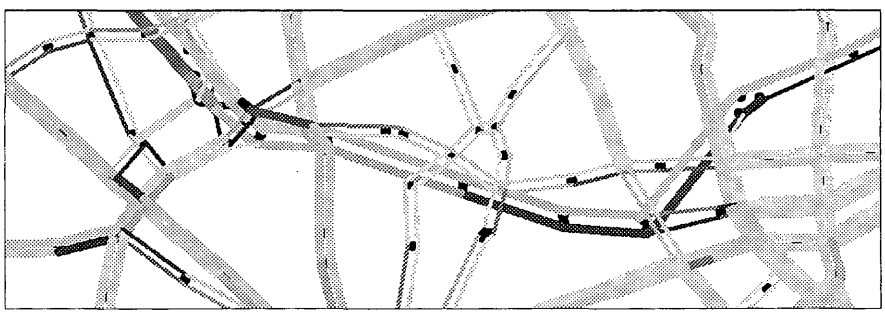

c)

FIGURE 7 Accident at I-66: (*a*) 5th period, 6:15 a.m., no diversion; (*b*) 10th period, 7:30 a.m., no diversion; (*c*) 10th period, 7:30 a.m., with diversion.

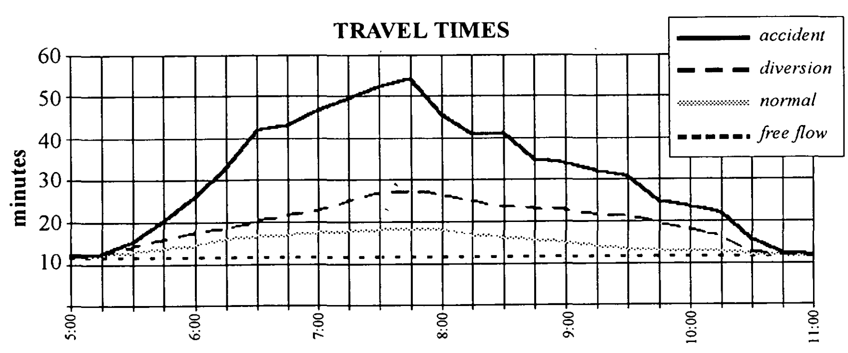

FIGURE 8 Travel times to traverse I-66 for four scenarios: free flow situation, normal peak hour, accident scenario, and accident with diversion scenario.

For ATMSs to be successful there is a large demand for more data and better (three-dimensional) matrices. New methods for OD estimation and data from more induction loops and probe vehicles will provide better results in the future.

With more time, more knowledge of the local study area, and more induction loop data the model has the potential to provide reliable information for real planning strategies and driver information systems.

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