A Research Program for Comparison of Traffic Assignment Techniques

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One purpose of this paper is to describe a computer program that has been prepared to compare techniques of assigning traffic to a transportation network. The program has been prepared principally as a research tool. However, one option permits a new type of assignment technique to be used involving the incremental loading of the network and the use of a generation curve function to revise input interzonal transfers in the event of excessive network overloading.

The program may be used as a research tool to perform a number of experiments on the same network and input data. These include assignment by minimum path trees, assignment by single paths using various increments of interzonal volume, assignment by a combined technique of trees and single paths, and investigation of effects of different random numbers.

•AN INCREMENTAL traffic assignment technique has been incorporated into a more general traffic assignment computer program, which can be used for the comparison of several current traffic assignment procedures. The more general traffic assignment program is termed a research tool as it is to be used in a project to develop a better understanding of the characteristics of both proposed and existing traffic assignment techniques and is not intended to be suitable for immediate use by operational groups for purposes such as large-scale transportation studies.

The more general research assignment program to be described includes the incremental technique as a special case. The research program is very flexible and may be used in a number of ways.

The paper discusses the difficulties inherent in the comparison of traffic assignment techniques and suggests some statistics of program performance as a basis for the comparison of one assignment technique with another.

To establish a framework of reference for consideration of the incremental technique to be described and to show the relevance of a quantitative comparison of assignment techniques, a brief review will be given of the development of traffic assignment and of the techniques now available.

DEVELOPMENT OF TRAFFIC ASSIGNMENT TECHNIQUES

During the development of transportation planning techniques, the use of an assignment procedure has become increasingly important. In the first use of assignment techniques, the volume of vehicles assigned to any particular link in the network often did not correspond with the flows occurring in the real network. However, the technique did provide the engineer with a general indication of the volumes to be expected and the level of service being provided by the network under evaluation. Most of the manipulation of the trips to be assigned was undertaken manually and the engineer was

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able to apply his own judgment at many stages. In 1952 the technique was summed up as follows:

> Traffic assignment is fundamental to the justification of a proposed highway facility and to its structural and geometric design, to spotting points for access and for advance planning of traffic regulation and control measures. As yet, traffic assignment is considered to be more of an art than a science. (12)

Since 1952, the large urban area transportation studies and other planning agencies have developed assignment procedures to the point where less and less emphasis is placed on personal judgment. There are probably three main reasons for this development of more formalized assignment techniques. First, the scale of problems attempted by planning studies has become very large, making manual methods too time-consuming and costly. Second, the general availability of high-speed electronic computers permits the engineer to use more involved approaches to problems for less cost and time than previously. And third, the attempts to formalize other phases of the transportation planning process are aimed at the development of an integrated set of prediction models for the evaluation of alternative combinations of land use and transportation facilities.

The result of this intensive development activity has been the creation of several different traffic assignment techniques. The first of these is the diversion curve technique in which the total number of trips between an origin and destination are divided between two routes, one of expressway characteristics and the other an arterial or equivalent highway (9, 10, 11). The technique originated as a solution to the problem of locating a single expressway relative to some existing highway. The diversion curve is based on data obtained from observations at some other location where two "similar" facilities exist. Curves have been developed for various parameters, such as time saved by using the expressway, ratio of time by expressway to time by alternative, and similar expressions for distance; in some cases curves have been developed relating the cost differences between using the expressway and some other facility. In each case, the curve indicates for a given value of the parameter used, such as time saved, the percentage of drivers who will use the expressway.

If suitable data can be found, the diversion curve approach is quite workable for a small network where only one additional expressway-type facility is being considered. However, in large networks, where the system effects are significant, other forms of assignment are required. Perhaps the first alternative to the diversion curve technique was the "all-or-nothing" or "desire" assignment technique used in the Detroit Transportation Study in 1958 (1). In this procedure, the total interzonal transfer is assigned to the minimum time path between a zone pair. No account is taken of the capacity of the system between a zone pair during the assignment. The technique is termed desire assignment since it shows the volumes that would occur if everybody could choose the shortest route through an unloaded or constant travel time system. Frequently in practice, this amount of capacity cannot be provided in one corridor and the procedure does not effectively utilize all facilities in the network. The results of this type of assignment are not particularly useful in evaluating the performance of economically feasible networks.

The next development was an attempt to account for the capacity of the system, which clearly restrains the number of vehicles that can use any particular corridor and, in fact, the whole system. Each program that has included this feature has done so in a different way, but all of the techniques are generally referred to as "capacity restrained." There are four techniques, each of relatively recent origin, so no attempt will be made to rank them in historical order.

In the U. S. Bureau of Public Roads assignment technique an all-or-nothing procedure is used without changing the link speeds during the execution of the assignment. On completion of one assignment the volume-capacity ratio is determined for each link, and the link speed is obtained from a function relating volume-capacity ratio to speed.

The assignment is then repeated using the revised link speeds and the new volume-capacity ratios computed. The procedure is repeated until the speeds at the beginning of an assignment approximately equal the speeds obtained from the volume-capacity ratio-speed curve at the conclusion of the assignment.

In the traffic assignment technique developed by the Chicago Area Transportation Study, the capacity restraint option operates on a zonal basis (2, 3). One zone is randomly selected from the possible loading zones, and the minimum path tree is determined from the selected zone to all other zones. All trips from the selected zone are then assigned to the minimum path defined by the tree. The network is then updated with new travel times calculated for the links in the minimum path tree according to a relationship between speed and volume. The procedure is now repeated with the random selection of one of the remaining loading zones and the computation of a new tree. The assignment is complete when each loading zone has been selected as the origin for a minimum path tree. The procedure does not involve any iteration since the network is updated before the computation of each tree, and the speeds will always be related to the link volumes. The Chicago technique also includes the computation of the interzonal transfer from the opportunity model.

Traffic Research Corporation has developed a traffic model incorporating both distribution and assignment phases (4, 5). An initial set of minimum path trees are computed for the network using travel times based on an unloaded network. These trees are then employed to make an initial trip distribution using the gravity model and an initial assignment using an all-or-nothing technique, keeping the link times constant during the execution of the assignment. A series of curves relating unit travel time in minutes per mile to volume in vehicles per hour is then employed to determine new link travel times from the assigned link volumes. The new link travel times are used for the computation of a revised set of minimum path trees. A new distribution of trips is computed and an assignment is made: trips are assigned to the original and revised minimum paths in proportion to the travel times over the two routes. At the completion of the second assignment, the link travel times are again revised using the unit travel time-volume relationship. These new link times will be used to repeat the whole procedure with up to four routes possible between each origin and destination. The assignment procedure is concluded when the total number of vehicle hours of travel in the system becomes approximately constant.

A technique developed at Wayne State University also involves a series of iterations (6). The first assignment is made using the all-or-nothing technique with travel times based on typical speeds for the facilities in the network. At the completion of the first assignment, the volume on each link is expressed as a percentage of the capacity of the link and used to modify the link travel time in the following expression:

$$V_i = e^{(R_i - 1)} V_o \qquad (1)$$

where

V_i = travel time on link for a given iteration,

R_i = ratio of volume assigned (average from all previous iterations) to capacity; and

V_o = original travel time based on typical speed.

The second iteration of the assignment consists of computing new trees based on the revised travel times and assigning the traffic evenly over the old and new paths. At the end of the second iteration the travel times are revised using Eq. 1. Smock describes the continuation of the procedure as follows:

> For the third pass the same procedure is followed, and such passes can be repeated, dividing interzonal volumes over more and more paths, until capacity-adjusted speeds, on the average, come to approximately typical speeds. The two measures of speed will converge as assigned

> volumes converge on capacities. This particular type of "convergence" will happen quickly when the network provides sufficient capacity exactly in the places where it is needed, and will never happen completely if the network does not contain sufficient capacity for the volumes assigned to it. (6)

It is evident from the foregoing brief summary that there are several traffic assignment techniques currently available. Each of the techniques that has included a capacity restraint has done so in a different way. Although a lot can be said, and has been said, about the different techniques in a qualitative manner, there is little, if any, quantitative data showing the results of using different techniques on the same problem. Arguments for or against a particular technique are often academic and philosophical in nature, and may leave the practicing engineer or planner confused. In the following sections of this paper we will describe an iterative assignment technique which, while of interest in itself, has been extended to a more general assignment program suitable for making a number of useful comparisons between some of the existing traffic assignment techniques.

AN INCREMENTAL TRAFFIC ASSIGNMENT TECHNIQUE

When an engineer uses traffic assignment, he is attempting to simulate the manner in which drivers will use the network under evaluation. An assignment technique must, therefore, be designed to reproduce the decision-making behavior of drivers choosing routes. At the present time there is not a complete understanding of the manner in which drivers make this decision. It is fairly evident that a number of factors are involved and, from the survey data available, travel time appears to be the most predominant factor. Hence, assignment techniques have been developed which assign all of the trips, between an origin and destination, to the shortest time path.

However, to assign all drivers to the minimum time path is often unrealistic in terms of our knowledge and experience of the operation of existing systems. As noted previously, there are two assignment techniques that use several alternate paths between an origin and destination. In essence, there is a conflict between using an assignment principle, that of minimum time, and obtaining results that correspond with the operation of a real network.

It seems likely that this conflict occurs because the assignment program is basically a static technique attempting to simulate a dynamic system. The driver about to make a trip must, consciously or subconsciously, assume that all other drivers have made their decisions as to which route to take, and base his own decision on his knowledge of the system in its present state. This knowledge will consist principally of his previous experience in the network. The behavior of the total population of drivers can perhaps be summarized as follows: each driver attempts to minimize his own travel time, given the state of the system as he sees it, but as drivers enter the system at various times, the state of the system is constantly changing. Therefore, at different times different routes will have the shortest travel time. From this initial statement one may further postulate that given these decision conditions, the travel time over all the reasonable alternatives, between any origin and destination, will be approximately the same for a system carrying a significant volume. If this were not so, then under the decision framework postulated, drivers would switch routes until this "equilibrium" condition was achieved. Several researchers have for some time felt that equilibrium condition of a network is true of real systems (7).

To reproduce this behavior exactly in an assignment technique would probably require more knowledge of the time distribution of trips than we have currently available and would involve a rather large computer program. However, the following incremental technique may, in fact, assign vehicles to a network in such a way that these conditions of network equilibrium are fulfilled. We would hasten to point out that it has not been proven that other assignment techniques do not fulfill this condition, since it is difficult to come to any rational conclusions without experimenting with the techniques themselves.

The incremental assignment procedure consists of five phases:

1. The random selection of a zone pair;
2. The determination of the minimum time path between the zone pair;
3. The use of a generation rate characteristic to determine the potential volume to be assigned between the zone pair;
4. The addition of a small increment of the potential volume to the minimum path; and
5. The use of a volume-delay characteristic to update the travel times of the links in the minimum path due to the increase in volume.

These five phases are continually repeated until, for each zone pair, the traffic assigned is equal to the interzonal potential volume determined from the generation rate characteristic. The procedure is summarized in Figure 1 and is described in detail in the following paragraphs.

The input assumed to be available for the program consists of five groups of data.

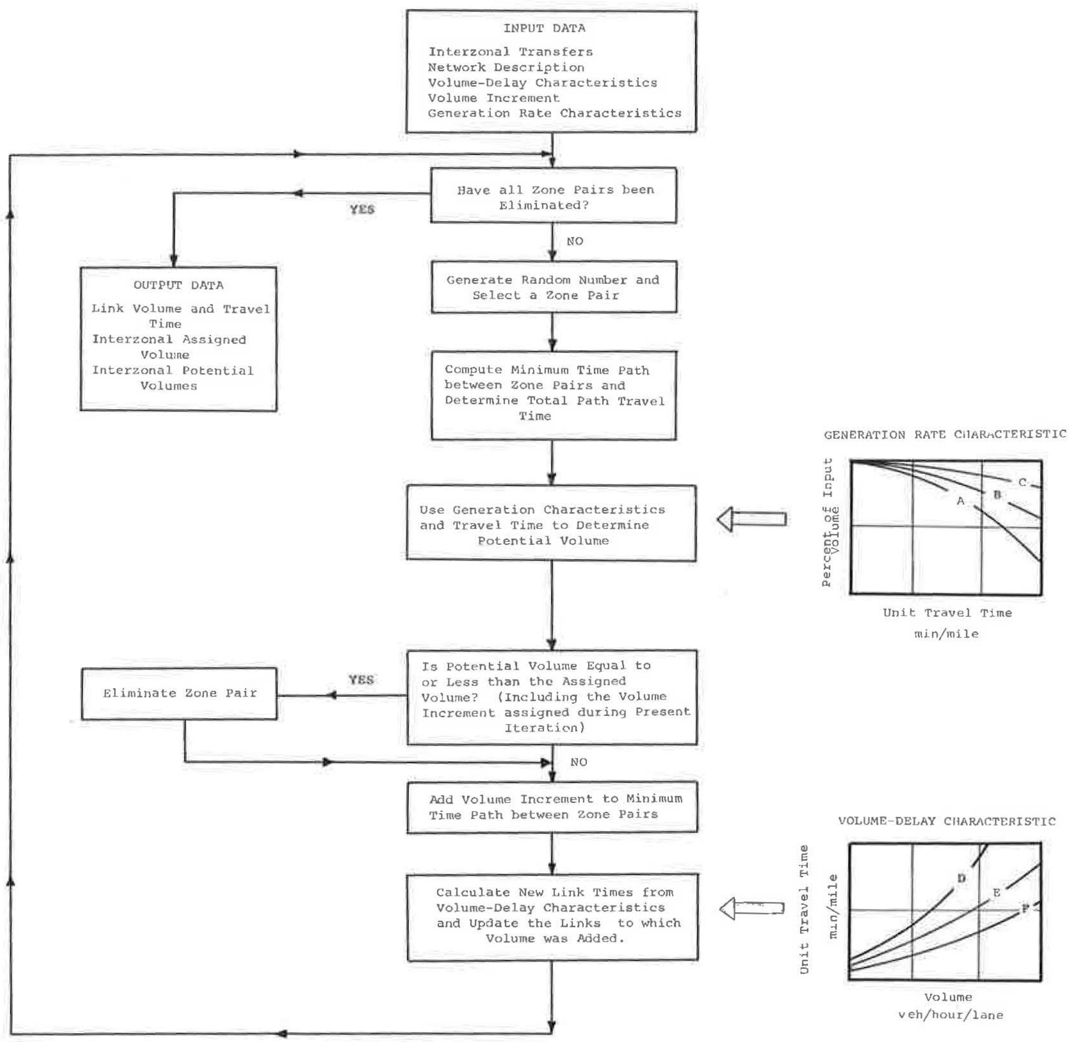

Figure 1. Summary of incremental assignment procedure.

1. Potential interzonal volumes—assumed to have been prepared by a distribution model such as the gravity model, using ideal travel times to measure the interzonal separation. They are termed potential volumes since they are based on ideal travel times which will change during the loading of the network. The potential volume will then also be changed.
2. Network description—includes the identification of links by node numbering, the lengths of the links, the number of lanes of road in each link, and the type of road each link represents.
3. Volume-delay characteristics--relationships between link travel time (min/mi) and link volume (veh/hr). There is a separate curve for each type of road designated in the network.
4. Volume increment—a variable set by the user, indicating either the percentage of an interzonal transfer to be assigned on each iteration of the program or the absolute number of vehicles to be assigned on each iteration of the program, for example, 200 vehicles.
5. Generation rate characteristics—indicating the percentage of the input interzonal potential volume that will be realized as a function of the unit travel time between zone pairs (which is an indicator of network congestion).

The procedure commences with the generation of a random number used to select a zone pair from a table indicating those zone pairs to be assigned. The minimum time path is then determined between the zone pair. This is not a complete minimum path tree, but just that portion required to determine the minimum path between the two zone pairs (8).

The minimum path time is used to compute the unit travel time (min/mi) between the zone pair. The generation rate characteristic is now entered with this time to obtain the percentage of the input interzonal potential volume that will be realized at the given level of network congestion. At the beginning of the assignment the figure will probably be 100 percent. Thus, if the input potential volume was 1,000 trips, the result of the generation rate curve inspection is that 1,000 trips are still to be assigned between the zone pair being considered. The procedure now continues, and a check is made to determine the volume that may have been assigned between the zone pair on previous iterations. Obviously, on the first iteration this will be zero, so the volume increment as specified by the input data will be added to the minimum path between the zone pairs. Thus, if the input had specified a 10 percent increment, 100 trips would be added to the minimum path. If the input had specified an increment of 200 trips, then 200 trips would be added to each link on the minimum path.

If the assignment procedure had already completed many iterations, it is quite likely that trips would have already been assigned between the zone pair, and it is also possible that the network has become relatively congested. Thus, reconsidering the previous example, the generation characteristic may have indicated that only 95 percent of the input interzonal potential volume should be assigned, i. e., 950 trips in this example. On inspection of the trips already assigned it is found that 800 of these 950 trips have been previously assigned. Thus, if the 10 percent increment is being used, a further 100 trips will be added to the current minimum path between the zone pair. If the 200-trip increment is being used, only 150 trips will be added to the minimum path; the zone pair will be considered fully assigned, and the corresponding entry will be removed from the table of zone pairs to be assigned.

After an increment of volume is assigned to the minimum path, the volume-delay characteristic is used to determine the new link travel time, corresponding to the link volume resulting from the addition of the increment. The volume-delay curve used will depend on the type of highway the link represents, as specified by the input data. It is, therefore, possible for several different curves to be used along the total length of a minimum path.

As soon as the network has been updated, the procedure returns to the initial phase, the generation of a random number for the selection of a zone pair. The procedure is repeated with zone pairs picked randomly from the table of available zone pairs. As zone pairs become fully assigned, their entry is removed from the table of available zone pairs and, therefore, the assignment is complete when the table is empty. Any one zone pair may be considered, and in general will be considered, several times during the course of the assignment.

To clarify the concept of the incremental technique further, the volume-delay characteristic, the incremental loading and the generation rate characteristic will each be discussed in more detail.

VOLUME-DELAY CHARACTERISTIC

The purpose of the volume-delay function is to relate the travel time over a link to the volume assigned to the link. At the beginning of an assignment the travel time over a link will correspond to the time required to travel the length of the link at the posted speed limit. As traffic is assigned to the link, the volume-delay function is used to increase the travel time over the link. For low volumes this increase is relatively small, although it may be enough to change the minimum path between a zone pair. As the volume reaches the operating capacity of the link, the travel time begins to increase significantly. If the volume exceeds the operating capacity of the link, the travel time will increase rapidly. The general form of the volume-delay curve is shown on the flow chart in Figure 1, where unit travel time (min/mi) is plotted vs volume (veh/hr/lane). The volume-delay characteristic is a link characteristic and will have a different shape, depending on the physical properties of the link and the form of traffic control.

INCREMENTAL LOADING

The incremental loading affects the operation of the procedure in several ways. Basically, it is an attempt to load the network in a balanced manner so that all regions of the network approach the fully loaded condition at the same time. The incremental loading permits several paths to be used between each origin and destination, makes the inclusion of the volume-delay characteristic more significant, and probably permits the network to be loaded in such a manner that the network equilibrium condition mentioned previously will be obtained.

These features can perhaps best be illustrated with the aid of a simple example. Let us consider two zones connected by three fairly direct routes: A, B and C. At the beginning of the assignment the travel times over the routes are as follows: A, 9 min; B, 11 min; and C, 12 min. As the assignment commences, the first increment of traffic will be added to the minimum path between the zone pairs, Route A. The volume-delay function is now used and the travel time over Route A increases to 10 min. When this zone pair is next considered it is very likely that because of traffic assigned between other zone pairs, the travel time over Route A has increased to 11.5 min. The next increment, therefore, will be added to Route B, and the travel time on Route B is increased to 12.5 min. Further increments might then be added to the original Route A, increasing the travel time to 13 min. Route C is now the shortest route between the zone pairs and will be used for any further increments until its travel time reaches or exceeds the next best route, B.

Two things can be noted from this simple example. First, the volume-delay function has more effect when small increments are added than when a very large, perhaps the total interzonal transfer, is added, which will mean that the link becomes immediately congested. Second, the alternative routes between a zone pair will be used in such a way that the travel times will tend to converge toward a common value. Since the same behavior will occur between each zone pair and the zone pairs are being selected at random, the rate at which volume is added will be approximately the same for the whole network. In assignment techniques where the complete interzonal transfer is added in one operation, it is possible for one section of the network to be congested and an adjacent section to have no loading at all.

GENERATION RATE CHARACTERISTIC

In all existing traffic assignment techniques, the total number of interzonal transfers put into the program will always be assigned to the network, regardless of the re-

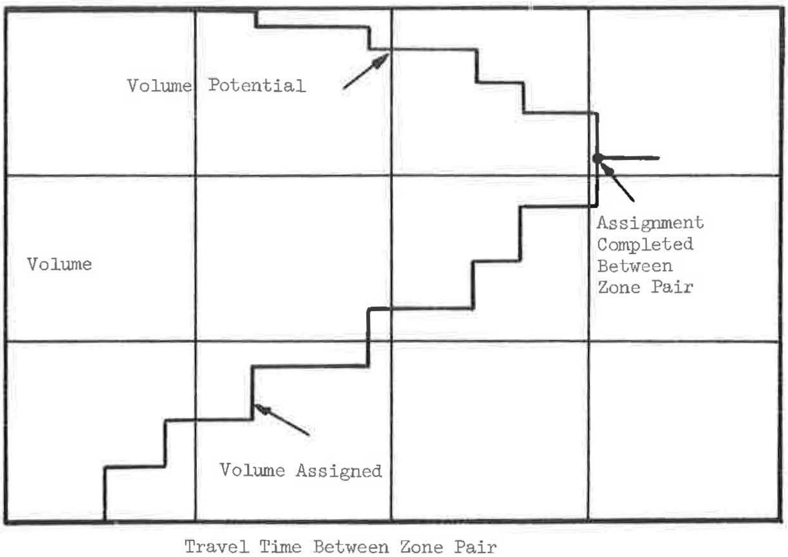

Figure 2. Curves showing combined effect of generation rate characteristic, volume-delay characteristic, and volume increment.

sulting state of the system. This procedure is adopted because it is assumed that the amount of travel is affected only by the land use and that the network controls only the actual routing of this travel. In effect, this says that the demand can be predicted, without considering any restrictions in the supply. This assumption is probably not true for any product and would certainly seem questionable in the urban transportation case. It is true that this factor has been considered in an intuitive manner when making the initial land-use predictions. However, until very recently there has been no attempt explicitly to consider the effect of the transportation network on the amount of travel predicted.

In the original formulation of the incremental assignment technique, an attempt was made to take into account the effect of the capacity and service restrictions of the transportation network on the amount of travel generated, by the introduction of the generation rate characteristic. The general form of the curve has been shown in the flow chart in Figure 1, where the percentage of the initial interzonal transfer that will be realized is shown plotted as a function of the unit travel time between a zone pair. As the unit travel time increases between the zone pair, and hence the network congestion increases, the percentage of the initial interzonal transfer realized is assumed to decrease.

No theoretical formulation can be given for the generation rate characteristics and as yet no attempt has been made to obtain any empirical data to determine their shape. In fact, at the present time the curves are more an interesting idea than a workable concept. However, if the effect of the generation rate characteristic, the incremental loading and the volume-delay function are considered together the results are interesting. If the volume assigned between a zone pair and the potential volume obtained from the generation rate characteristic are plotted as a function of the travel time experienced between the zone pair at different stages of the assignment, Figure 2 is obtained. The horizontal steps in the volume assigned curve indicate the increase in travel time due to the volume between the zone pair being considered, and the volume between other zones using common links. As the travel time increases between the zone pair, the potential volume is reduced by the generation rate characteristic, the volume assigned is increased by increments until it intercepts the potential volume curve. Figure 2 might be thought of as a crude supply and demand curve for travel between the zone pairs.

The implementation of the generation rate characteristics will clearly require more study, and it may even turn out that the development of more sophisticated land-use prediction techniques, which take account of the service characteristics of the transportation network, will eliminate the need for such a function. However, during the development of our ideas, another interpretation of the possible use of the generation rate characteristic has been considered.

In this second interpretation, the characteristic would be used at the end of an assignment to provide the engineer with more information about the deficiencies in the transportation network. At the present time, when the engineer is formulating a transportation network to be evaluated by a traffic assignment, he is limited by the available information and may not determine the best location and capacity of all facilities. By using the results of traffic assignments, the network layout can be modified before further assignments. However, the results of an assignment only indicate the links in the network which are overloaded. They do not provide any information about the origins and destinations of the trips involved. Furthermore, it is possible that the network congestion has resulted in the use of rather circuitous paths by some trips. It is thought that the generation rate characteristic could be used to provide the engineer with more information about the trips not served adequately and reduce the likelihood of circuitous paths being used.

This could be done in the following way. The generation curve would be based on the desired level of service required in different directions in the network, based on average speeds. As the network is loaded, the generation curve could be used to prevent the assignment of trips between a zone pair if the level of service was below that desired. This would also reduce the possibility of using circuitous routes in the network. At the end of the assignment the engineer could compare the input interzonal volumes with those actually assigned, and be able to determine immediately which zone pairs were not being served adequately. The engineer may now reduce the level of service desired by shifting the curves to the right, or provide additional capacity before the next assignment. Thus, the use of the curves in the program does not change, but the results themselves are given a different interpretation.

TRAFFIC ASSIGNMENT PROGRAM FOR RESEARCH

The incremental traffic assignment technique has many interesting possibilities. However, considerable experimentation is required before some of the features can be fully understood. This statement is also true of other traffic assignment techniques in use today and is, in fact, a general criticism of many of the models used in the various phases of the transportation planning process. The U. S. Bureau of Public Roads has recently been involved in a series of comparisons of the traffic distribution models as an initial step toward learning more about the characteristics of models in use. It became clear in the conduct of our work at M.I.T. that much could be learned from a quantitative comparison of several different assignment techniques, each applied to the same problem. It also seemed possible that the incremental technique could be the basis for the development of a more general traffic assignment program which could be used for the comparison of several existing techniques.

The operating procedure of the research assignment program is summarized in Figure 3 and is based on a development of the flow chart shown in Figure 1. The principal change in the procedure is the added flexibility obtained by revising the minimum path algorithm so that either single paths, as required in the incremental technique, or complete minimum path trees may be obtained. The remaining portions of the program have also been revised so that either of the options can be used.

The input to the program is basically the same as described for the incremental technique. The items added are for the procurement of additional data during the execution of an assignment to provide a better basis for the evaluation and comparison of the results from different techniques.

During the comparison of traffic assignment techniques, the generation rate characteristic can be set to a constant value of 100 percent so that it will have no effect. The volume increment and the volume-delay characteristic, together with the path or

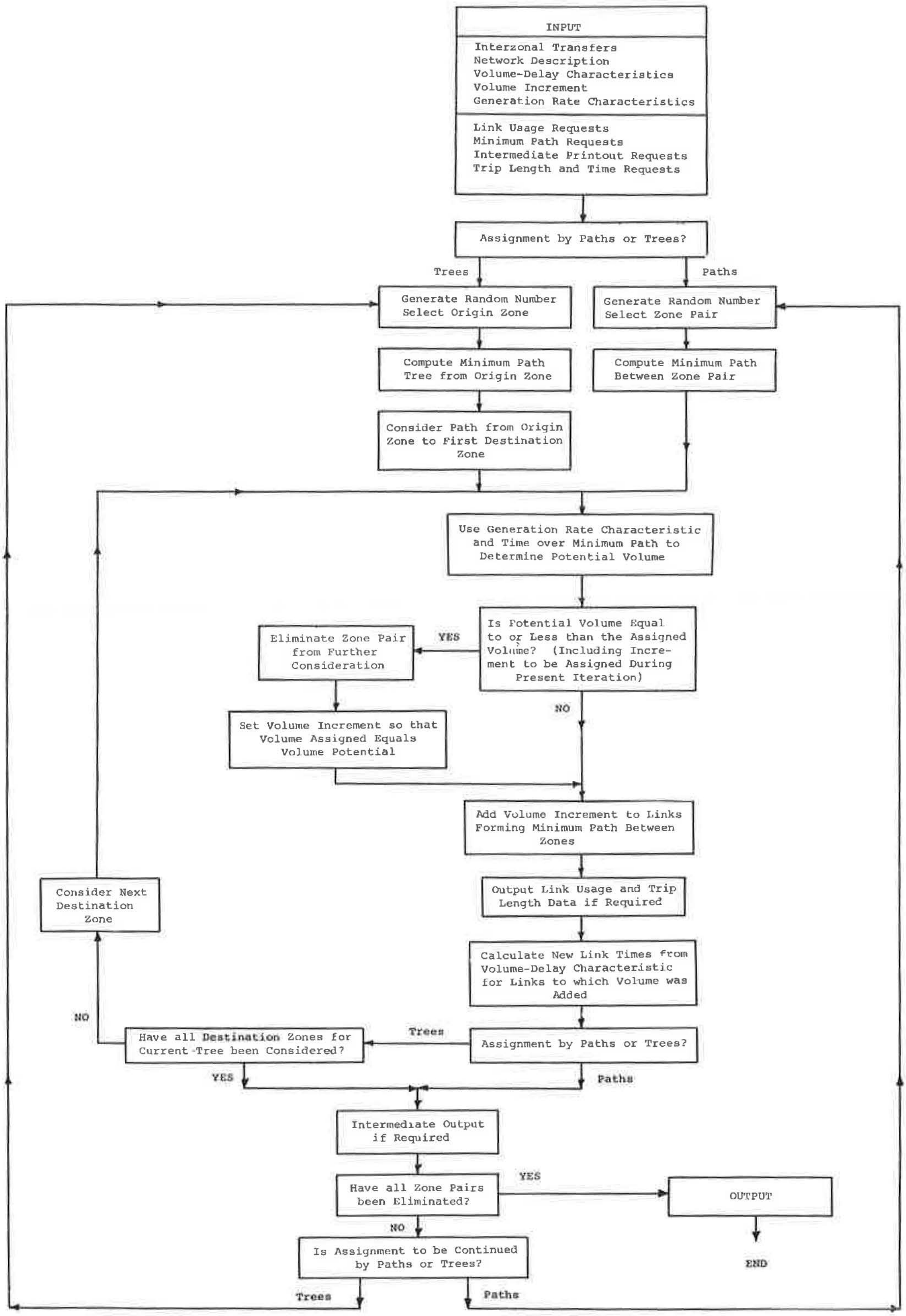

Figure 3. Flow chart of research traffic assignment program.

tree mode of operation, can be used to obtain a number of different assignment techniques.

Mode 1—all-or-nothing assignment using minimum path trees, without a capacity restraint (a desire assignment).

Mode 2—all-or-nothing assignment using minimum path trees and a capacity restraint, operative during the execution of the assignment. This is essentially the pro-

TABLE 1

DIFFERENCES IN OPERATING PROCEDURE TO OBTAIN VARIOUS MODES OF OPERATION OF ASSIGNMENT PROGRAM

Mode	Mode Specified on Initial Input	Volume-Delay Characteristic	Volume Increment	Procedures Required External to Main Program
1	Trees	Function for each type of facility represented by horizontal line equal to constant unit travel time required.	Must be 100 percent of interzonal transfer.	None
2	Trees	Volume delay function for each type of facility as generally shown in Figure 1.	Must be 100 percent of interzonal transfer.	None
3	Trees	Normal volume delay curve as in mode 2, or some other relationship.	Must be 100 percent of interzonal transfer.	Adjustment of link times according to volume-delay relationship.
4	Paths	Volume delay function for each type of facility as in mode 2.	May be a percentage of the interzonal transfer, or a constant increment.	None
5	Trees	Volume delay function for each type of facility as mode 2.	May be a percentage of the interzonal transfer, or a constant increment; if a percentage, should not be 100 percent if operation is to be distinguished from mode 2.	None

cedure used in the Chicago Area Transportation Study program with the capacity restraint option, but the Chicago program also included the computation of the interzonal transfers from the opportunity model. However, as a method of traffic assignment, the two programs are the same.

Mode 3—all-or-nothing assignment using minimum path trees and a capacity restraint operative at the end of a complete assignment cycle. This is the technique used by the U. S. Bureau of Public Roads. The adjustments of the link speeds or travel times would be done outside the structure of the program as shown in Figure 3.

Mode 4—incremental assignment by single paths using a capacity restraint during the execution of the program. This is the incremental technique described previously. A complete range of possibilities exists in the selection of the volume increment; an increment of 100 percent would be an all-or-nothing assignment by minimum paths. This mode of operation does not simulate the techniques used by Traffic Research Corporation and Wayne State University but is similar in as far as several routes are used between each origin and destination. However, in the research program, no iteration is involved.

Mode 5—incremental assignment commenced by minimum path trees and completed with single paths, using a capacity restraint during the execution of the program. This is an extension of the incremental technique as previously described, in which the first increment from each zone is made on a minimum path tree basis. However, remaining increments are added on an individual path basis. It is reasoned that this approach might produce essentially the same results as the original incremental technique with a saving of computer time.

Table 1 indicates the actual operational procedures required to use the program in each of these modes.

ANALYZING RESULTS OF RESEARCH PROGRAM

In analyzing the results of experiments with the research traffic assignment program, there are two basic questions to be answered: what type of input data should be used for the comparisons and how are the results of the various techniques going to be compared and evaluated?

The choice of a network and origin and destination data is a difficult problem. Because of the large quantities of data involved in traffic assignment and the limited resources of a research effort of this nature, very large network problems have to be avoided. On the other hand, it is likely that a very small problem would not give meaningful results in most practical situations. A desirable feature of the network used, at least in the initial comparisons, would be a completed expressway network, since these are the facilities most affecting the accessibility patterns and, therefore, are likely to cause the differences in assignment technique to stand out more clearly. Many medium-sized cities do not have completed expressway plans, other than on paper, and there are no field data describing the network flows. At the present time we have available a network of approximately 1,000 links and 250 nodes, with 60 loading zones, together with origin and destination data, for 1980 based on the predictions of two transportation studies. The advantage of the problem is that most of the desirable features are present and we know the existing network. The undesirable feature is, of course, the lack of network flow data.

For the initial comparisons it is expected that this network will be used, and in the meantime an effort will be made to locate a complete set of data for use in future comparisons. Ideally, comparisons should be made between techniques on a variety of cities with different network configurations and located in different parts of the United States.

The second question concerned the methods to be used for the analysis of the output of the research traffic assignment program. The problem is complex in the sense that the amounts of data involved are very large. The problem, therefore, is to summarize the large quantity of results obtained from several assignments so that the performance of a particular technique can be interpreted conveniently, without suppressing too much of the detail relevant to the comparisons. This problem was considered in formulating the research assignment program and is the reason behind much of the output obtained. There are five different sets of data available from the program output.

1. Link Usage Data. At the beginning of a run the user may specify any number of links so that each time one of the links is assigned traffic, the origin and destination and the number of trips is recorded. These link usage requests may be arranged so that detailed information is available about the vehicles assigned to certain key facilities such as tunnels and bridges, or a particular route such as a circumferential belt, or for the analysis of a particular screenline. The exact location of links referred to by link usage requests would depend on the individual network being used.

2. Trip Length and Trip Time Data. For each iteration of the program the user may obtain, on an optional basis, the trip length (mi), the trip time (min), and the number of trips assigned. This information can be used to construct a distribution of trip lengths and a distribution of trip times for vehicles assigned to the network. It will also be useful in comparing the performance of different techniques.

3. Minimum Path Data. The user can specify the output of minimum path data, between specified origins and destinations, during the execution of the program. These data can be used to obtain an indication of the number of different paths being used between specified origin and destinations.

4. Intermediate Network Data. The user may specify certain intervals during the execution of the program when the current status of the network will be output, in terms of link times, link volumes, the volumes assigned and the input volume between each zone pair. The intermediate network data can be used to study the manner in which the system is loaded by various techniques, and also may be used to obtain additional minimum path data.

5. Final Output Data. The final output data include the link times and link volumes, the volume assigned between each zone pair and the input volume between each zone pair. These data can be used to compute the following quantities: (a) total system vehicle-miles of travel; (b) total system vehicle-hours of travel; (c) vehicle-miles of travel by type of route, expressway, etc.; (d) vehicle-hours of travel by type of route; and (e) detailed analysis of the volumes assigned to a few selected routes. When field data are available, the total assignment can be compared with the real network flows and statistical measures can be developed indicating the variation.

It is anticipated that the preceding analysis would form the basis from which to make deductions about the characteristics of each technique and would provide some information of a comparative nature. Undoubtedly, as the comparisons are made and results are obtained, other forms of analysis may suggest themselves or be brought to our attention.

RESULTS WITH RESEARCH PROGRAM TO DATE

The principal effort so far has been the preparation of the research traffic assignment computer program. After several preliminary versions, the final program form is ready for the first series of comparisons. The results given here were obtained during the preparation of the program and the testing of earlier versions. They are included to give an indication of what might be expected from future use of the program, but since they are provisional in nature, no attempt will be made to describe them in detail.

The first set of results is based on tests made with a small network, using the incremental traffic assignment technique. Assignments were made using increments of 50, 100, 150, 200, 250, 300, 350, 400, 500, 600, 900 and 1,800 veh/hr. The increment of 1,800 veh/hr corresponds to a 100 percent increment in the problem used. The resulting total system vehicle-hours of travel for each assignment are shown in Figure 4. Table 2 gives the number of paths used between four zone pairs for each increment used.

The second test was made on a provisional form of the network to be used in the first series of comparisons, consisting of 1,000 links and 250 nodes, with 60 loading

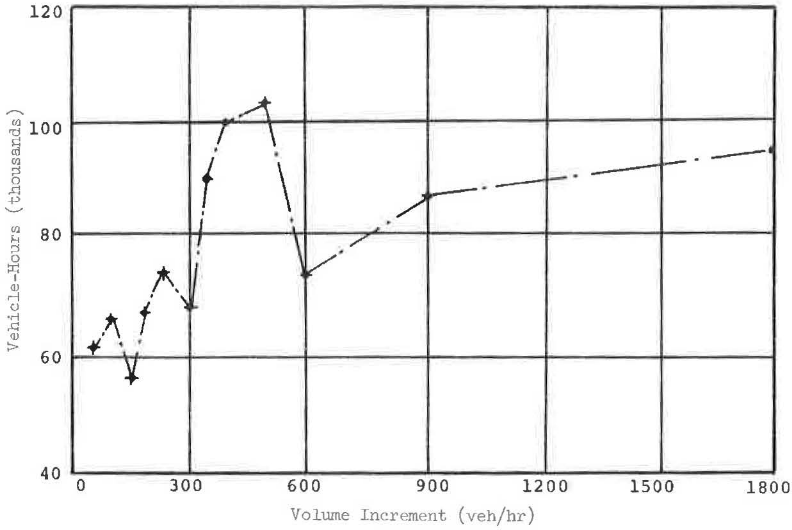

Figure 4. Total system vehicle-hours of travel as function of volume increment.

Number of Iterations	Travel Time For Different Paths in Minutes 1	2	3	4
0	12.01	13.08	13.55	14.73
373	13.58	14.14	14.34	15.77
693	16.79	15.00	15.33	16.66
994	18.98	17.16	15.99	17.54
1314	23.31	20.53	19.73	19.23
1603	31.43	24.67	35.78	23.68

Entry underlined indicates minimum

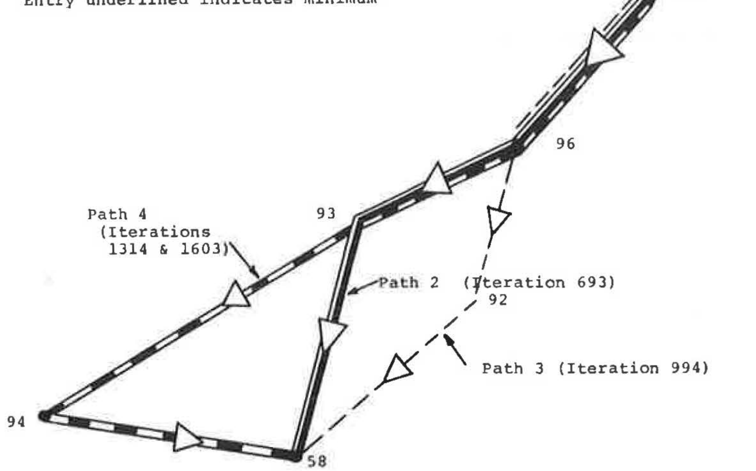

Figure 5. Variation in paths used between Zones 52 and 58.

TABLE 2

NUMBER OF DIFFERENT PATHS USED BETWEEN ZONE PAIRS IN TEST PROBLEM

Volume Increment	No. of Paths			
	Zone Pair 1	Zone Pair 2	Zone Pair 3	Zone Pair 4
50	4	3	5	2
100	3	4	4	2
150	4	2	2	1
200	4	3	4	2
250	3	2	4	1
300	4	2	3	1
350	2	2	2	1
400	3	2	3	2
500	4	4	5	1
600	2	1	2	1
900	2	1	2	2
1,800	1	1	1	1

TABLE 3

PERCENTAGE OF VEHICLE-HOURS AND VEHICLE-MILES OF TRAVEL ON DIFFERENT TYPE OF FACILITIES

Iteration No.	Expressways		Parkways		Arterials and Local Streets	
	Veh-Hr (%)	Veh-Mi (%)	Veh-Hr (%)	Veh-Mi (%)	Veh-Hr (%)	Veh-Mi (%)
373	43	62	5	5	52	33
693	35	58	4	4	61	38
994	26	56	3	4	71	40
1,314	23	54	4	5	73	41
1,603	27	52	4	5	69	43

points. The incremental assignment technique was used with an increment of 200 veh/hr. Figures 5 and 6 show the variation in travel time over several routes used between two zone pairs. The routes themselves are illustrated, but the remainder of the network is not shown. The intermediate output was analyzed and a summary of the results is given in Table 3, where the percentage of travel occurring on three types of facilities, at various points during the assignment, is indicated. (Note that the total system vehicle-miles and hours of travel increases with increasing iterations.)

Now that the program has been developed to an operational stage, we will begin the experimental program. Our purpose in presenting the paper at this time is to keep practicing engineers and other researchers aware of our work, so that we might benefit from their suggestions and opinions. Inquiries relating to the use of this computer program for research by others will be considered.

Number of Iterations	Travel Time For Different Paths in Minutes		
	1	2	3
0	8.31	8.63	13.29
373	9.00	9.15	14.37
693	10.73	9.74	15.07
994	14.48	11.54	15.60
1314	19.68	14.43	15.97
1603	25.02	23.43	20.26

Entry underlined indicates minimum

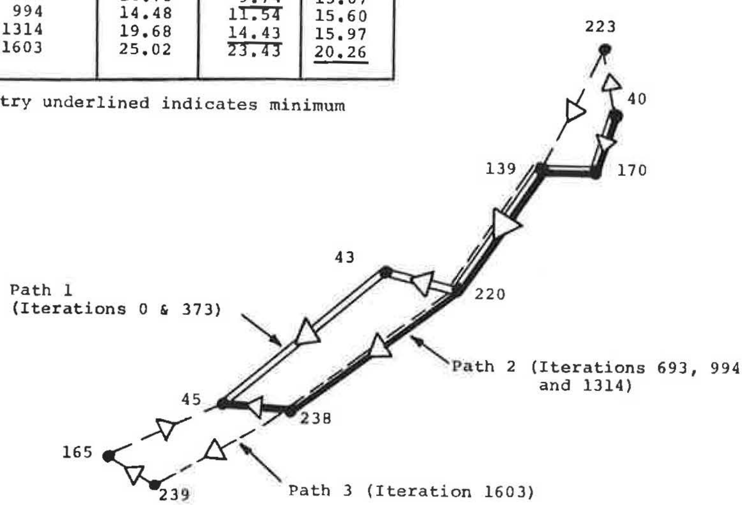

Figure 6. Variation in paths used between Zones 40 and 45.

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