Using GIS-Based Network Analysis to Evaluate UNT E-Trans Bus Routes

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Introduction:

Transportation is a system that considers the complex relationships between networks, the demand and space. Transit on the other hand is dominantly an urban transportation mode. Since transit is a shared public service, it potentially benefits from economies of agglomeration related to high densities and from economies of scale related to high mobility demands. Mass bus transit is highly suitable for any university campus, which experiences a high volume of traffic flow during a fixed time frame. Space on the other hand is limited due to its characteristic built environment.

The bus service, which caters the demand of the students at the University of North Texas, is the E-Trans bus service. The service currently runs the shuttle on five routes, across the campus, on Mondays – Thursdays between 7:30 a.m. – 5:30 p.m. and on Fridays between 7:30 a.m. – 4:30 p.m. The shuttle recently started two night routes running from 5:45 p.m.- 2:45 a.m. The route no. 3, which loops to and from the Student Union via the West Hall, University Courtyard, Environmental Education Science and Technology Building (ESSAT), Willis Library and Highland Hall, has been chosen for the analysis purpose.

General Objective: The objective of the study is to find out optimal route for the E-link bus route no. 3 and to examine them with the present route.

Specific Objectives: To meet the general objective, the problem is broken down into two sub problems:

1) To find out the near optimal routes by using the network pathfinding analysis using the tour command.
2) To examine the resultant routes with the present routes and see if they are different.

Literature Review:

In GIS, information is all about a geographic event in the sense that it is tied to a unique location defined in a given referencing framework (J.C. Thill, 2000). With the spatial referencing of objects, the data can be defined, enabling a host of spatial query operation of objects. Duker (1987), Fletcher (1987) and Vonderohe et al. (1993) in their early research identified the nature of the dynamic nature distributed attributes of the network and suggested linearly referencing data. In 1993, Vonderohe cross fertilize GIS with an enhanced ITS with GIS to form GIS-T. This emerging technology has seen a lot of research activity by transportation researchers and professionals in recent years.

GIS is increasingly becoming the tool for the transportation developers and researchers. It has been adopted as tool by many state departments of transportation (DOTs), metropolitan planning organizations (MPOs) and many university planning agencies across USA who are associated with development of transit system on their campus. The primary tasks achieved by GIS is the geocoding of the survey data like student locations, analysis of demographic characteristics, use of network analysis models and map display and analysis. Advanced techniques like network analysis and dynamic segmentation are also used in some of the studies. Similar studies have

been undertaken by numerous school districts in USA e.g. the location-allocation model to allocate students to the schools within 30 minutes of driving time. Wang et. al (2000) and Sutton et. al (2000) on the other hand tries to incorporate the temporal dimension to their studies. Several researchers are trying to automotized the preparation of the turntable essential for the network analysis. Nielson et. al(1998) classified intersections into groups – such as prioritised and signalized intersections and required input data for turn delay models was calculated. Sutton et. al (2000) on the other hand employed 'dynamic location' which facilitates spatial intersection queries from geographic shapes without the use of topological relationship. This approach was an alternative to dynamic segmentation usually employed in these studies. In contrast to dynamic segmentation, dynamic location stores geometry as an object within a single database field.

Methodology:

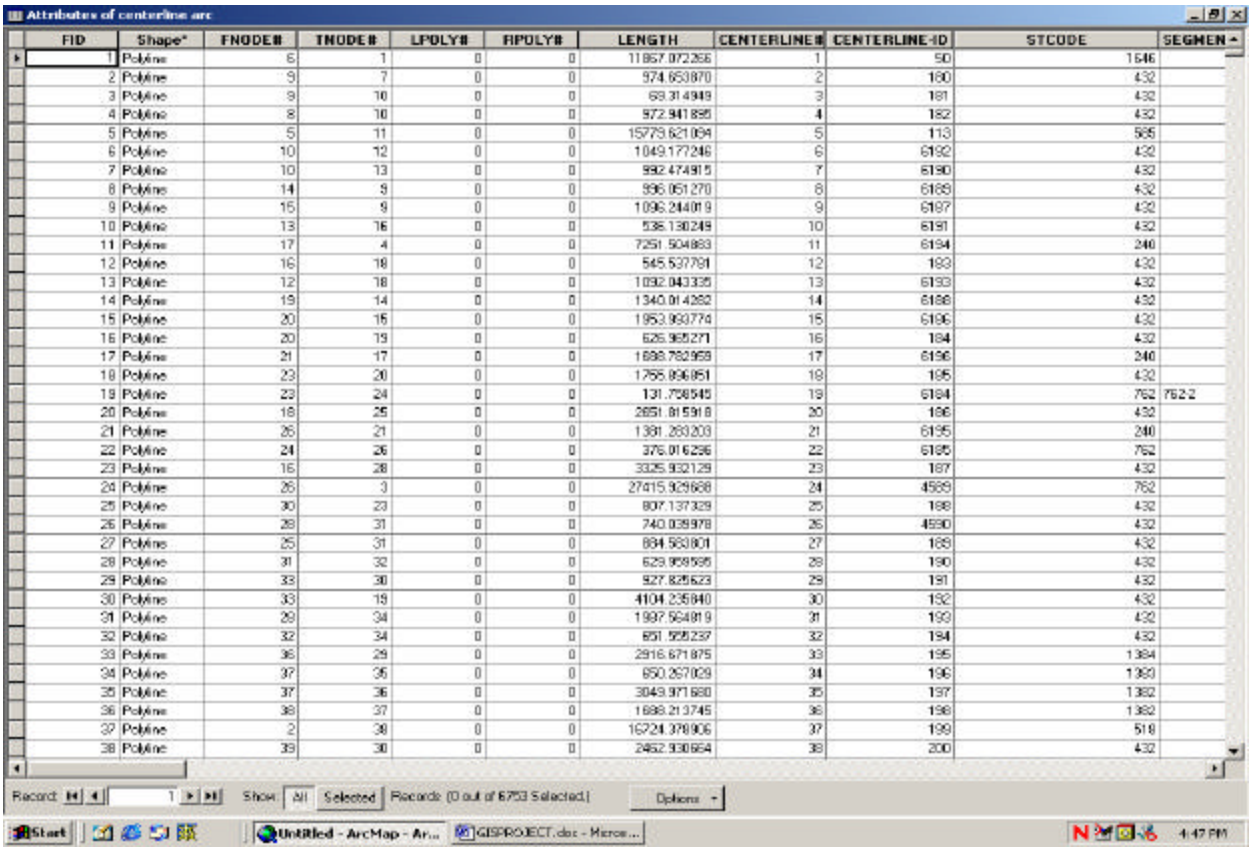
The methodology for the project will be application of network analysis. Network provides tools to find the shortest or minimum impedance path through a network. The study area is the city of Denton. The two important data layers for the project are: -

a) The geocoded map showing the location of student residences (done in the previous semester).

b) The network coverage and the turntable (obtained from Andy Oppong).

c) Some features were manually digitized.

✍✍ The Denton coverage and turntable was in the Central American Datum of 1983 and the projected coordinates were in State Plane Coordinates in internal feet. The to and from impedances were calculated based on road width, traffic congestion (static data) and time to travel.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3 | Polyline | 9 | 10 | 0 | 0 | 69.314949 | 3 | 181 | 432
4 | Polyline | 8 | 10 | 0 | 0 | 972.941895 | 4 | 182 | 432
5 | Polyline | 5 | 11 | 0 | 0 | 15779.621094 | 5 | 113 | 565
6 | Polyline | 10 | 12 | 0 | 0 | 1049.177246 | 6 | 6192 | 432
7 | Polyline | 10 | 13 | 0 | 0 | 992.474915 | 7 | 6190 | 432
8 | Polyline | 14 | 9 | 0 | 0 | 996.051270 | 8 | 6188 | 432
9 | Polyline | 15 | 9 | 0 | 0 | 1096.244019 | 9 | 6187 | 432
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18 | Polyline | 23 | 20 | 0 | 0 | 1755.896851 | 18 | 185 | 432
19 | Polyline | 23 | 24 | 0 | 0 | 131.758545 | 19 | 6194 | 762 762.2
20 | Polyline | 18 | 25 | 0 | 0 | 2851.815918 | 20 | 186 | 432
21 | Polyline | 26 | 21 | 0 | 0 | 1381.283203 | 21 | 6195 | 240
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27 | Polyline | 25 | 31 | 0 | 0 | 884.563801 | 27 | 189 | 432
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37 | Polyline | 2 | 38 | 0 | 0 | 16724.378906 | 37 | 199 | 518
38 | Polyline | 39 | 30 | 0 | 0 | 2452.930664 | 38 | 200 | 432
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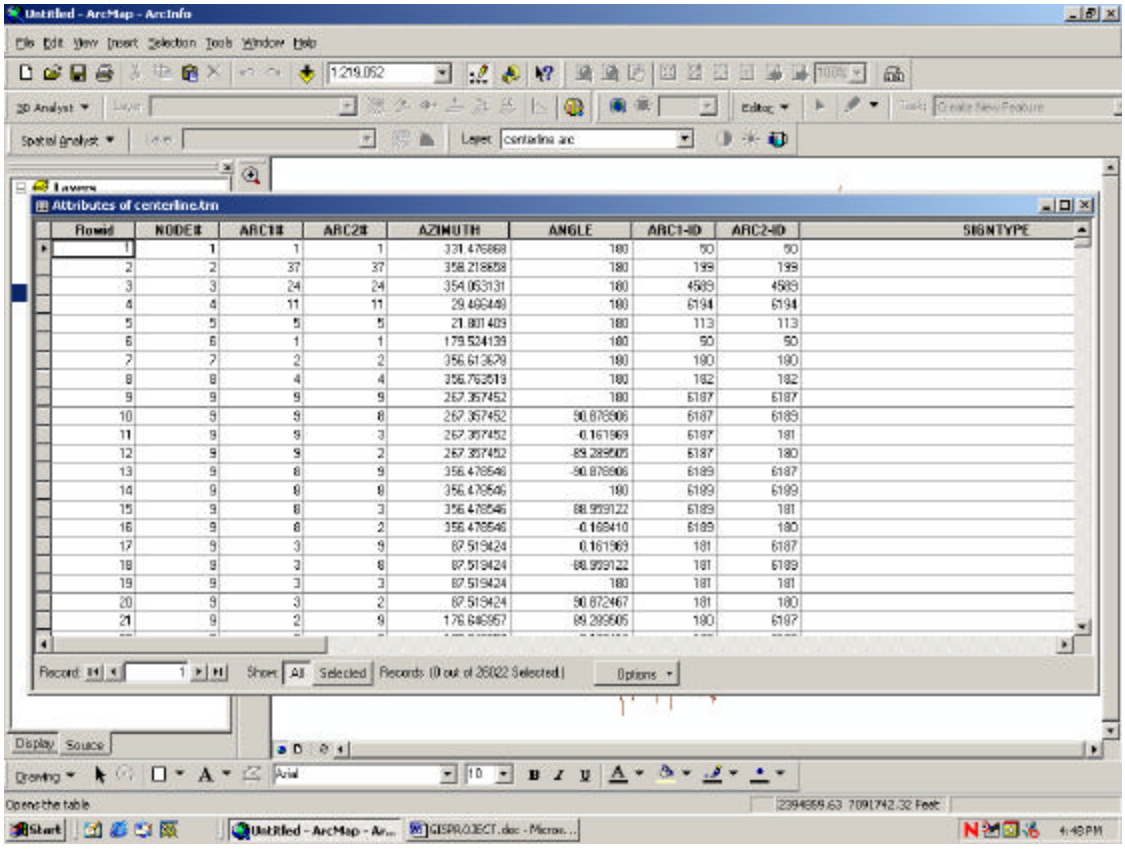
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2 | 2 | 37 | 37 | 358.218858 | 180 | 199 | 199
3 | 3 | 24 | 24 | 354.053131 | 180 | 4589 | 4589
4 | 4 | 11 | 11 | 29.469449 | 180 | 6194 | 6194
5 | 5 | 5 | 5 | 21.801409 | 180 | 113 | 113
6 | 6 | 1 | 1 | 175.524139 | 180 | 50 | 50
7 | 7 | 2 | 2 | 356.613678 | 180 | 190 | 190
8 | 8 | 4 | 4 | 356.763519 | 180 | 182 | 182
9 | 9 | 9 | 9 | 267.357452 | 180 | 6187 | 6187
10 | 9 | 9 | 8 | 267.357452 | 90.878906 | 6187 | 6189
11 | 9 | 9 | 3 | 267.357452 | -0.161969 | 6187 | 181
12 | 9 | 9 | 2 | 267.357452 | -89.289505 | 6187 | 180
13 | 9 | 8 | 9 | 356.478546 | -90.878906 | 6189 | 6187
14 | 9 | 8 | 8 | 356.478546 | 180 | 6189 | 6189
15 | 9 | 8 | 3 | 356.478546 | 88.959122 | 6189 | 181
16 | 9 | 8 | 2 | 356.478546 | -0.168410 | 6189 | 180
17 | 9 | 3 | 9 | 87.519424 | 0.161969 | 181 | 6187
18 | 9 | 3 | 8 | 87.519424 | -88.959122 | 181 | 6189
19 | 9 | 3 | 3 | 87.519424 | 180 | 181 | 181
20 | 9 | 3 | 2 | 87.519424 | 90.872467 | 181 | 180
21 | 9 | 2 | 9 | 176.646957 | 89.289505 | 180 | 6187
Record: 1 Show: All Selected Records: (0 out of 26022 Selected) Options
Display Source
Drawing
Open the table
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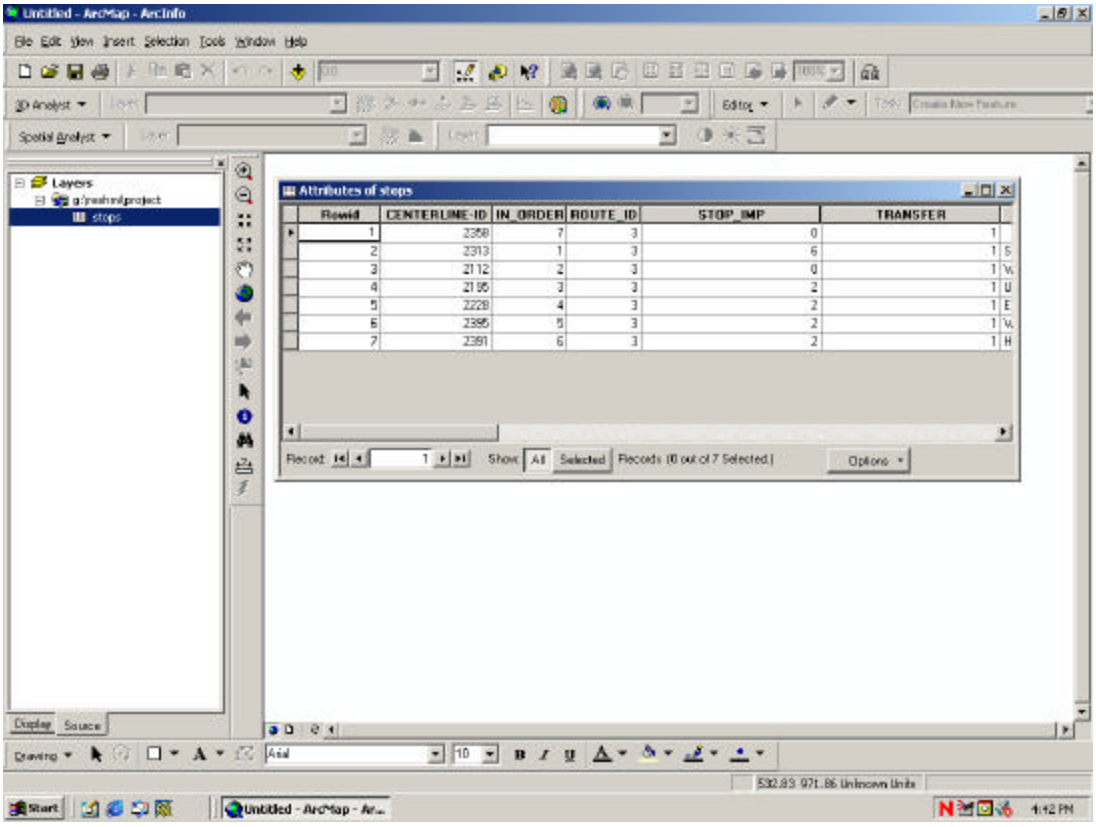
✍✍ The six stops on the route Student Union, West Hall, University Courtyard, ESSAT building, Willis library and Highland Hall was digitized on the map. Route 3 was also digitized and saved as a layer.

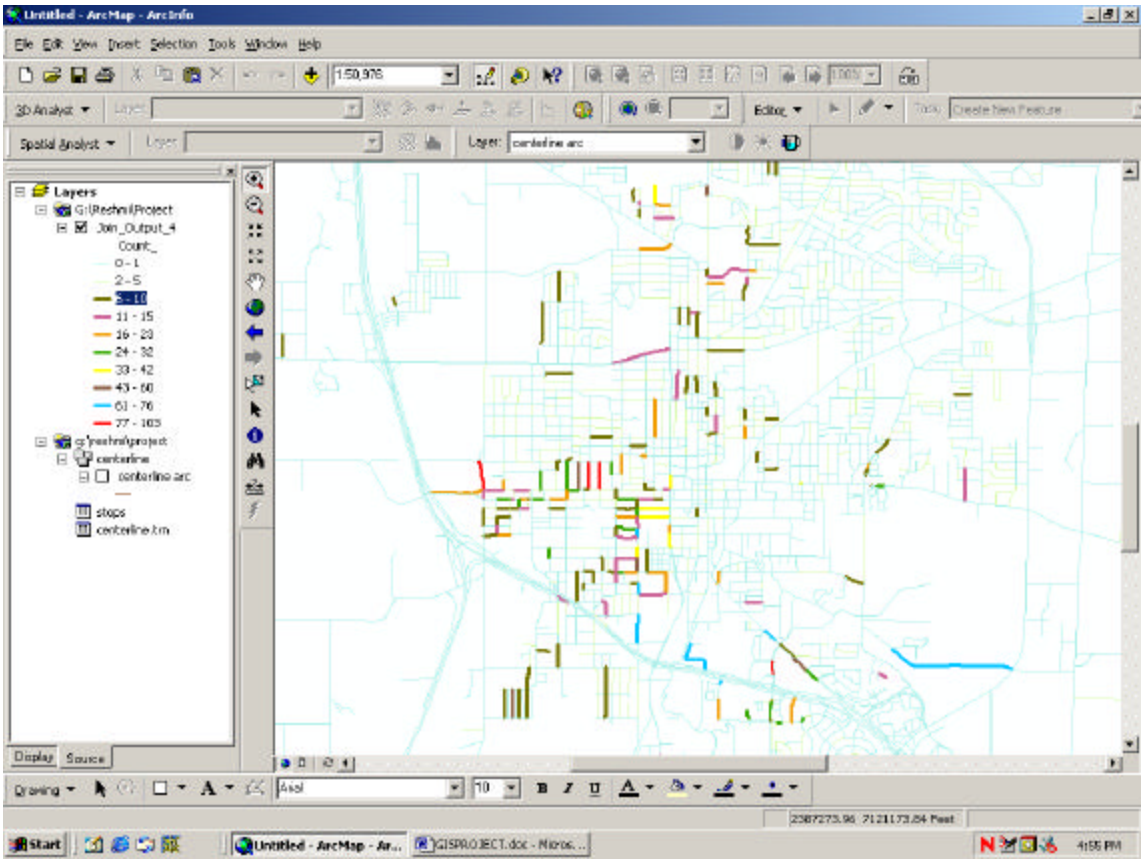
✍✍ The stops file was created as an INFO file in ArcCatalog and ArcMap. The cover ID item was provided from the nodes in Denton coverage nodes. However since the starting and ending point was the same two separate nodes were allocated to avoid confusion.

✍✍ The stops order was put according to the order, which the stops were visited by the bus service. The route-id was the same, as I was only examining one route. The stop impedances were given according to the time the bus stops now at each stop.



✍✍ The geocoded shapefile showing the location of the student map was then joined (spatial join) with the arcs of the coverage. Now each arcs will have the total counts of the students on them. The resultant shapefile was then symbolized as the arcs showing students 0-10,

11-21, 22-31, 32-41, 42-52, 53-62, 63-71, 73-81, 83-91 and 94-103 were shown and marked by different colors. Fry Street, Bryan Street, Normal Street and Jagoe Street showed large no. of students. The University Courtyard on Bonnie Brae also showed a large no. of students.



✍✍ The network analysis was carried in the ArcInfo workstation. The following commands were used in ArcPlot to carry out the network analysis.

- netcover centerline tour1
- impedance from_to_imp to_from_imp turn imp
- stops stops denton-id in_order route-id stop_imp transfer
- tour stops
- mapextent centerline

- arcs centerline
- reselect centerline nodes keyfile stops denton-id
- textcolor 2
- nodes centerline ids
- routelines centerline tour1 3

Since the transfer was default it was overwritten. The resultant tour was then added to the Arcmap and displayed in the map.

Importance of the Study:

The E-Trans Bus service is designed for transfer of students on the campus and for picking up students from a selected stops and transfer them to the Student Union. The bus service doesn't take into account the concentration of the students but delivers students at different points on the campus, like the ESSAT building, Willis Library or the Student Union. It picks up students from west Hall, Highland Hall and University Courtyard. If the optimal route is found based on the link and turn impedances then it will help authorities design routes which will lead to more effective transfer of the students on the campus and may be at the lesser time and cost efficient manner.

Timeline:

The project was started in the Fall 2003 and completed by the end of the semester. The preparation of the Stops INFO file will be completed by March 2003. The digitization of the routes and bus stops will be finished during the spring break. The network analysis will be completed by April and the final report will be done by the first week of May.

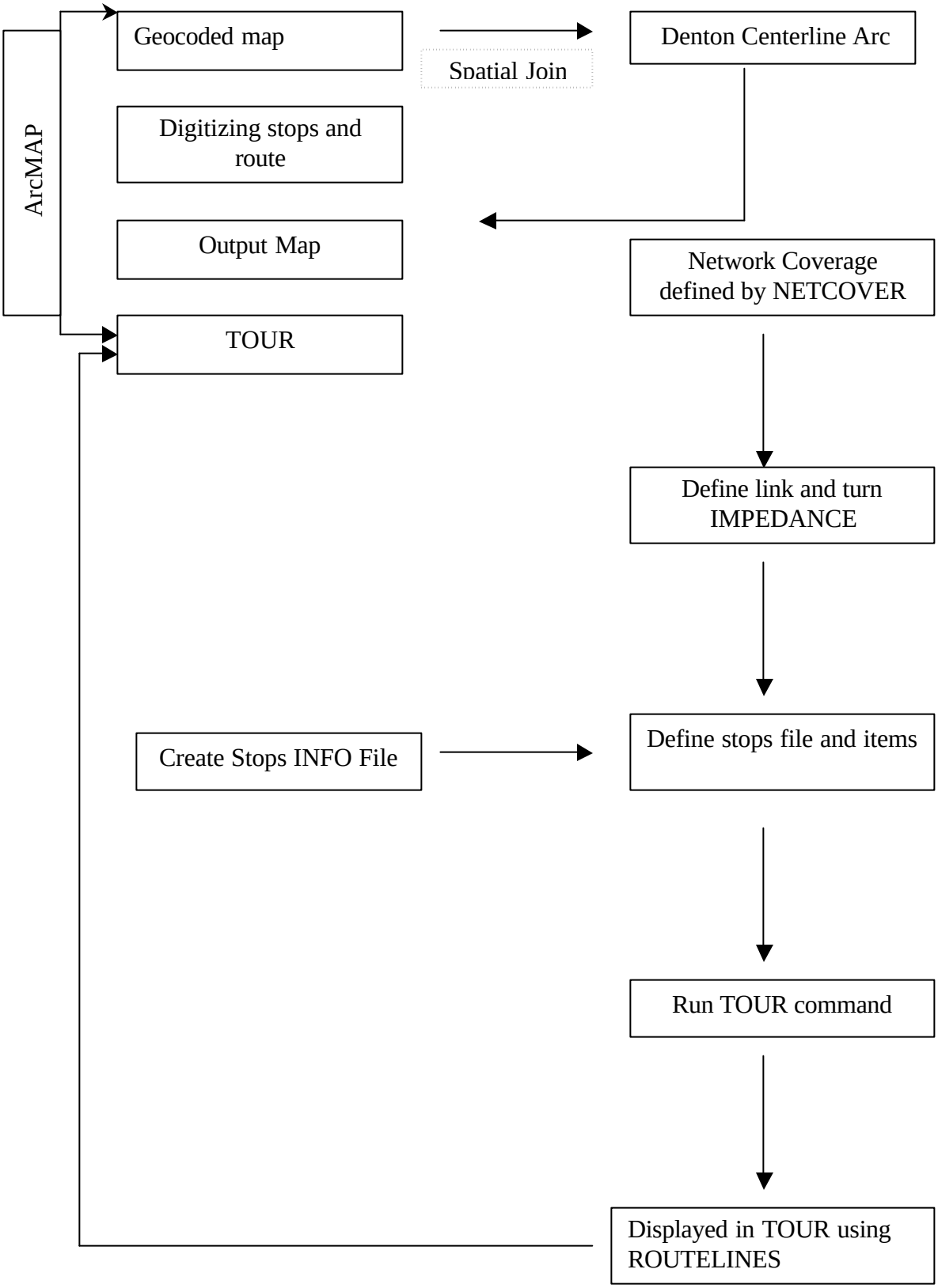
Conclusion:

The route created by the tour when overlaid on the present routes, showed that both the routes are very similar. The tour starts from the student Union to West Hall following Welch Street and take left at Oak Street. The next stop visited is the University Courtyard. The route takes a left in Avenue G and goes on the West Hickory before visiting the stop. The present E-Trans route takes left at Bonnie Brae before visiting the stop. Since the link impedance for the arc is high at Bonnie Brae the tour seem to take West Hickory Street instead of Bonnie Brae. The next visited stop is at ESSAT building by taking a U-turn at West Hickory. In contrast the present route takes left at Stella and then left to Avenue F before reaching ESSAT. Both the routes follow similar pattern in visiting the other stops. The route takes right at Avenue C and the left to Highland to visit Willis library stop and the Highland Hall stop. After Highland Hall it takes a left hand turn at Bernard and then to Prairie to reach Student Union and to finish the loop. When compared to the number of students picked up by the routes. The present route seems to pick up a slightly large number of students (44) compared to the tour (36). So the present route might not be the optimal route in terms road width, congestion and travel time but larger number of students was picked up by this route than the route provided by the tour. However both the routes seem to cover the streets large concentration of students like Fry Street, Bryan Street, Normal Street and Jagoe Street and University Courtyard.

References:

1. Shaw, Shis-Lung, 2000. ESRI User Conference Proceedings (2000). Moving towards Spatiotemporal GIS for Transportation Applications.

2. Sutton, J.C., M.M. Wyman, 2000. Transportation Research Part C 8 (2000): 37-52. Dynamic location: an iconic model to synchronize temporal and spatial transportation data.
3. Nielson, O.A, R.D. Frederiksen, 1998. Int. Trans.OPL.Res: Vol5 No.6: 569-581. Using Expert System Rules to Establish Data for Intersections and Turns in Road Networks.
4. Choi, K., W. Jang, 2000. Transportation Research Part C 8 (2000): 129-146. Development of a transit network from a street map database with spatial analysis and dynamic segmentation.
5. Eli Cortez; Randy Meek; Jim Koger, 1995, Proceedings of the 1995 Annual Urban and Regional Information Systems Association. An enterprise GIS to support school district operations
6. ARC/INFO User's Guide, Network Analysis: Modeling network systems. Environmental System Research Institute Inc.


Geocoded map
Spatial Join
Denton Centerline Arc
ArcMAP
Digitizing stops and route
Output Map
Network Coverage defined by NETCOVER
TOUR
Define link and turn IMPEDANCE
Create Stops INFO File
Define stops file and items
Run TOUR command
Displayed in TOUR using ROUTELINES