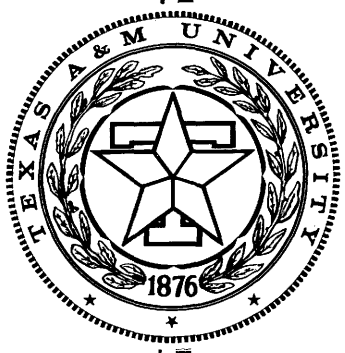

TEXAS
TRANSPORTATION
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HIGHWAY
DEPARTMENT

COOPERATIVE
RESEARCH

THE EFFECT OF TURN PENALTIES ON MINIMUM PATHS IN CODED STREET NETWORKS

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration
Bureau of Public Roads

Research Report 60-10

Study 2-9-63-60

Traffic Assignment

THE EFFECT OF TURN PENALTIES ON MINIMUM PATHS IN CODED STREET NETWORKS

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Sponsored by

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College Station, Texas

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CONCLUSIONS

Minimum path trees without a turn penalty (zero turn penalty) did not differ significantly from those when a 0.2 minute turn penalty was used.

Illogical routings resulted just as often or more often with the 0.20 minute turn penalty as with the zero turn penalty.

No significant stair-stepping occurred in any of the paths -- even with the well defined grid system of the detailed network which is a block-by-block representation of the Waco Street network. It is believed that this is due to the level-of-service speed concept used in defining the link speed parameter. The coding of a higher level-of-service speed for the more important - higher volume links appears to prevent stair-step paths.

INTRODUCTION

The use of a minimum path concept to select routes between zone pairs is the basis of computer traffic assignment procedures. Early experience indicated that with a grid system having relatively uniform speeds on several parallel links, there was a tendency to produce "stair-stepping" through a coded network when a turn penalty was not used. This "stair-step" routing was most pronounced when the zone pair being considered was approximately on a diagonal to the grid system.

Preliminary studies of the traffic assignments to the Waco detailed network revealed that routings in several cases were rather illogical with a turn penalty. Analysis of these paths suggested that the cause might be the turn penalty.

Further investigation of the effect of the use of the turn penalty was undertaken. Several trees from the detailed and intermediate networks with and without a turn penalty were compared and differences within each set of trees analyzed.

The purpose of these comparisons was to determine what, if any, differences would result in the minimum path trees using a 0.2 minute turn penalty and those using a zero turn penalty. Further, would the minimum paths "stair-step" through the coded street system when not using a turn penalty?

COMPARISON OF TREES

A total of 33 sets of trees with and without a turn penalty were plotted and analyzed. Of these there were eleven sets each from the E-2, intermediate and the detailed networks.

The location of the tree origin of each of the trees plotted and included in the analysis is shown in Figure 1. Sets of typical trees are shown in Figures 2 through 8; five sets are from the E-2 network and one each from the intermediate and detailed networks. Each set consists of a print of the tree resulting with the use of a zero turn penalty (part A of each figure) and a transparent overlay (part B) showing the tree which resulted when a 0.2 minute turn penalty was used. The centroid connectors have been omitted from these trees for clarity at the reduced scale for reproduction in this report.

When comparing these sets of trees, various differences can be observed. Evaluation of these differences involved the following three measures:

a) number of route sections affected by the difference in routing,

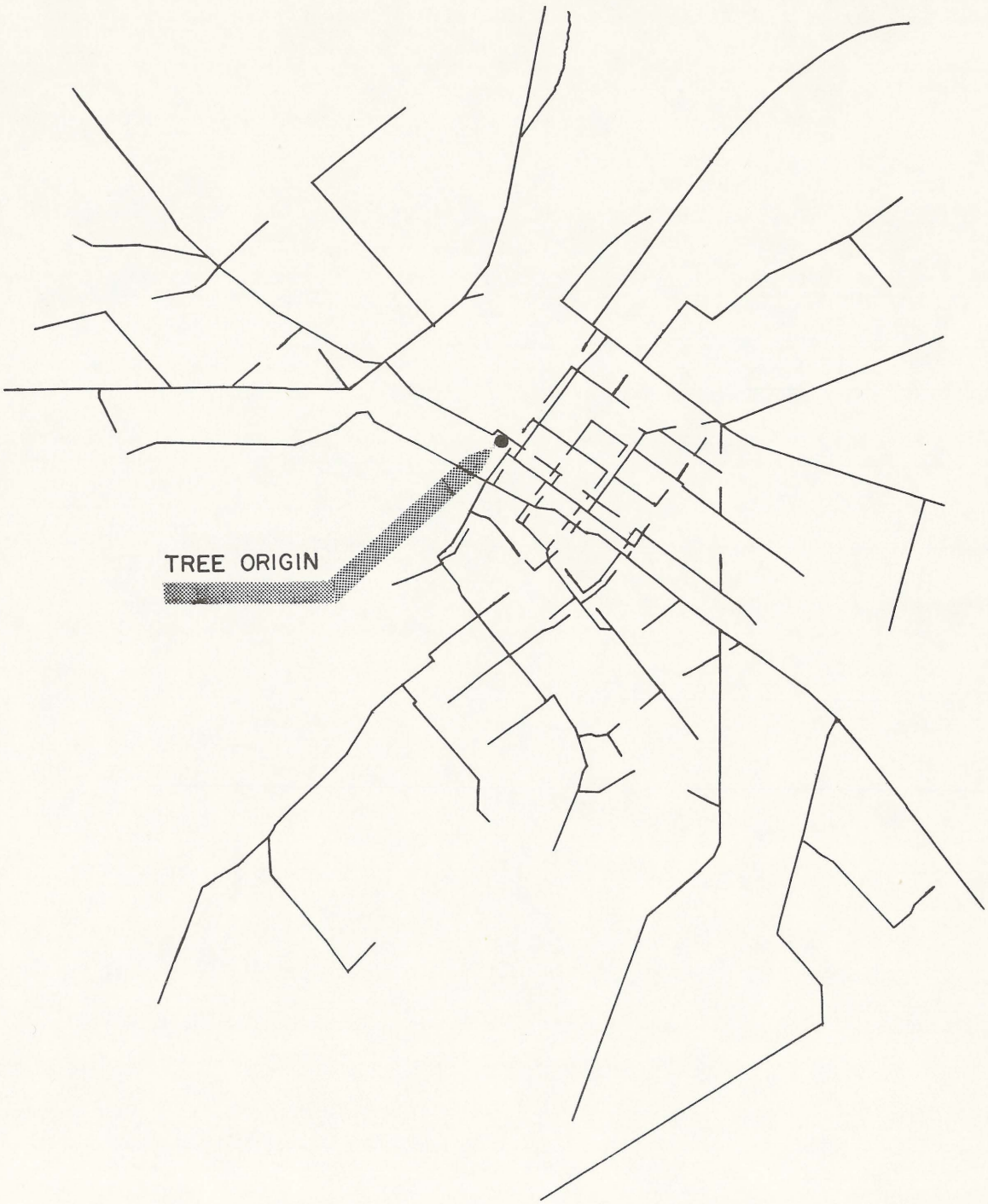
b) which routes appeared to be more logical, and

c) stair-step routing.

TP = .20 MIN

TREE 10 FROM E-2 NETWORK

FIGURE 2B



TP = 00 MIN

TREE 10 FROM E-2 NETWORK

FIGURE 2A

TP = .20 MIN

TREE 23 FROM E-2 NETWORK

FIGURE 3B

TP = 00 MIN

TREE 23 FROM E-2 NETWORK

FIGURE 3A

TP = .20 MIN

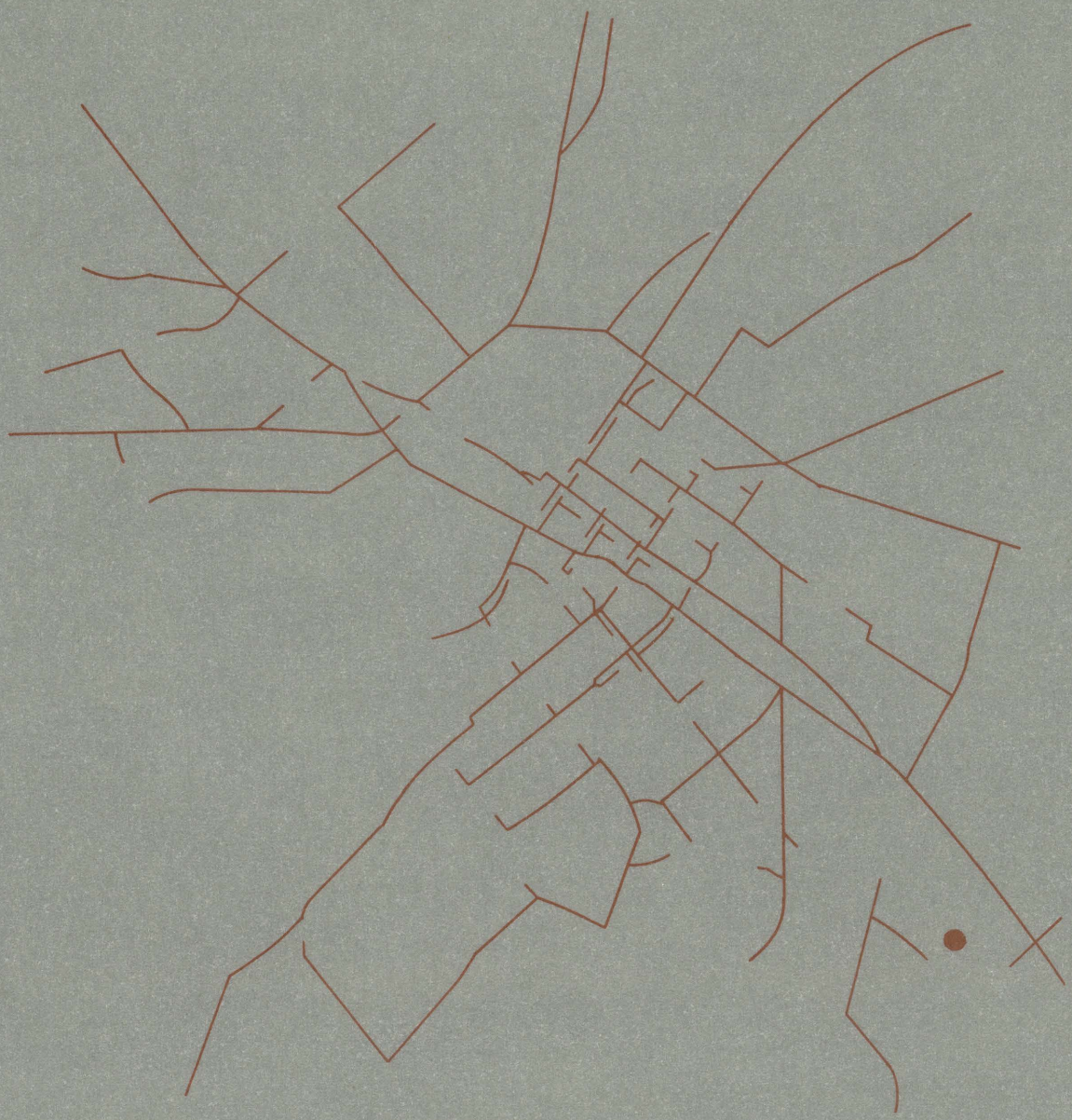
TREE 26 FROM E-2 Network

FIGURE 4B

TP = 00 MIN

TREE 26 FROM E-2 NETWORK

FIGURE 4A



TP = .20 MIN

TREE 157 FROM E-2 NETWORK

FIGURE 5B

TP = 00 MIN

TREE 157 FROM E-2 NETWORK

FIGURE 5A

TP = .20 MIN

TREE 177 FROM E-2 NETWORK

FIGURE 6B

TP = 00 MIN

TREE 177 FROM E-2 NETWORK

FIGURE 6A

TP = .20 MIN

TREE 4118 FROM INTERMEDIATE NETWORK

FIGURE 7B

TP = 00 MIN

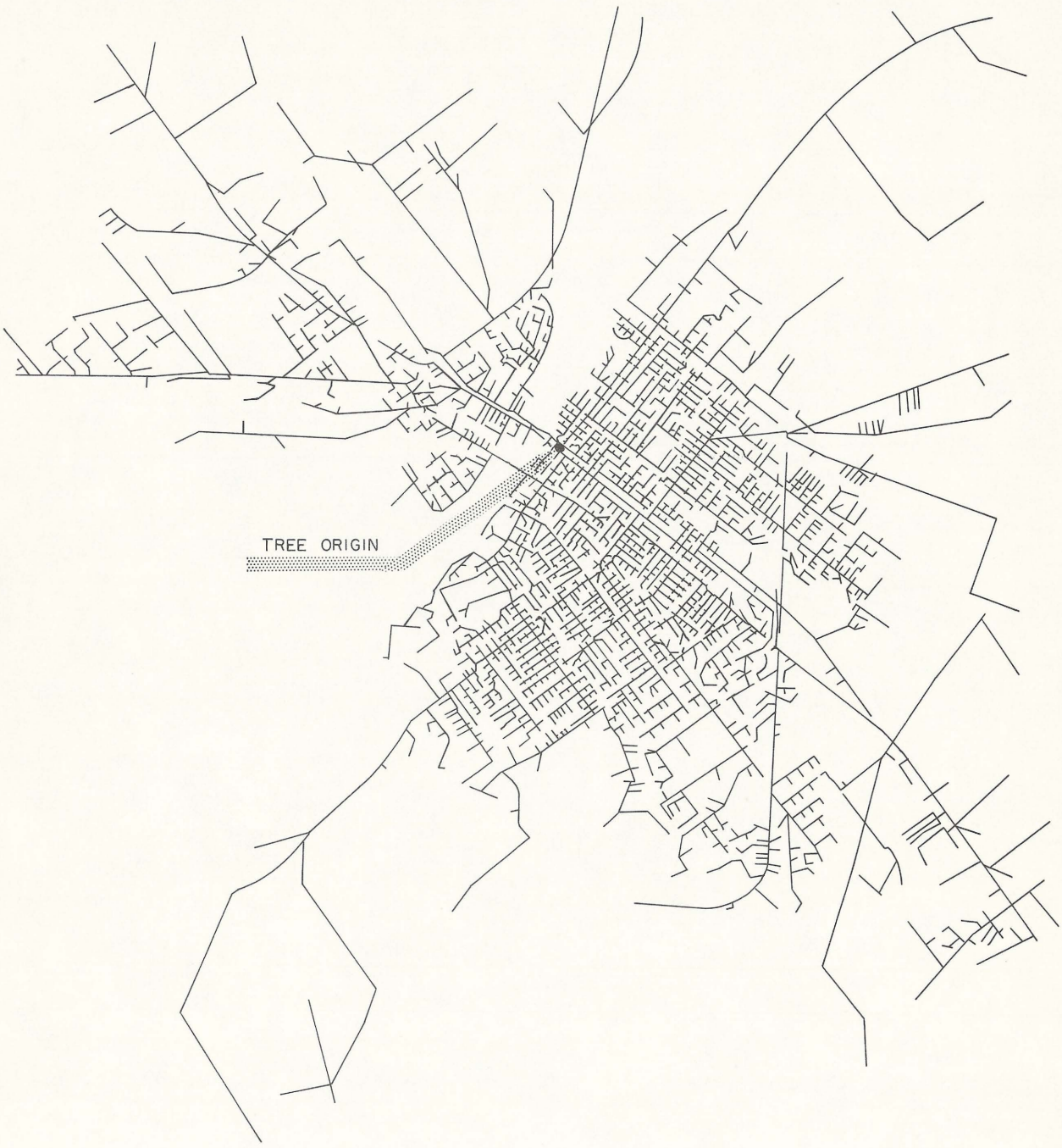
TREE 4118 FROM INTERMEDIATE NETWORK

FIGURE 7A

TP = .20 MIN

TREE 4318 FROM DETAILED NETWORK

FIGURE 8B



TP = 00 MIN

TREE 4318 FROM DETAILED NETWORK

FIGURE 8A

Number of Route Sections Affected By the Difference in Routing

An analysis was made of the number of route sections affected by the difference in several sets of trees (with and without a turn penalty). A difference in routing as used here implies any section of a path(s) between the tree origin and other zones that changes when using and not using a turn penalty.

It was reasoned that the larger the number of route sections affected, the greater the total effect on the system and the more likely that one or the other route would be more logical. However, it was soon apparent that the number of route sections affected was not related to the logic of route selection. For example, in one case the difference in routing affected a number of route sections, but was not considered significant as both routes were about equally logical. In another case, however, the differences in routing affected only a small number of sections, but was considered significantly different as one route was considerably more direct and logical than the other. Thus, it was concluded that the number of route sections affected does not appear to be a reasonable criterion for evaluating the differences in a set of trees.

Selection of the More Logical Path

The differences between sets of trees with and without a turn penalty were classified according to how logical or illogical individual paths appeared to be. All 33 sets of trees from the E-2, intermediate and detailed networks were included in this analysis. The primary criterion for evaluating the logic of path selection was directness of path; however, turns were also considered to be

important.

Table 1 shows the result of these evaluations for the eleven selected sets of trees from the E-2 network. In general, when different paths resulted with and without a turn penalty, one was as logical as the other. In those instances where one was more logical, the path resulting with the use of a zero turn penalty was the more logical more often than not.

Similar conclusions were drawn from the analysis of the sets of trees from the intermediate and detailed networks. However, with the intermediate network, illogical paths appeared to be slightly more frequent with a zero turn penalty. On the other hand, the detailed network seemed to have relatively more illogical paths selected when using a turn penalty. Nevertheless, the instances when paths were considered illogical were rather infrequent for trees from either network.

The same location was taken, insofar as possible, as tree origin for the three networks (E-2, intermediate, and detailed). In comparing same (similar) tree from the intermediate and detailed networks, a path resulting from using a zero turn penalty that was judged illogical in one network, was not necessarily in the other. The same situation was found when using the 0.2 minute turn penalty.

As a matter of fact, there appeared to be larger differences in path selection between coded networks than between paths resulting with and without a turn penalty within each network. This indicates that the selection of paths is as sensitive, if not more sensitive, to the network coding as it is to

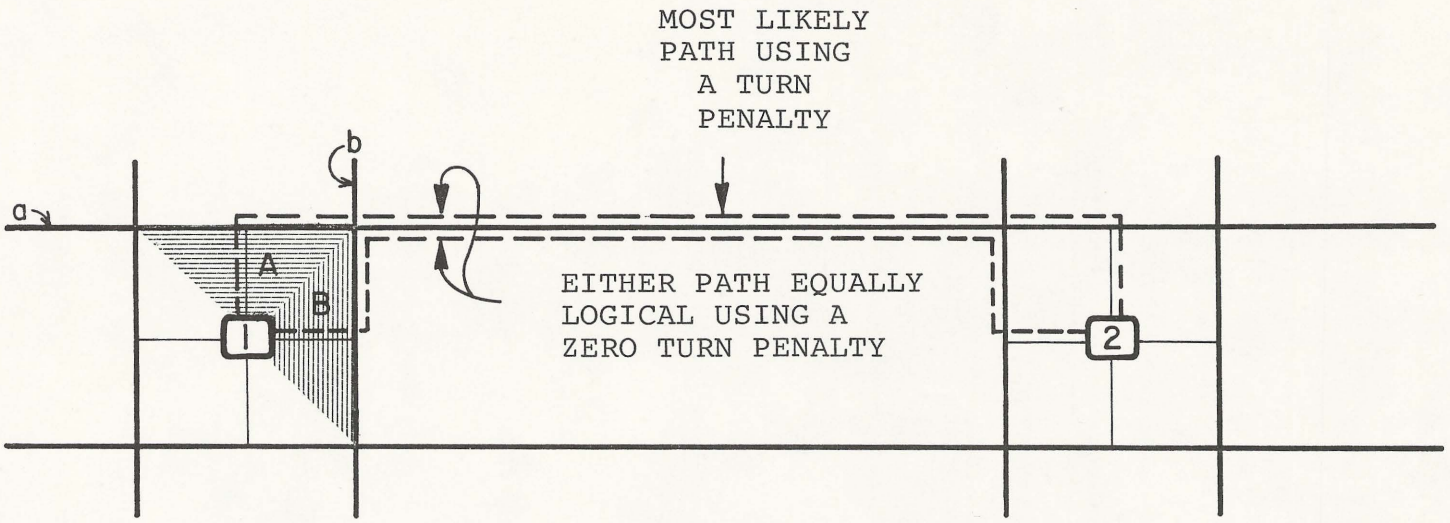
the turn penalty.

Stair-Step Paths

The Waco street system is essentially of the grid type both for major and local streets and as a result the possibility exists of minimum paths "stair-stepping" through the coded networks. In reviewing the trees with a zero turn penalty, "stair-stepping" was found to exist mostly in association with the centroid connections to link representations of the street system. Figure 9 shows an example of the type of "stair-stepping" that might occur in association with centroid connectors when using a zero turn penalty. Such routing is logical for a certain portion of trips originating in a zone.

Referring back to Figure 9, trips originating from section B of zone 1 going to zone 2 will generally enter onto street "b" and trips from section A onto street "a". Thus, assuming a uniform distribution of trip ends in zone 1, loading onto street "b" is on the average just as logical as loading onto street "a" even if more turns are involved for the path that includes street "b".

Furthermore, the Waco Street network is such that a reasonable amount of "stair-stepping" is logical and in fact often represents the only likely route. This is in part due to the system of one-way streets and discontinuities in the street system. Paths are selected directionally and when analyzing a tree it must be kept in mind that paths are built away from (the zone representing) the tree origin toward other zones. Trips from the other zones back to the tree



EXAMPLE OF STAIR-STEPPING
ASSOCIATED WITH CENTROID CONNECTIONS

FIGURE 9

origin will frequently have different paths from trips going away from the tree origin because of numerous one-way links in the network. These one-way links tend to create circuitry of routing and apparent "stair-stepping", but such routings are to an extent logical where the street system contains numerous one-way facilities.

Overall, excessive and/or illogical "stair-stepping" did not result from assignments without a turn penalty, even though there was considerable opportunity for "stair-stepping" in the intermediate and detailed networks.

Discussion of results

Overall, illogical routings were found to result as often, or more often, with a 0.2 minute turn penalty than with a zero turn penalty. In a few instances the paths between zone pairs were considerably different. However, in most of these cases, both routes were considered to be equally logical. The use of a 0.2 minute turn penalty resulted in the selection of paths with the fewest number of turns while assignments without a turn penalty resulted in the selection of a shorter path to the major street. A level-of-service speed takes into account the observed speed, desirability of the routes, relative side friction, and many other factors associated with a street. The fact that no significant differences occurred in paths selected with and without a turn penalty, indicates that when using level-of-service speeds, a turn penalty is not required and will not improve on the selection of paths between zone pairs.

Using a turn penalty will generally reduce the number of turns for each

TABLE 1

COMPARISON OF OBSERVED DIFFERENCES IN PATHS
FOR THE E-2 NETWORK WITH AND WITHOUT TURN PENALTY

Tree Number	Number of Routes		
	Essentially The Same	Different	
		0.20 TP More Logical	0.00 TP More Logical
10	9	0	1
23	5	2	2
26	10	0	1
73	4	1	0
82	7	0	0
84	3	0	0
105	5	0	1
107	3	1	0
144	4	0	2
157	6	0	0
177	3	0	0

path as compared to those using a zero turn penalty. However, a large number of these turns are associated with centroid connectors where turns for a portion of the total trips from a zone are logical.

Thus, the level-of-service speed used in Texas traffic assignment practice appears to differentiate between the various classifications of streets and highways represented in the assignment network. It apparently tends to prevent illogical routings through the coded network representation of a street system, such as in Waco, even with a zero turn penalty.