CHECKING THE NETWORK DESCRIPTION FOR ARTERIAL HIGHWAY AND TRANSIT NETWORKS

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INTRODUCTION

Background Review

Previous Technical Record articles\(^1\) have described the delineation of the arterial street and highway network and the transit network, and the inventory of the physical facilities represented by the network components. After inventory data were reduced to punched cards, it was necessary to connect or assemble the component parts represented by the punched card data into a numerical description of the complete regional arterial street and highway system and the complete regional transit system. These numerical network descriptions can then be used to calculate minimum time paths between traffic analysis zones, which are used, in turn, in the assignment of interzonal trips. Trips determined from the 1963 survey data will first be assigned to the existing networks as a check of the accuracy of the data. Calculated future trips will be later assigned to planned networks. In each such assignment, traffic volumes will be accumulated by electronic computer on the network links comprising the interzonal minimum time paths to determine capacity deficiencies and verify the overall feasibility of the planned networks.

Purpose of Checking

Before using a network description for traffic assignment by computer, it is necessary to find and eliminate any errors in the link data and in the link connections at nodes. The available computer programs for building a network description include tests, or checks, for incorrect or questionable link data, thus providing an excellent edit of the link data at the time the network description is formulated.

In addition to these edits, however, it is desirable to test how well the network description represents the real transportation system. One convenient method of doing this is to calculate, for a few carefully selected zones, the minimum time paths to other zones. These minimum time paths are read from numeric tabulations printed by the computer and are plotted manually by connecting colored lines on prints of the network maps. Examination of the resulting traces

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reveals major discrepancies which may have occurred in the network description due to faulty link data. Such traces may also be inspected to see whether they represent the routes people actually use in making trips between certain points of origin and destination.

Conversion of Link Inventory to Link Data Cards
In order to use the computer program for building a network description, and subsequently, to calculate minimum time paths and to assign zone-to-zone trips to these minimum time paths, it is necessary to prepare a data card containing prescribed information for each link in the following format:

<table>
<thead>
<tr>
<th>Column</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jurisdiction (optional). Used by the SEWRPC to designate freeways and expressways.</td>
</tr>
<tr>
<td>3-6, 8-11</td>
<td>Node numbers. For one-way links this must be in order from node of entry to node of exit.</td>
</tr>
<tr>
<td>16-17</td>
<td>Link length, in miles and tenths with a decimal point assumed between columns 16 and 17.</td>
</tr>
<tr>
<td>20</td>
<td>S, indicating speed data to follow. (T may be used to indicate time as was done in the Transit Network.)</td>
</tr>
<tr>
<td>28-29</td>
<td>Speed in mph (or running time in tenths of minutes).</td>
</tr>
<tr>
<td>35</td>
<td>For two-way links only, same as column 20.</td>
</tr>
<tr>
<td>43-44</td>
<td>For two-way links only, same as columns 28 and 29, but in opposite direction. SEWRPC has thus far used the same speed in both directions.</td>
</tr>
<tr>
<td>56-60</td>
<td>Capacity.</td>
</tr>
<tr>
<td>61-66</td>
<td>Counted volume.</td>
</tr>
<tr>
<td>72</td>
<td>4 (identifies card as Link Data Card).</td>
</tr>
</tbody>
</table>

NOTE: Columns 73-80 are available for any identification data, but are not read into the computer. SEWRPC uses the following identification:

| 73 | H for Arterial Highway Network; T for Transit. |
| 74, 75 | Year of network. |
| 76, 77 | Network number for identification. |
| 78-80 | Card layout identification number for data processing control. |
This format was used for both the arterial highway network and for the transit network. Since these networks have inventory data in different formats, it was necessary to develop a routine to convert from each inventory format to the specified link data format. For the arterial highway network, this included calculating link capacity from certain link characteristics with a given table of capacity multipliers. An IBM 1401 computer was used to make the calculation and punch the link data cards. For the transit network, no link capacity was used since transit within the Region does not approach the capacity of the arterial street and highway system to carry it, nor is it likely to do so.

USE OF LINK DATA

Building a Network Description
The link data cards are used as input to Program 6 "Build Network Description" of the U. S. Bureau of Public Roads (BPR) program library. This program connects within its memory all links at their nodes, treating them all as one-way links. Programs 6, which does not store link capacity or volume, has a limitation in that not more than four links may provide exit (outbound movement) from a node. The network description is written in binary numbers on magnetic tape. Program 12 converts this binary number information to decimal numbers, and writes the decimal number network description on another magnetic tape from which it can be printed. This printed record sets forth for each node the links that are connected, their distance, time, and speed.

As noted, both Program 6 and Program 12 have edit checks included. Edit messages are printed out when link data is inconsistent with the programmed edit checks. Generally, it is found that some of these edit messages do not represent real errors, but all should be carefully examined. For example, a link of zero length will have zero travel time. This is valid. But when Program 12 recomputes speed from distance and time, the quotient is undefined and an edit message is printed. Checks must be made for duplicate links, links whose time or distance exceed maximum values previously designated on a parameter card, more than four links at a node, links whose speed is outside a range specified on the "speed limit" card, nodes having no links outbound, and other such contingencies.

Building Minimum Time Path Trees
Program 1 "Build Trees" utilizes the Moore algorithm for finding the minimum path through a network. It creates a table which contains for each node only the minimum time and corresponding back node. By tracing from one back node or zone centroid to the next back node until the "home node" is reached, the trace of the minimum path from any designated node to all other nodes or zone centroids may be drawn onto a network map. The appearance of such a tracing of many branching paths led to its being called a "tree." The binary "tree" table produced by Program 1 is converted to decimal numbers, for printing, by Program 11, "Format Trees." It shows the home node at the top of each page and lists each node in the network with its minimum path time from the home node and its back node.

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2 These capacity multipliers will be described in a future issue of the Technical Record.

3 Speed is calculated from the distance and time in the binary record. Rounding may sometimes cause this printed speed to differ from the speed on the link data card input to Program 6.
A newer program, Program 50, finds the sequence of nodes from one back node to the next and lists these across the page. This program, which has a destructive trace option, has proven to be convenient in providing data for plotting trees in the selected high numbered zones. This destructive trace option, which has a computer time comparable to that of Program 11, does not list all of a trace; but merely lists that part of a trace from a loading node to a point in the network that has been used as a part of a previously listed trace of the same tree.

CHECKING ROUTE SELECTION

Selection of Trees for Plotting Minimum Path
It is usually expedient to plot trees emanating from the central business districts and from zones at or near the geographic center and corners of the network. By doing this, traces may be drawn representing routes from "downtown" to surrounding areas and also showing routes all the way across the network in directions that are generally oblique to each other. If links are incorrectly or poorly described so that calculated paths are not realistic ones, this procedure offers a high probability of detecting such discrepancies.

Some of the more common errors detected from this procedure are:

1. Decimal shifts: e.g., a link of length 5.0 miles is entered as 0.5 miles.

2. Incorrect node number: If the number of another node is erroneously entered, such as by transposing a digit, an unwanted connection may result. This is commonly called a "tunnel" by some practitioners and "bridge" by others, since when the path is drawn, it appears to connect a trace across an area where no true links exist. The path distortions resulting from this error are usually gross.

3. The trace may be a possible one, but simply not the known best route, or the one usually driven by people. This is usually caused by a sum of link times along the calculated path that is only a little different from that along the preferred path. A difference of 0.1 minutes is the smallest difference recognized. To correct such route selection some of the link times must be slightly adjusted so as to cause the accumulated running time to be smaller for the path actually used. Other trees utilizing this link in a different direction, however, must not be ignored when doing this. It is usually desirable to make several small changes so as not to distort the minimum path in another direction.

Very short links pose special problems due to rounding, since it requires a relatively large change in speed along a link of length 0.1 miles to effect a time change of 0.1 minutes.

Illustrative Example
To illustrate the process described above, it may be helpful to examine an actual trace obtained.
Node 0396, the loading node for zone 396, is at the center of the City of Waukesha. The minimum path "tree" from this node was selected to be built and plotted for checking. The trace obtained along Waukesha County Trunk Highway "HH," north of Tess Corners, appeared unrealistic. Going east on "HH" (see Figure 1) it turned south on CTH "MM." It seems unlikely that any real driver, proceeding east on "HH" to its intersection with STH 24, would travel such a route.

Figure 1

EXAMPLE OF LINK DESCRIPTION ADJUSTMENT ON THE ARTERIAL NETWORK

Upon investigation of the link data, it was found that links 2781-2776 and 2776-2775 were each entered at length 0.5 miles, speed 20 mph. A further check of the measurements revealed that each of these links was actually 0.45 miles long, with a total length of 0.9 miles. The original link descriptions were not considered wrong, since link lengths were rounded up to the nearest tenth mile and running speeds were generally entered in multiples of 5 mph. However, as may be seen, the cumulative effect was erroneous. Since link lengths are recorded only to tenths of miles, it was decided to change 2781-2776 to 0.4 miles to obtain a more realistic total along "HH." At the same time, its speed was raised to 22 mph, providing a better representation of the transition from the longer, higher speed link to the west and to the average speed to the next link to the east where stop time is included. These changes reduce the link time to 1.1 minutes, making path time along "HH" from node 2781 to nodes 2776 and 2775 less than that via Tess Corners from node 2781 to nodes 2312 and 2775.
Update Program
The technique for making these changes in the network description is a simple one. Update cards are keypunched following the same general format as for the initial link data cards. The corrected or "add" cards are in the same format as the original link data cards. The "delete" cards, however, have one node in columns 3-6, as before, and the second node, in the direction of travel, in columns 50-53 instead of columns 8-11. If an S or T is punched in Column 3, it is read by the computer as a two-way deletion. A combination delete and add, utilizing all the fields, is a "change" card. A modified version of Program 6 is used to accomplish network update. The binary network tape previously produced is read into the computer, along with the update card data. The indicated changes are made in core; and the updated binary network description is written on an output tape, where it is available for subsequent use by Program 12, "Print Network Description," or Program 1, "Build Trees."

LINK CAPACITY

Network Description with Capacity and Volume Record
Another BPR computer program is available which builds a network description containing for each link, its traffic capacity and volume. It also produces a "historical" record of a sequence of traffic assignment iterations, showing at each iteration the volume assigned. This is Program 60, "Build Capacity Restraint Binary Historical Record." Program 61, "Apply Capacity Restraint to Network Description," is used following Program 60 to compare link volume with the given capacity and to apply an adjusting ratio to each link travel time, so that the network description is modified for the next iteration. This procedure is "capacity restrained" assignment.

A limitation of Program 60 is that it cannot update the binary tape on which it has written the network description. Network updates can be made, but this must be done by reading into the computer all the original link data card records followed by the update card data. Therefore, it does not permit the considerable economy obtained by means of Program 6, "Update Network Description," when editing and checking a network description.

It is intended to utilize Program 6 throughout the editing phase of developing the highway network and for assignment to the transit network, on which no capacity restrained assignments seem warranted. After obtaining a free (unrestrained) traffic assignment on the arterial highway network and making any needed network updates which this might reveal, it is then intended to make a capacity restrained assignment using Programs 60, 61, and 63. (Program 63 converts the binary results to decimal numbers in format for printing.)

Updating Inventory Cards
As changes in link data are made in the update procedure, including the addition and deletion of links and changing of link speed or distance, these changes are noted in the listing of link inventory cards. When all network updating for a particular network is completed, a corrected deck of link inventory cards will be prepared incorporating all the changes that have been made in descriptive link data. This will include not only
the changes determined from computer edit of link data cards and from plotting selected trees, but also the changes in capacity values determined after review of link capacities by state and local highway and traffic engineers in the Region.

These revised link inventory cards will then be processed by a program, similar to that described earlier, which converts inventory data to link data, thus producing another complete deck of link data cards with all revisions included. This is judged to be a "cleaner" method, in the sense of being less prone to error, than to remove cards for all revised links from the original link data deck, make necessary changes, and replace the cards.

Final Three-Way Check of Arterial Network Description
To double-check the above procedure, the network description produced by Program 60 from the new link data cards will be checked against the network description obtained by Program 6 through a series of updates and against the arterial network map. This will be done by three people, each with one of the network descriptions (map included) going through the network, link by link, until all links are accounted for and cross-checked. (In the SEWRPC highway network, there are about 2,600 nodes and about 4,500 links.)

Cost and Time Duration
The checking procedure described in this article was accomplished in the SEWRPC study for a cost of approximately $6,000 in salaries of transportation planning personnel, approximately $2,000 in drafting and reproduction costs for producing and revising network maps, and approximately $800 in computer time. These salary costs include the man-hours spent in preparing control cards for computer runs, plotting selected trees, analyzing these plots, and reviewing the plans and procedures with local officials and with members of the Technical Coordinating and Advisory Committee.

Nine months elapsed between the time the first network description was built and the time the O & D survey data was ready, in summary form, for the first traffic assignment of O & D trip data. During this time, the arterial highway network was revised five times. The reasons for these updates include 1) the edit messages printed by the computer when it built a network description from data cards, 2) the needed improvements in minimum path selection that were identified from plotting selected trees, and 3) additions and changes to the system recommended by the SEWRPC staff and the Technical Coordinating and Advisory Committee. During this same interval, the transit network was revised three times. The revisions were based almost entirely on edit messages from the computer and on the detection of needed improvements in the minimum time paths.

It is expected that the need for further minor revision of both networks will become apparent after analysis of the assignment to the networks of O & D survey trips.

Summary
The arterial highway network description and the transit network description, which are essential tools for traffic assignment, were extensively checked to see that they accurately represent the corresponding "real world" systems. This was accomplished
by edit routines in the standard BPR computer programs which were utilized by plotting selected minimum path trees and examining these for validity, and by review of the Technical Coordinating and Advisory Committee.

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(Backward Glance continued from page ii)

Certain of these "garden city" objectives were adopted in the planning of many American "new towns", including Riverside, Illinois; Garden City, Long Island; Baldwin Hills Village, Los Angeles; and Kohler, Wisconsin. But the preplanned American communities which perhaps came closest to fulfilling the English garden city concept were the "greenbelt towns" planned and developed during the great depression. Three such greenbelt towns were developed: Greenbelt, Maryland; Green Hills, Ohio; and Greendale, Wisconsin. A fourth such greenbelt town, Green Brook, New Jersey, was planned but never developed.

The Great Depression and the Greenbelt Towns
The great economic depression of the 1930's raised the question as to whether the nation could ever hope to provide full-time, gainful employment to everyone within the labor force who needed and sought such employment. This question, in turn, gave rise to the concept of resettling a portion of the urban labor force in satellite communities around the larger central cities in which good low-cost housing and subsistence garden plots could be provided to low and medium income families. The Resettlement Administration of the U. S. Department of Agriculture was assigned the task of planning and developing four model resettlement communities on an experimental basis, and decided to apply the "garden city" concept. The purposes of this planning experiment were threefold:

1. To demonstrate in practice the soundness of planning and developing a community according to certain of the garden city principles.

2. To provide good housing at reasonable rents for low and moderate income families.

3. To provide jobs to the unemployed labor force which would result in lasting economic and social benefits to the community in which the work was undertaken.

A 3411 acre tract was selected in Milwaukee County for one of these greenbelt towns. The site chosen lay astride the Root River in the then gently rolling farmlands of the Towns of Greenfield and Franklin, approximately 8 1/2 miles southwesterly of the central business district of the City of Milwaukee. The community was to be known as Greendale.

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