DEVELOPMENT AND TESTING OF A MULTIPATH-ASSIGNMENT TECHNIQUE

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ABRIDGMENT

•IN MOST conventional traffic-assignment techniques, the travel between 2 points is assigned to the minimum or shortest path between the 2 points. Even in capacity-restraint assignment, in which a capacity function or speed-flow relation is used in successive assignment runs to modify link speeds for use in the assignment, minimum-path assignment is used in each run. A distribution of trips over several paths is usually obtained by combining the results of successive assignment runs.

A multipath-assignment technique has several advantages over the conventional minimum-path technique. First, in networks without capacity limitations (unrestrained or demand assignments), empirical studies have shown that travel between 2 points usually distributes itself over several routes. Further, minor network changes can often produce major changes in assigned volumes when minimum-path assignment is used. Second, in capacity-restrained assignments, the multipath technique enables each assignment to be considered on its own, so that (a) all the volume on a given link is assigned at the same speed, and the consequent link volumes are consistent with the speed-flow relation for the links, and (b) extreme speed oscillations and unrealistic paths produced by them are largely excluded.

In the method developed and tested, the algorithms used for building the multiple-route trees are the same as those used in most conventional minimum-path assignment programs, except that a different set of link costs is used to build each tree. Each link time is chosen at random from a distribution of 8 values having a mean value equal to the specified link cost and a mean deviation specified by the user according to link type and cost. When a large number of trees are built, the paths will be divided among the feasible routes with the largest number normally on the minimum path and the numbers on alternative paths decreasing as the extra cost involved in using them increases. This principle also applies between any pair of nodes along a route, thus making trivial alternatives unlikely where the extra cost is high in proportion to the distance covered between the points where the alternatives exist. This overcomes a problem with some previous multipath techniques that assign to the n shortest routes, which may only be minor deviations of the same basic route.

In its simplest form, the assignment may consist of building just 1 tree for each origin zone. Although this permits only 1 path between a specific pair of zones, there may still be multiple choices of routes between pairs of nodes because large numbers of different zone-to-zone movements may pass through the same nodes. Building 1 tree per zone may create problems near the origin zone if the volumes assigned because of that zone are a major part of the total link volume. This problem was solved, without the computer cost of building several complete trees, by introducing a cost cordon around each origin zone and by building several "inner trees" inside the cordon for each complete "outer tree" outside the cordon.

Ideally, the probability of a given path between 2 points being chosen should be independent of the number of links constituting it, and this is achieved by making the mean deviation of the link times within each link class proportional to the square root of the specified link times.

The method of capacity restraint adopted is one of successive assignments and speed adjustments, the object of which is to reach an equilibrium point where the volumes assigned to each link in the network are consistent with both the speeds at which they were assigned and the link capacities. Speed-flow relations are specified by link class and a capacity indicator. After each assignment, the link speeds are adjusted according to the assigned volume-capacity ratio and the speed-flow relations. The program includes several options as to the formula used to derive the new link speed.

The speed adjustment procedure used for the capacity restraint may be 1 of 2 methods. The first of these is an iterative procedure where the complete trip table is reassigned at each stage and all previous assignments are ignored. This method has always produced poor results when used with a minimum-path assignment technique because it may produce large oscillations in assigned volumes for very small speed changes on some links while a similar change on other links has no effect. Multipath techniques should produce better results because they permit trips to be diverted from 1 route to another in small increments.

The second method of capacity restraint is an incremental one where a proportion of the trip table, specified by the user, is assigned at each stage and the speed adjustment is based on the total assigned volume in all the previous increments and the link speeds at which the latest assignment was made. The speed adjustments may be made (a) according to the total capacity of the link or (b) according to a proportion of it equal to the proportion of the trip table already assigned (effectively making all speed adjustments on the basis of a fully loaded network). (Some planners have called this latter technique an iterative method because of the repeated adjustments to the link speeds. In this paper, it is called the incremental method and is distinguished from the iterative method in which the assignment process is applied more than once, but each assignment run is considered complete on its own.) The latter technique is more dynamic and responsive to volume buildups at an early stage in the assignment process and is therefore preferred to the former.

The testing and evaluation of the program were carried out in 2 stages. The first series of tests consisted of unrestrained assignments on 3 Ontario networks of different types for comparison with minimum-path assignments. These were a small urban network, a rural area network, and a comprehensive regional network from the 1964 Toronto Area and Region Model Study (TARMS).

In each case, the first assignment was made on the final networks that were used for the base years of the respective studies and were assumed to have been calibrated for a reasonable minimum-path assignment. On all 3 networks, the link volumes obtained by the multipath were closer to observed volumes than those given by the minimum-path assignment with a very substantial improvement on the TARMS network. Further improvements were obtained with a better calibration for the multipath.

The second series of tests was designed to evaluate different combinations of capacity-restraint and assignment techniques. The network used for this was the metropolitan area of the 1969 TARMS network. The methods tested were as follows:

1. Minimum-path iterative,
2. Multipath iterative,
3. Minimum-path incremental,
4. Multipath incremental, and
5. Multipath iterative followed by multipath incremental.

Early tests eliminated method 1 as being unworkable. In methods 2, 3, and 4 it was found that the iterative method produced link speeds closer to those observed and much higher on the average than the incremental methods; nor were the extreme values of link speeds so pronounced. These differences can be explained by the manner in which the 2 techniques work and were to be expected.

The greater differences in link speeds from run to run in the incremental assignment caused some large detours from the minimum path, raising the total vehicle mileage by a considerable amount at each stage. The iterative method was found to give a stable average speed very quickly, and the total vehicle-miles assigned also changed very little between speed adjustments.

The comparison of the assigned volumes with observed volumes for 1,378 links where counts were available was the principal basis of evaluating the methods. All of the methods produced roughly the same error when compared to the observed volume and, because there are many sources of this error other than the assignment technique (network representation, trip table, capacity functions, and errors in the counts), the only conclusion that could be drawn was that no method was significantly better than any other for producing accurate assigned volumes. Method 4 gave marginally better results than methods 2 or 3. Method 5 was tested because preliminary tests had indicated that better results could be obtained at the initial stages by using a cost function of time and distance instead of just time for the tree building. This was found to be true at the early stages, but the benefits diminished rapidly in subsequent stages.

With all the incremental methods it was found that, although the assigned volumes came closer to the speed-flow relations as the capacity restraint proceeded, the comparison with observed link volumes started to deteriorate after 3 or 4 speed adjustments. The fact that the assigned volume appears to be a closer fit to the speed-flow relation is artificial because the assigned volume has been obtained at several different link speeds that cannot be represented by a single speed-flow point. The value of making a large number of speed adjustments for an incremental assignment in order to obtain settlement would seem questionable.

Some of the conclusions indicated by the results were that the multipath-assignment technique can be used to advantage for most types of network with or without capacity-restraint assignment. When the multipath technique for capacity restraint is used, an iterative method should be adopted to produce realistic link speeds; otherwise, the method of capacity restraint used has little effect. With either method of capacity restraint, there is likely to be little benefit gained by making more than 4 or 5 speed adjustments.

The multipath assignment and capacity restraint techniques are contained in 1 program but may be used independently if required. The program is written in FORTRAN IV for use with an IBM 360/65 computer and will accept networks with as many as 2,000 zones, 6,000 nodes, and 14,000 links.