Applications for Interactive Transportation Planning GIS (TPGIS)

Final Report / User's Manual
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Researchers

Reginald R. Souleyrette, Ph.D., Principal Investigator
Associate Director for TP/IS, Center for Transportation Research and Education
Associate Professor of Civil Engineering

Michael D. Anderson, MSCE, E.I.T.
Graduate Research Assistant
Center for Transportation Research and Education

Zachary N. Hans, MSCE, E.I.T.
GIS Specialist, Center for Transportation Research and Education

Phillip J. Mescher, MS TrPl
Graduate Research Assistant
Center for Transportation Research and Education

Brad Roeth
Undergraduate Research Assistant
Center for Transportation Research and Education

Chris Thompson
Undergraduate Research Assistant
Center for Transportation Research and Education

Iowa State University

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PROJECT DESCRIPTION

This project builds upon the previously Midwest Transportation Center (MTC) sponsored project, "High Speed Computing to Facilitate Real Time Analysis of Transportation Planning Alternatives Through GIS." The Transportation Planning Geographic Information System (TPGIS) procedures developed here are converted into a "user guide" format suitable for most planning agencies. The planning tools developed in the TPGIS project are designed to be interactive tools which utilize GIS and graphic user interfaces to change planning model inputs as well as display results of model runs and alternatives analyses. This type of system provides an environment for transportation modeling which is superior to older, non-graphic methods which are primarily driven by batch files created in a batch mode. Planners and engineers can more easily visualize data inputs (e.g. socioeconomic variables) using the GIS color graphic displays. Collections of data used to support a particular model scenario can also be more efficiently stored in a GIS than in a tabular environment. In addition, the interactive nature of TPGIS permits an analyst to perform what-if scenarios in response to requests by decision makers while they wait.

The TPGIS project expands by developing an array of interactive tools utilizing GIS that are designed to aid transportation planning agencies in conducting alternatives analyses, transportation forecasting, and facilitate other planning functions. The TPGIS provides an analyst with the ability to modify data and assumptions and to recognize the implications of changes. Although the system, as developed, uses a combination of advanced hardware and sophisticated software, technology is becoming available to many planning organizations to allow similar capabilities (desktop mapping and high-speed yet affordable personal computers).

The goal of the this research is to develop a user-friendly version of TPGIS which may be used for investigating the outcomes of alternative decisions and understanding the sensitivity of forecasts to network supply and demand assumptions and quality of data. **<u>Standard hardware and software</u>** available to the Iowa Department of Transportation (Iowa DOT) Office of Systems Planning, Iowa Metropolitan Planning Organizations (MPOs), and Iowa Regional Planning Affiliations (RPAs) are used in this project. Results extend to other areas of the Midwest and Nation as these packages are widely used.

MOTIVATION

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 and Clean Air Act Amendments of 1990 have greatly increased the need for analytical tools applicable to urban and regional transportation planning. Areas of concern include congestion management, air quality analysis, travel demand management, economic development and equity issues. Planners, analysts, and decision makers alike are faced with the need to better understand the impact of policies, plans and growth on transportation networks and populated regions.

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PROJECT OBJECTIVES

The goal of the research project is to develop the TPGIS which may be used for investigating the outcomes of alternative decisions and understanding the sensitivity of forecasts to network supply and demand assumptions and quality of data. The goal of the TPGIS is met through the following objectives:

1) evaluate the design of the TPGIS with regard to transfer and application of the system to the Iowa DOT, MPOs, and RPAs

2) modify and enhance the TPGIS as required for implementation in a production environment

3) evaluate the usefulness of the TPGIS for alternatives analysis, and demonstrate the ability of the TPGIS to study the implications of selected policy decisions

4) use the TPGIS to study the sensitivity of model outputs to input data and assumptions thereby enhancing model calibration techniques

5) evaluate potential TPGIS for statewide transportation planning and congestion management.

Description

The following are brief descriptions of each proposed project objective:

1) The methodology included application of GIS-based socioeconomic and demographic data from the census bureau and other sources, conversion of existing land-use and network digital data, and discussion of priority demonstration application areas with DOT and local officials.

2) Manipulation of supply and demand inputs and the resulting impact on Urban Transportation Modeling Software (UTMS) outputs revealed the sensitivity of the input-output relationship and the acceptable levels of input accuracy. The UTMS outputs of interest were those with the greatest impact on transportation planning decisions such as vehicle hours traveled (VHT), vehicle miles traveled (VMT), travel time, delay, and traffic volumes.

3) The MapInfo-Tranplan interface facilitated the objectives set forth in the Iowa DOT GIS Strategic Plan.

4) A TPGIS platform was developed which performs better in a production environment. The new platform did not include the Cray Supercomputer but remains functionally similar. Components of the new platform include an Intergraph workstation, Intergraph

software, Fortran software, an IBM compatible personal computer (PC), and an Alpha workstation.

5) In conjunction with objectives one and two, the TPGIS was used to analyze and evaluate national transportation policies regarding travel and congestion levels. An attempt was made to characterize cities of different sizes to determine how and if ISTEA policies are applicable to specific regions, including those without congestion problems.

6) Potential use of TPGIS for statewide transportation planning was examined with regard to functionality, application, modeling capabilities, data availability and practicality, regional model connectivity, modal choice (freight), and modal movement.

Methodology

The following are tasks and methodologies followed to obtain each project objective:

1) A new TPGIS platform was developed for a production environment available to most planning agencies. The new platform does not require advanced computers, but remains functionally similar to that developed in the "high-speed" project. Two hardware environments were developed, one which utilizes an IBM-compatible PC and the other which combines the capabilities of PCs and a workstation. Two software platforms were also studied, Tranplan and Intergraph's MGE, and Tranplan and MapInfo.

2) To identify issues and develop a prototype system for MPOs and RPAs, the project identified and converted GIS-based socioeconomic and demographic data from the census bureau and other sources, existing land-use data, and street network digital data. Priority demonstration application areas were identified with DOT, MPO and RPA input. For example, the Des Moines MPO is interested in possible applications of TPGIS for Iowa 5, the Southeast and Southwest connectors, and the Martin Luther King extension. Particular interest was given to the integration of aerial photography within the TPGIS.

3) Manipulation of supply (network) and demand (landuse/socioeconomic) inputs and the resulting impact on model outputs revealed the sensitivity of the input-output relationship and the acceptable levels of input accuracy. The model outputs of interest are those with the greatest impact on transportation planning decisions such as VHT, VMT, travel time, delay, and traffic volumes.

4) A MapInfo-Intergraph interface was designed and tested to assess potential GIS data exchange between the DOT and MPOs. A Mapinfo-Tranplan linkage was established and the functionality of both MapInfo and Intergraph evaluated. The software interfaces and evaluations support objectives of data integration and standardized applications development set forth in the Iowa DOT GIS Strategic Plan.

5) Possible extensions of the use of the TPGIS were examined. Among these were statewide transportation planning and congestion management systems.

SPECIFIC AREAS OF STUDY

Developing a TranPlan Model Using the Integrated GIS Environment

In this section, a set of recommended "steps" is described for developing Urban Transportation Planning (UTP) models using desktop GIS tools.

Interactive Transportation Planning in the TranPlan / MapInfo Environment

The goal of this section is to describe tools developed to provide a modeling environment more appropriate for the technical knowledge level and budget requirements of small urban or rural areas. Specifically, the needs of MPOs and RPAs in Iowa were considered in the system design.

Bicycle Route Planning

The bike route research concentrates on using GIS to analyze the placement of bikeway facilities. Included in the analysis is the development of a methodology utilizing an internet-based Delphi Technique to identify and weight criteria to be considered when planning new facilities. An optimal path algorithm utilizes these weighted criteria to calculate and display the best route through a network. Included in determining the optimal route is weighting factors for items such as terrain, traffic volumes, and roadway widths. The optimal path algorithm can also be used to analyze different user defined paths to rate each.

QRSII / MapInfo Interface

A working linkage was developed between the forecasting package, QRSII, and MapInfo GIS package. This interface operates similarly to the TranPlan / MapInfo interface using the GIS to analyze, modify, display, and store data required by the forecasting model.

Census Transportation Planning Package

The analysis and use of the Census Transportation Planning Package (CTPP) data resulted in programs being written to extract the desired information from the CD-ROM and associate the data to the appropriate traffic analysis zone (TAZ). The city of Des Moines will be used as a case study and the data, mostly in the form of thematic maps, will be presented to the Des Moines MPO.

Transit Analysis

The transit analysis concentrates on using GIS to develop transit routes. This section of the project has been studied in detail but has not currently been implemented. CTPP data was used to make thematic maps illustrating transit trip ends as a percentage of total work trips and population density.

TransVIEW Software

TransVIEW software is the tool which enables the use of the CTPP data. It is a limited display package that can show and extract CTPP data. This package was investigated to determine if it was functionally capable to be used in practice.

National Highway Planning Network

Work was done to develop GIS tables for the National Highway Planning Network. The information was retrieved from CD-ROM and placed into MapInfo format through the use of Fortran programs.

Airport Location

A study was performed to determine the number of people living within a certain radius of airports. This information was requested by the Iowa DOT.

World Wide Web Applications

The use of the World Wide Web (WWW) for transportation was analyzed and many new ideas about displaying and handling transportation data were discovered.

Department of Natural Resources

Data from the Department of Natural Resources pages on the WWW were accessed and provided to local agencies.

Raster Images

Aerial photos were made into raster images and imported into a GIS to examine the use of these images within a GIS environment. An aerial photo of the city of Ames was used for UTP model development. An aerial photo of the city of Dubuque was utilized to determine access locations along a corridor.

Census Summary Tape Files

The objective of this task was to develop a method, utilizing desktop GIS, for aggregating and disaggregating census block and block group data to a TAZ level.

SUMMARY

This documentation was developed to serve as a user's guide to aid professionals in the use of the tools developed in the TPGIS project. The user's guide coupled with the TPGIS report complement each other to provide a comprehensive analysis of the tools developed. The user's

guide is designed to give step by step instructions for using each of the transportation planning tools developed in this research.

CHAPTER 2.
DEVELOPING A TRANPLAN MODEL USING
THE INTEGRATED GIS ENVIRONMENT

OVERVIEW

Personal computer implementations of urban transportation planning (UTP) packages have resulted in a proliferation of modeling efforts. The proliferation has generated a need for improved access to spatially referenced data and enhanced graphical interfaces and visualization tools, particularly for agencies with limited resources. A geographic information system (GIS) for transportation modeling can meet these needs. In this chapter, a set of recommended "steps" is described for developing UTP models using desktop GIS tools. Using the City of Ames as a case study, the methodology improves data integration, allows for cost-effective and timely model development, and provides GIS visualization tools for enhanced model calibration and validation.

OBJECTIVE

Develop a UTP model for smaller urban areas (up to 100,000 population) using GIS technology.

REQUIREMENTS

Data needed to create the model represent the main requirements for the environment. Possible data sources includes CAD line files, tax assessor's data, employment statistics, TIGER line files, aerial photographs, and other spatially referenced data.

Note: One important remark is that the methodology presented is one way to create a model. It is not to be viewed as the best way, and changes to the procedures may be desired or necessary.

PROCEDURE

Step 1. Incorporation of Data

The first step is to incorporate data into the GIS environment.

1) Department of Transportation (DOT) files can be brought into MapInfo through an export from Intergraph's MGE into MapInfo.
2) TIGER street file can be brought into MapInfo via export from another GIS package or through shareware programs.
3) Aerial photo can be scanned into GIF images and registered into MapInfo.
4) Employment data can be addressed matched to the TIGER street files.

5) Assessor data can be brought into MapInfo through address matching or direct import as an ASCII table.

6) Census data (block and block-group) can be brought into MapInfo through the same procedure used for the TIGER file.

Step 2. Removal of the Extraneous Streets

Extraneous streets are removed for network development. Viewing the street network, select and delete all streets not required for the model. After removing streets, pack the network table to remove empty rows in the table.

Step 3. Combine Remaining Streets

Remaining streets need to be combined into single links. Either redraw the network links to a new layer or combine link elements by utilizing the combine feature.

Step 4. Add Centroid Connectors

Add centroid connectors to the network table by drawing links as appropriate. Existing links may need to be split to allow the placement of centroids. Splitting involves placing a box around a portion of the link either to the left or right of the centroid. Then the object is set as the target object and the link is split into smaller links. External connectors can also be added at this point.

Step 5. Alter the Network Table

Alter the network table to include link beginning and ending X-Y coordinates and link length. Additional columns for the links table include starting X coordinate, starting Y coordinate, ending X coordinate, ending Y coordinate and length. Link information can be determined using the ObjectGeography and the Objectlen functions in MapBasic. A MapBasic program examines each graphic element and places the information in the appropriate column of the network table.

Step 6. Run Fortran to Manipulate Network

A Fortran program can be used to read an exported ASCII file of the link table. The program assigned 1000 and 1001 to the A and B node of the first record, respectively; then sequentially examined the X-Y coordinates for each endpoint to determine if any nodes had the same X-Y coordinates. If two records had the same X-Y coordinates, the program assigned the same node number to each record.

The program also developed a file containing the node number and X-Y coordinates for each node. This file is the node file to be used in Tranplan.

Step 7. Alter Node Numbers for Centroids

Node numbers for the node file can be changed to represent centroids. Centroids need be numbered starting from one up to the total number of external connectors. Selecting nodes and modifying the node table completes this task.

Step 8. Renumber Nodes

Export the node data to ASCII format by running a Fortran program that finds the new node numbers for the links. The program updated the link file with the proper A and B node number.

Step 9. Alter Links Table

Link information needs to be altered to provide additional columns for placing Tranplan information. The additional columns required include assignment group, speed option, speed, direction code, link group options, capacity, and one-way designation. Maps of the study area can be used to determine the speed and capacity for each link in the network.

Step 10. Select Trip Generation Procedure

Select the appropriate trip generation procedure to use. One acceptable methodology is the update to National Cooperative Highway Research Program 187 (NCHRP 187). However, others are available and work equally well.

Step 11. Obtain Necessary Data Inputs

Obtain the necessary data inputs to the trip generation equations. Using the update to NCHRP 187, the number of households was taken from Summary Tape File 1 (STF) and the income ranges for households was taken from STF 3.

Step 12. Incorporate Employment Data

Incorporate data related to the number of employees. Data from the Department of Employee Services contains the name, address, Standard Industrial Code and number of employees for the business. The geocode, or address match function in MapInfo can be used to place points for businesses on the street network. Manual manipulation may be required for both data sets to ensure a high percentage of businesses address matched. Examples of possible problems encountered during geocoding are that the addresses for the businesses might have the road name coded as "Duff Avenue" and the TIGER street name might be coded as "Duff Ave" or the TIGER street file would be incomplete with street names or address ranges.

Step 13. Creating Traffic Analysis Zones

A starting assumption is that traffic analysis zones (TAZs) should match the census block-groups. Alterations may be necessary after an examination of the street network, the Tranplan link file and the land-use characteristics. The requirement that the TAZs not cross block-group boundaries ensures that the data from the block-group would not have to be aggregated with another block-group.

Step 14. Alter Traffic Analysis Zone Table

Update the TAZ table with data to calculate productions and attractions. The TAZ table may need alterations allowing for new columns including TAZ number, number of employees by type, number of households, if located in central business district, attractions by type, number of households in income ranges, percentage of households in income ranges, number of households by occupancy, total population, number of households by income range and occupancy, and productions.

Step 15. Update Socio-Economic Data

Update the new columns in the TAZ table through the table update command using a "summation" of number of employees located in each TAZ. Updating of data from the Census Department requires census blocks to update the "number of households" column and block-groups to update the "number of households by income level" columns and the "number of households with specified occupancy" columns. The appropriate columns were summed and aggregated to the TAZ table. After the data was updated into the TAZ table, the equation from the trip generation program was used to update the productions and attractions for each of the trip purposes.

Step 16. Update Node Table

Update the node table with the socio-economic information. The node table needs to be altered to add additional columns for Home-Based Work (HBW) attractions, HBW productions, Home-Based Other (HBO) attractions, HBO productions, Non-Home Based (NHB) attractions, NHB productions, to label productions and attractions, and to represent trip purpose.

Step 17. Calculate External to External and External to Internal Trips

Calculation of external to external (E-E) and external to internal (E-I) trips can be performed by following the procedure outlined in the update to NCHRP 187. Other methods can also be used to calculate these trips.

Step 18. Place External to Internal Trips into Node Table

The productions and attractions for the external stations can be manually entered into the node table.

Step 19. Create External to External Trip File

　　　E-E trips can be converted into an ASCII file. A Tranplan control file can be used to convert the ASCII file into an E-E trip table to be used when running Tranplan.

Step 20. Creation of Tranplan files

　　　Creation of Tranplan files include friction factors, which are needed to perform a Tranplan run. These can be obtained by examining of other networks with similar size and land-use characteristics or through the use of quick response tables (such as those provided in NCHRP 187) and control files.

Step 21. Calibration and Validation

　　　Calibration and validation of the model should be performed using the Tranplan - MapInfo interaction to ensure the model is accurately predicting traffic volumes. Methods for performing calibration and validation include screenlines, cutlines, and examining individual links.

　　　The first tool developed to perform this step consists of running a MapBasic program which plots Tranplan model volumes by buffering the link with the volume. The tool also labels the loaded volume and percent difference from the ground counts. The second tool developed consists of a module developed to display turning movement counts for specified intersections. The turning movement diagrams are drawn on the map and labeled with the turning volume. The final tool developed consists of a module to determine and display the shortest path between any two specified nodes.

CHAPTER 3.
INTERACTIVE TRANSPORTATION PLANNING IN
THE TRANPLAN / MAPINFO ENVIRONMENT

OVERVIEW

Geographic Information Systems (GIS) have shown to be an effective tool for transportation forecasting and scenario analysis. Previous efforts have linked full function GIS packages with transportation forecasting models. The goal of this chapter is to describe tools developed to provide a modeling environment more appropriate for the technical knowledge level and budget requirements of small urban or rural areas. Specifically, the needs of Metropolitan Planning Organizations (MPOs) and Regional Planning Affiliations (RPAs) in Iowa were considered in the system design. In the work described in this chapter, a desktop mapping package, MapInfo (MapInfo Corporation, Troy, NY), is integrated with an urban transportation planning (UTP) model, Tranplan (Urban Analysis Group, Danville, CA), to provide an interface for network analysis. With the system, network modifications and changes representing alternative demand scenarios are made in the GIS environment, data are exported to the Tranplan format, and returned to the GIS for effective presentation of results. User tools were tested and a case study demonstrating alternatives analysis and display capabilities is presented. Although developed and tested for Des Moines, the system can easily be transferred to other agencies to enhance transportation planning capabilities.

OBJECTIVE

This chapter demonstrates steps required to the use the programs in the Tranplan - MapInfo modeling environment.

REQUIREMENTS

The node, link, and production/attraction files should be stored as individual files and not as one input file. If this information is not available in ASCII format, run netcard on the binary network file and save as individual files. All files need to be placed in one directory. For multiple scenarios, the files must be placed in separate directories and each directory should represent one scenario.

The total number of centroids and external stations in the network needs to be known to operate the programs. The projection system used to develop the network needs to be known to correctly place the network and allow for overlay of other data sets.

Tranplan Files: User Provided

1) Node file - a file containing the node data (in large coordinate format)
2) Link file - a file containing the link data
3) Production and attraction file - a file containing the Ps and As for the centroids (maximum of five trip purposes)

4) <u>External trip file</u> - a file containing the external trip table for use in Tranplan (must be named EXTEXT90.TRP)

5) <u>Friction factor file</u> - a file containing the friction factors for use in Tranplan (must be named FRICFAC.DAT)

<u>Files Provided By CTRE/ISU</u>

1) <u>DOSXSMF.EXE</u> - a file required to run Fortran programs

2) <u>TP_MI.EXE</u> - Fortran executable for developing MapInfo tables and maps for node and link information

3) <u>BLDNET.EXE</u> - Fortran executable for developing a Tranplan control file to build the initial network in Tranplan.

4) <u>LOADED.EXE</u> - Fortran executable for stripping out unnecessary information from output of Tranplan

5) <u>REGISTER.MBX</u> - MapBasic program for registering the node and link files

6) <u>UPDATE.MBX</u> - MapBasic program for updating new information into links table

7) <u>TURN-REG.MBX</u> - MapBasic program to register the turning movement data into MapInfo

8) <u>TURNMOVE.MBX</u> - MapBasic program to display turning movement diagrams for specified nodes

9) <u>PLOT.MBX</u> - MapBasic program to display the visualization plot

10) <u>C-PLOT2.MBX </u>- MapBasic program to display the validation plot

<u>Intermediate Files Created By Programs</u>

1) <u>FILENAME.TXT</u> - a list of filenames needed for REGISTER.MBX created by TP_MI.EXE

2) <u>FLENAME2.TXT</u> - a list of file names needed for UPDATE.MBX created by LOADED.EXE

3) <u>NEW_DATA.TXT</u> - the output file from LOADED.EXE with the unnecessary NETCARD information removed

PROCEDURE

Note: This is a narrative description beginning with an existing Tranplan model.

<u>Step 1: Run Initial Fortran Program</u>

The first step is the development of a node and link Tranplan network in MapInfo. This is begun by collecting the required Tranplan files and running the program TP_MI.EXE. The program is operated by typing TP_MI at the DOS prompt in the directory containing the files or by double clicking TP_MI.EXE in the Windows File Manager. This program prompts the user for the required file names and number of traffic analysis zones (TAZs). The program also prompts the user for output filenames which must be exactly six characters with an extension. The program then asks for the same six character filename without the extension. Defaults have

been provided for your convenience. If the default is chosen, the output files will be named nodes1 and links1 and the MapInfo tables will be named nodes1z.tab and links1z.tab.

Step 2: Run MapBasic Program to Register Network

After running the initial fortran program, enter MapInfo. Select FILE - RUN MAPBASIC PROGRAM and run REGISTER.MBX. This program develops tables and maps for the links and nodes. However, before any linework is placed on the map, the appropriate projection needs to be selected. This is done by selecting MAP - OPTIONS - PROJECTION and then selecting the appropriate projection.

Step 3: Create Graphics

To place the linework, open a MapBasic window by selecting OPTION - SHOW MAPBASIC WINDOW and type:

update 'node table name' set obj = createpoint (x,y)
update 'link table name' set obj = createline (ax,ay,bx,by)

Note: the node and link table name can be found at the top of the map window.

Example:
If the defaults are chosen for the table names, the lines to type are:
update nodes1z set obj = createpoint (x,y)
update links1z set obj = createline (ax,ay,bx,by)

Step 4: View all Layers

Once the tables have been generated, select MAP - VIEW ENTIRE LAYER - ALL LAYERS to view the network.

Step 5: Make Modifications to Network

In order to make modifications to the tables and maps, a copy needs to be made. The process needed to make the copy of the base table is to select the SAVE COPY AS command from the FILE menu. The selection of this command will prompt the user to select the table to be copied and given a different file name.

After the table has been saved, the existing table should then be closed and the new table opened. The new table will not be editable until selecting the LAYER CONTROL option from the MAP menu, highlighting the particular layer to be edited, and selecting the editable box in the right side of this window. Possible modifications include changing the production and attraction values associated with each centroid, changing link attributes (speed and capacity), and the addition or deletion of new nodes and links to the network.   Once the modifications have been made the analyst is ready to determine the new loaded speeds and volumes.

Step 6: Export the Network Data

        To perform a Tranplan run, the tables need to be exported from MapInfo into ASCII format. The procedure for exporting the tables involves running EXPORT.MBX. This prompts the user for the name of the link table and node table.

Step 7: Run Fortran Program to Create Tranplan Input File

        The exported files are the input files for NET.EXE. This program uses the exported node and link files and creates a Tranplan control file. The program creates a new file which contains the production and attraction information which is used as an input to the gravity model. To run the program, double click on the file name in the file manager or change to a DOS window, move the specified directory, and type NET. The program asks for the number of internal zones and the total number of zones in the network. The program builds a Tranplan control file which is used to run the model. To run the control file, run Tranplan with the file name, NETWORK.IN, as the input file.

Step 8: Run Netcard and Turns to Create ASCII Files

Loaded Speeds and Volumes

        Running Tranplan produces a binary file, OUT.BIN, containing the new volumes and speeds for the network. The Tranplan module, NETCARD, must be run to convert the binary file into a text file for further use. The NETCARD options to specify include:

> Enter Y or N
> Enter N
> Enter 99 (if prompted for the number of iterations)
> Enter N
> Enter Y.

Turning Movement Information

        Running the Tranplan module, TURNS, produces a text file containing the turning movement data. The TURNS option to specify is the through node (enter B).

Step 9: Run Fortran Programs to Format Loaded Data

        The output file from NETCARD is entered into the Fortran program LOADED.FOR. This program takes the loaded output file from the Tranplan run and removes all of the values that were not changed with the exception of the A node, B node, and the ID column. These files must be entered or the default values will be used. To run the program, double click on LOADED.EXE in the file manager or enter a DOS window, move the specified directory and type LOADED.

The output file from TURNS, turns.tp, is entered into the Fortran program TURNS-F.EXE. This program takes the output from Tranplan and uses the file NODES.TP to develop a file in the correct format for MapInfo to develop turning movement diagrams. To run the program, double click on TURNS-F.EXE in the file manager or enter a DOS window, move to the specified directory and type TURNS-F.

Step 10: Run MapBasic Program to Update Tables

After running the Fortran programs, enter MapInfo and open the link and node tables. Then run the MapBasic program UPDATE.MBX. This will update the link table in MapInfo with the new speeds and volumes. Next execute the MapBasic program TURN-REG.MBX, which will register the turns file as a MapInfo table.

Note: There are no graphic elements associated with the table and no maps can be developed from the registered table. The ID column in the table allows for the loaded values table to be joined to the links table from which the values were determined.

Step 11: Run Turns Utility

The next step is to select the nodes where the turning movements are desired. Then run the MapBasic program, TURNMOVE.MBX which will develop the turning movements.

Step 12: Run Visualization Utility

To develop the visualization plot for the network, run the MapBasic program, PLOT.MBX. To develop the validation plot for the network, run the MapBasic program, C-PLOT2.MBX.

CHAPTER 4.
UTILIZING GIS TO FACILITATE BICYCLE ROUTE PLANNING

OVERVIEW

In recent years the amount of attention focused on bicycle facilities has steadily increased. The rise in attention is primarily due to federal programs that have been created to promote bicycling as a mode of transportation. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) requires that all Metropolitan Planning Organizations (MPOs), in cooperation with the State, develop transportation plans and programs which incorporate the development of bicycle and pedestrian facilities. Due to these requirements, there is an increasing need for an efficient and consistent method to identify alternative locations which would best suit a bicycle route.

Geographic Information Systems (GIS) have become an effective resource that aids transportation planners in conducting alternatives analyses. Several attempts have been made to develop analytical tools for bicycle facility planning, yet no one identified has attempted to couple these tools with the spatial and analytical power of a GIS. This chapter reports on the development and application of a GIS for planning the location of on-street bicycle routes. A multi-objective decision making process is used to identify and determine weights for criteria to be considered when planning the location of these facilities. Criteria and their weights are integrated into programs that run within a GIS environment. These programs calculate the optimal bicycle route between two points. The simple GIS-based tools are shown to be useful to planners performing alternatives analyses to support a sound decision making process concerning bicycle route location.

Note: For the purpose of this research, the term "optimal" is described as being the best or most desirable route based on the link scores and criteria weights obtained in the Delphi process.

OBJECTIVE

This chapter demonstrates the methodology and steps required to identify the optimal location for on-street bicycle routes within a network.

REQUIREMENTS

Data are needed to first establish a base street network. Possible data sources include Computer Aided Drafting (CAD) line files, TIGER line files, aerial photographs, or vendor provided street networks.

Once the base network is established attribute data is then assigned to links in the network. Attribute data may consist of topography, land use, on-street parking, heavy vehicles, surface type, traffic volumes, capacity, intersection signalization, posted traffic speed,

and other spatially referenced data. In this research attribute data were obtained from various sources. Some of the data were obtained from the City of Ames Traffic Engineer, the Iowa Department of Transportation (DOT), and through windshield surveys. Other data are calculated by MapInfo. These include link length and volume to capacity ratio. The method allows any combination of criteria appropriate for data analysis. Criteria utilized by the analytical tools were identified from a panel of experts in a Delphi analysis.

Note: One important remark is that the methodology presented is one way to identify optimal bicycle route location. It is not necessarily to be viewed as the best way, and changes to the criteria, weights, or procedures may be desired or necessary.

PROCEDURE

This section identifies the process for using these routing tools. The first part explains the process of setting up a base network and establishing criteria and their weights. The second part explains how to run the optimal route program. The final part explains how to run the user-defined route comparison program.

Establishing the System

Step 1. Identify Criteria

One of the more important challenges to planners or engineers when developing new bicycle facilities is the identification of criteria that should define route location. There are several methods that can be used to identify the criteria such as literature reviews and surveys. For this research, a Delphi analytical process is utilized to identify and weight these criteria. (Appendix C gives a detailed description of a Delphi analytical process.)

Note: The Delphi analytical process is one way to determine criteria weights and penalties. This process should not be viewed as the only or best way to accomplish this task.

A questionnaire is developed to identify criteria that should be considered when planning for new bicycle facilities. Experts are given background information on the objective of the study along with a list of example criteria such as traffic congestion, outside lane widths, and surface type. The experts are then asked to add any criteria they feel is appropriate to consider when planning new bicycle facilities.

Note: The criteria identified in this particular study are not to be viewed as the only or best that can be used, any combination of criteria can be utilized.

Step 2. Assign Criteria Penalty Weights

A Delphi analytical process is again used to determine penalty weights for each criterion. After the criteria to be included in the analysis are identified, a new questionnaire is drafted to determine the relative weights for each of the criterion. The panelists are asked to give a penalty

(in miles) to an otherwise "perfect" five mile route that exhibits each characteristic. For example, a respondent may give a three mile penalty to a "mountainous" but otherwise perfect route, resulting in a score of eight "equivalent" miles. In other words the five mile mountainous route is equivalent to an eight mile flat route, in the opinion of the respondent. Thus, all penalties are in miles. The panelists are then requested to submit their weights for each criterion and supply statements or arguments supporting their choice, that is, why the weights should not be higher or lower.

Step 3. Setting up a Base Network

The first step is to incorporate data into the GIS environment.

      1) TIGER street files can be imported into MapInfo by exporting from other GIS packages or through shareware programs.
      2) DOT CAD files can be imported into MapInfo through an export from Intergraph's MGE into MapInfo.
      3) Aerial photos can be scanned into GIF formatted images and registered into MapInfo. Street networks can be created by "heads up" digitizing or tracing the aerial photo.

Step 4 . Modify Link Network

The links in the street files that are obtained for the base network may not be in sections that match the data available. In this case, links can be split or combined to better match the data aggregation. MapInfo specifically has commands that split and combine link segments.

Step 5. Create Node Layer

A separate layer containing nodes is created by placing points at the intersection of all link segments. A new layer is created from FILE - NEW TABLE - select OPEN NEW MAPPER and name the layer "Nodes". Add the new layer to the map window by opening the LAYER CONTROL window. Select MAP - LAYER CONTROL - ADD. Select the nodes layer. Also from the layer control window make the nodes layer editable by selecting the editable box. Use the snap tool to locate the intersections between link segments. When an intersection is located, place a node using the symbol tool in MapInfo.

Step 6. Populating Links with Attribute Data

In this research, attribute data for the Ames street network were obtained from various sources. These include traffic volumes, capacity, intersection signalization, and posted traffic speed. Other data such as topography, land use, on-street parking, heavy vehicles, and surface type were obtained from city maps and windshield surveys. Other data are calculated by MapInfo. These include link length and volume to capacity ratio. The attribute data (in tabular and text form) were linked to corresponding segments in the network.

Step 7. Alter Links Table

     Additional columns are required in the links table to incorporate penalty assignments for each criterion and a link score column. This is accomplished using TABLE - MAINTENANCE - TABLE STRUCTURE - ADD FIELD (in MapInfo.) Add a new field for each new criterion used in the analysis plus a column for a link score to the link table.

Step 8. Use Structured Query Language to Assign Penalties

     Data can be grouped together into a selection by formulating questions or queries. Such a query may select all links within a network with a speed greater than 40 miles per hour. Using the structured query language (SQL) command allows the user to select from multiple tables and also from existing query tables. When a query has retrieved a list of all links matching the query parameters, the criteria fields in the table can be updated with a penalty. This is done by using TABLE - UPDATE COLUMN in MapInfo. From this window choose to update the links table. The column to update should be the one you are assigning a penalty. Also choose to "get value" from the links table. In the "value" field enter the penalty value. This will add the penalty value to all the links selected in the query selection.

Step 9. Calculate Score

     To calculate the scores for each link in the network the MapBasic program *"newscore.mbx"* is used. Select FILE - RUN MAPBASIC PROGRAM and select *"newscore.mbx"*.

Step 10. Run S-Export

     Any time a change is made to the links table, the MapBasic program *"s-export.mbx"* must be run. Select FILE - RUN MAPBASIC PROGRAM and select *"s-export.mbx"*. The node and link information associated with the network is exported into a text file format by using the MapBasic program *"s-export.mbx"*. The program *"s-export.mbx"* needs to be run only once unless changes are made to the node or link files. The file format of the node and link information is altered to enable the Fortran program to read it.

Identify the Optimal Route Between Two Points

Step 1. Select any Two Nodes

     Select two nodes between which a bicycle route is desired. More than one node can be selected by holding the shift button down while selecting.

Step 2. Run MapBasic Program 1st-Path

     The network is exported into text format and the two nodes are selected (in MapInfo) to be connected by a bicycle route.   Next, the MapBasic program *"1st-path.mbx"* is run to export

the selected node information into text format. Choose FILE - RUN MAPBASIC PROGRAM - "*1st-path.mbx*".

Step 3. Run Fortran Program S-Path

The next step is to run the Fortran program "*s-path.for*". This Fortran program, which must be run from the DOS prompt, calculates the lowest score route between the selected nodes by utilizing a simple shortest path algorithm. Without exiting MapInfo move to the DOS shell and go to the subdirectory containing the link and node files. Type "S-path" and enter. Exit DOS shell by typing exit and return to MapInfo.

Step 4. Run MapBasic Program Showpath

The final step is to run the MapBasic program "*showpath.mbx*" which registers the output from the Fortran program into MapInfo. The lowest score route is then illustrated on the map along with the cumulative route score (in equivalent miles). At this point the lowest score route between other nodes can be calculated. The same process and programs are used as before except the "*showpath.mbx"* program was replaced with the "*showmore.mbx"* program. The "*showmore.mbx*" program enables MapInfo to show more than one optimal path at once. Choose FILE - RUN MAPBASIC PROGRAM - SHOWPATH or FILE - RUN MAPBASIC PROGRAM - SHOWMORE.

Compare Route Scores

Route scores can be calculated easily by using the MapBasic program *"user-defined.mbx"*. Select each link along the route a score is desired. Once all the desired links are selected run *"user-defined.mbx"*. Choose FILE - RUN MAPBASIC PROGRAM - "user-defined.mbx".

VALIDATION

This section presents the process of validating the route planning tools presented in this chapter. Models may not be sufficiently accurate immediately after development. Thus, the tool should be validated to accurately represent real world conditions.

The first step in the process is to utilize the optimal route planning tool with previously determined criteria weights as inputs to identify the best route between two nodes. An assessment is made as to the reasonableness of the route identified (based on general knowledge of route preferences of bicyclists and common sense). If the route corridor illustrated was not reasonable, the routing tool would need to be re-calibrated. In the test case this process revealed that the distance criterion should not have been weighted because distance is the base unit of comparison.

Validation can also be done by adjusting the criteria weights until the optimal routing tool replicates actual route choices of bicyclists. For example, if steep topography is a major concern

in the planning region, a higher than normal penalty can be assigned to links with hilly or mountainous characteristics. When identifying a route, the optimal routing tool is then more likely to avoid links with steep topography. This type of validation can be accomplished using any of the criteria.

It should be noted that what appears to be a reasonable bicycle route is extremely subjective and may drastically differ from one jurisdiction to the next. The route planning tools were designed to be flexible in the criteria and weights they utilize to accommodate various jurisdictions. The link scores can be easily recalculated using the MapBasic program "*newscore.mbx*". When new fields are created for additional criteria, modifications must be made to the equation in the "*newscore.mbx*" program to include the new criteria weights in the calculation.

CHAPTER 5.
METHODOLOGY FOR DATA TRANSFER FROM QRSII TO MAPINFO

OVERVIEW

Quick Response System II for Windows (QRSII) is an urban traffic forecasting model. It consists of the General Network Editor (GNE) and the QRSII program window. The GNE is a graphical editing window in which a network can be drafted or viewed. The QRSII program window allows analysis of the network created in GNE.

Although GNE has graphical display, it is limited in its capabilities. For instance it lacks an effective zoom command, cannot perform data queries, and all information is contained in a single layer. The latter point means that nodes cannot be viewed independently of links and different types of links cannot be separated into individual layers. These types of capabilities are needed if an analysis of QRSII's output demands more than simply viewing the data. Most geographic information systems (GIS) packages are designed with analysis in mind and are well suited for this. MapInfo, another Windows based GIS platform, has superior viewing capabilities, the ability to perform queries, and to place various types of data into separate layers. These layers can be viewed and manipulated independently or in conjunction. In addition, other information accessed by MapInfo can be viewed along with the QRSII output. Information such as census information, TIGER line work, and aerial photographs can be overlaid with QRSII output in a MapInfo setting.

OBJECTIVE

To transfer data between QRSII and MapInfo.

REQUIREMENTS

1) MapInfo desktop GIS
2) QRSII travel forecasting network
3) 2 DOS executables: qrscomb.exe, dta.exe
4) 1 MapBasic executable: mapb.mbx

PROCEDURES

QRSII to MapInfo

QRSII network information is contained in a formatted ASCII file consisting of three parts. The first part of the file contains the system schema which describes network-wide settings. The second part of the file contains a list of nodes and nodal attributes. The final part of the file contains a list of links and link attributes. The format of this file is not compatible with MapInfo directly, so Fortran code is used to alter the QRSII format into a MapInfo format.

Step 1. Separate and Prepare QRSII File Entities for MapInfo Import

      1) Copy *qrscomb.exe* into the directory containing the QRSII file.
      2) At the DOS prompt, run *qrscomb.exe*.

      Qrscomb.exe is an executable file which converts a QRSII formatted file into files ready to be imported into MapInfo via a MapBasic executable. Six files will be produced by *qrscomb.exe*. Four of these files contain the node and link data. The names of these files are input by the user as prompted. The first file contains the intersection nodes, both with and without delay, and undefined nodes. The second file contains centroid and special generator nodes. The third file contains production and attraction tags, external stations, seed tags, and district tags. The fourth file contains the link data. *Filename.txt* is a file produced by *qrscomb.exe* and is used by the MapBasic program. *Temp.dat* is a temporary file used internally by *qrscomb.exe*, which may be deleted.

Step 2. Import Files to MapInfo

      1) Open MapInfo.
      2) With no other tables open, use FILE - RUN MAPBASIC PROGRAM - *mapb.mbx*.

      Mapb.mbx opens the data files created by *qrscomb.exe* as four MapInfo tables. *Mapb.mbx* needs to be in the same directory as the files created with *qrscomb.exe*. The names correspond to the user input names from Step 1. *Mapb.mbx* creates tables with a "1" after the filename. These may be deleted after *mapb.mbx* has finished processing.

<u>MapInfo to QRSII</u>

Step 1. Export MapInfo Tables

      Each table that is to be brought back to GNE, must be exported as an ASCII text file with a single space delimiter.

      1) Use TABLE - EXPORT, change "file format" to "Delimited ASCII." Name the file and click "Export."
      2) Click the "other" option and replace the comma with a single space. Leave the other options as the default settings.
      3) Repeat this process for each of the remaining tables.

Step 2. Translate Files to QRSII Format

      1) Go to DOS prompt.
      2) Run *dta.exe*.

Dta.exe requires five input file names and one output filename. It will ask for the original QRSII file, from which it takes the system schema section. Then it will ask for the name of the new QRSII file for output. Finally, *dta.exe* will ask for the four text files exported from MapInfo. *Dta.exe* will output a QRSII file which can be opened in GNE. Currently, the output filename cannot be the same as the input filename.

CHAPTER 6.
UTILIZING CENSUS TRANSPORTATION PLANNING PACKAGE DATA FOR TRANSPORTATION ANALYSIS

OVERVIEW

The U.S. Department of Transportation, Bureau of Transportation Statistics, provides transportation related data in the 1990 Census Transportation Planning Package (CTPP). This project examined methods to use CTPP information with MapInfo to answer transportation related queries. A Fortran program filtered the desired information from the CTPP CD and placed it in an ASCII file. This ASCII file was joined to a MapInfo table of Des Moines' traffic analysis zones (TAZ). The table could then be analyzed in MapInfo, including querying with structured query language (SQL). As a case study, the project estimated the number of people who live in Polk County and work in Des Moines.

Data such as population, school enrollment by grade level, trips to work by mode, and income levels were also extracted. These data were translated into Mapinfo format and linked to an existing table which represents the Des Moines TAZ boundaries. A join was performed linking each column in the new table with the TAZ table. This linked the data from the first table to the appropriate TAZ in the TAZ table. Joining tables makes file management easier when handling large and multiple data sets.

OBJECTIVE

To use CTPP data in MapInfo for transportation planning analyses.

Note: Fortran was used to extract the desired information. This Fortran code will need to be altered to extract the desired fields from the CTPP CD-ROM.

REQUIREMENTS

1) MapInfo desktop GIS
2) Fortran compiler
3) Census CTPP CD-ROM, available from the Census Bureau.
4) TAZ GIS coverage of CTPP area.

PROCEDURE

Step 1. Extract Data from CTPP

Write or alter Fortran to read columns from the CD and write them to an ASCII file with a delimiter. The geographic reference code must be included with this information. The description and location of the geographic codes and the census fields is available from the CTPP Data Dictionary on the CD.

Step 2. Combine with MapInfo Table

1) Open the ASCII table in MapInfo and verify that the columns are appropriately divided by the delimiter.
2) Use QUERY - SQL SELECT to join the tables together based on their common geographic identifier. A description of joining two tables based on a common field is available in MapInfo's Reference manual.
3) Save the Query as a new table. The new table now functions as any other table and can be queried and otherwise analyzed.

NOTES ON DEFAULT TRAFFIC ANALYSIS ZONES

In the 1990 Census, some responses to questions asking for the place of work could not be coded to the level of census tract and block. Information provided by respondents were either illegible or inaccurate, thus causing some workplaces not to have a full hierarchy of codes, (state-county-place-tract-block). Some records contained only state-county-and place codes.

Two sets of criteria are set up, one of which must be met, for providing data completely allocated to the tract and block level. At least 70% of the blocks within a county or place must have address ranges associated with them, or at least 70% of the workers coded to the place must have also been coded to the tract and block level.

For places that fail both of the above tests, the data coded to the detailed level will be reported at the tract or block group level in one of the block-level TAZ's in a TAZ package. For workers in these places that were not fully coded to a tract or block, only state, county, and place codes will be used in the CTPP.

Since the blocks of work for these people are not known, they cannot be assigned to TAZ's specified in the block to TAZ equivalency file. Therefore, a set of default TAZ's are needed to represent whole places. This acts as a place to TAZ equivalency file. Default TAZ's are not needed for all places, but only for those that fail both of the above described tests.

Note: A knowledge of Fortran is useful, if not required for the first step.

CHAPTER 7.
TRANSIT ANALYSIS UTILIZING MAPINFO

The transit analysis concentrated on using GIS to determine the location of transit routes. Census Transportation Planning Package Data (CTPP) was used to create thematic maps illustrating transit trip ends a s a percentage of total work trips and population density. This section of the project has been studied in detail but has not currently been implemented.

CHAPTER 8.
TRANSVIEW SOFTWARE

TransVIEW software is a tool which can be used to view and extract Census Transportation Planning Package (CTPP) data. This software was investigated to determine its functional practicality in the workplace. The results of the investigation revealed that TransVIEW software is a limited display package. An alternative to using TransVIEW to access and view data was to utilize a FORTRAN program to extract the data and import it into MapInfo. A detailed explanation of this processes is given in Chapter 6.

CHAPTER 9.
UTILIZING NATIONAL HIGHWAY PLANNING NETWORK (NHPN) DATA TO BUILD BASE MAPS

OVERVIEW

The Federal Highway Administration (FHWA) has released the databases required to build maps of the National Highway Planning Network (NHPN). These databases are filed state by state and can be built independently. The NHPN network consists of links and nodes. Nodes are located wherever a road in the network cross city, county, or state borders or other roads. Links extend from node to node. The NHPN network is contained in three files. The first file contains latitudinal and longitudinal coordinates and an identifying string for each node. The second file contains identifiers of each link's starting and ending nodes, latitudinal and longitudinal descriptions of the links shape in varying amounts of short line segments, and an identification string. The final file contains attributes of each link such as road type and jurisdiction.

Three executables, created with Fortran, extract the information from the NHPN CD and create the MapBasic code needed to create the links and nodes in MapInfo. This MapBasic code is then compiled by MapBasic. The resulting MapBasic executable is then run in MapInfo to create the node and link graphical files. The link attribute file will be translated into an ASCII file and then imported to MapInfo without graphical elements. It is then joined to the link file's graphical elements.

The process need only be performed once for each state. The MapInfo coverage for Iowa has already been created. Contact the Center for Transportation Research and Education (CTRE) for information.

Since the time this project took place, Modular GIS Environment (MGE) from Intergraph has offered a free utility program that converts the NHPN into MGE format. MGE can then translate this coverage into MapInfo. Contact CTRE's Geographical Information System (GIS) Lab at Iowa State University for assistance.

OBJECTIVE

To create a MapInfo coverage from the NHPN file for Iowa.

REQUIREMENTS

1) NHPN CD, available from the FHWA.
2) Fortran code. The code for Iowa is available in the appendix. This code has been written for Iowa, if another state is used, the code must be altered.
3) Fortran compiler.
4) MapBasic compiler.
5) MapInfo desktop GIS

PROCEDURE

Step 1. Extract Data from NHPN CD

  Three Fortran programs extract the data from the NHPN CD and create either a MapBasic program or a text file. Each Fortran program, in turn, creates the node MapBasic program, the link program, and the link attribute text file.

Step 2. Compile the MapBasic Programs

  The MapBasic programs create either a point or a polyline in MapInfo using the geographical references from the NHPN. In the case of the node file, the MapBasic program then populates a MapInfo table with its associated attributes. The MapBasic code does this by specifying a MapInfo column heading, selecting an empty line (the next line in the table), and replacing it with the new information. In the case of the link files, the attributes are in the separate link attribute text file and are joined to the graphical file later, in MapInfo. MapBasic's compiler is limited to approximately 1,000 lines of code before it begins to produce errors, so the Fortran code must write to a new file after 1,000 lines. The files of MapBasic code must be compiled independently.

  Note: A Map Basic compiler is required for this step.

Step 3. Create a New Table in MapInfo

  An empty table must be created in MapInfo with column headings corresponding to the fields established by the Fortran program to receive the information placed by the MapBasic code. Select FILE - NEW TABLE.

Step 4. Run the MapBasic Executables

  The MapBasic executables must then be run in MapInfo one at a time. The new MapInfo table must be open before the executable is run.

CHAPTER 10.
METHODOLOGY FOR ESTIMATING
POPULATION SURROUNDING AIRPORTS

OVERVIEW

This project utilizes MapInfo to develop a method of estimating the population surrounding an airport. A similar procedure could estimate the population within a certain distance of a highway or other feature. The procedure uses two data sets: a point coverage of airports and a polygon coverage of census block groups. Both are available to download from the Department of Natural Resources (DNR) World Wide Web (WWW) site. The DNR WWW site is explained in Chapter 12.

The method consists of four general steps. The first step is to create a buffer area around the airport. The second step is to divide the buffer area into subareas using the block group boundaries. The third step is to estimate the population of each subarea. The final step is to combine the subareas back together to find the total population.

The population estimate is based on the population density field in the block group coverage. Inaccuracies in the estimate are due to the nature of a population density. The population is not uniform throughout the block group and may be more or less dense around the airport than in another area of the block group. This method assumes that the population density is uniform throughout the block group.

OBJECTIVE

The objective of this procedure is to estimate the population surrounding an Iowa airport.

REQUIREMENTS

1) A point coverage of airports and a polygon coverage of block groups; both are available from the DNR WWW site.
2) MapInfo desktop Geographic Information System (GIS).
3) WWW browsing software.
4) Modem or ethernet access.

PROCEDURE

Step 1. Create Buffers Around Airports

1) Make Cosmetic Layer editable - the buffer area will be added to this layer.
2) Select airport or element to be analyzed.
3) Use OBJECTS - BUFFER to create buffer of appropriate radius.
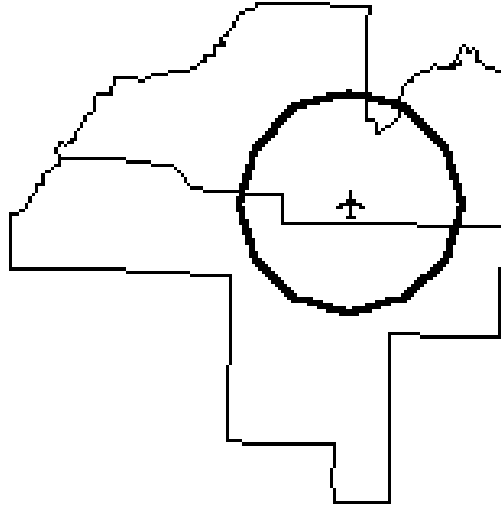4) Use MAP - SAVE COSMETIC OBJECTS to save the buffer area as a new table. See Figure 10-1.

Figure 10-1. Buffer around airport.

Step 2. Split Buffer with Block Group Boundaries

1) Select the buffer area.
2) Make buffer layer editable.
3) Use OBJECTS - SET TARGET to prepare the buffer to be split.
4) Select the block groups in and around the buffer area.
5) Use OBJECTS - SPLIT to divide the buffer area into subareas.
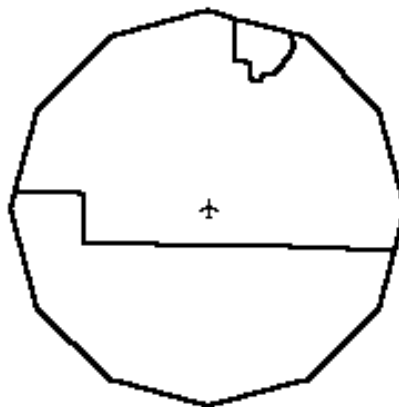6) Save changes to the buffer table. See Figure 10-2.

Figure 10-2. Split buffer zone.

Step 3. Populate Buffer Table

1) Use TABLE - MAINTENANCE - TABLE STRUCTURE - *Buffer Table* to alter the structure of the buffer table. Add fields: area, population density, population (type = float for new fields).
2) Reopen buffer table.
3) Use TABLE - MAINTENANCE - PACK TABLE to condense gaps in the buffer table.
4)   Reopen buffer table.
5) Calculate the area. Use TABLE - UPDATE COLUMN (the *Update Column* window is now open).
Table to Update: select *buffer*
Column to Update: select *area*
Get Value from Table: select *buffer table*
Value: select the *Assist* button and type "Area"   This populates the "area" column with the value of its area. The area units used by MapInfo must first be set to the same units used for population density in the block group data ("sq km"). See Figure 10-3.
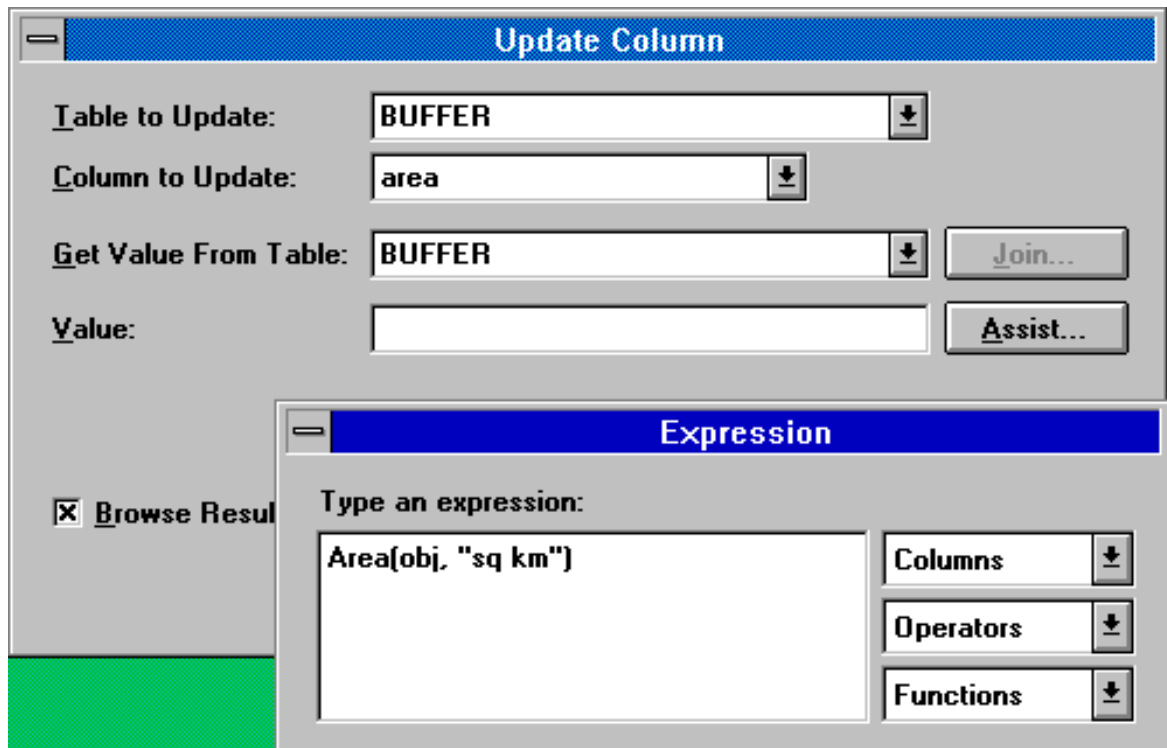

Figure 10-3. Calculating area values.

6)   Copy population density to buffer table. Use TABLE - UPDATE COLUMN
Table to Update: select *buffer*
Column to Update: select *population density*

Get Value from Table: select *block group*
Select the *Join* button **Join**: Where *block group* <u>contains</u> *buffer* object, **Value** of
POPDEN] This populates the <u>population density</u> column with the population density of
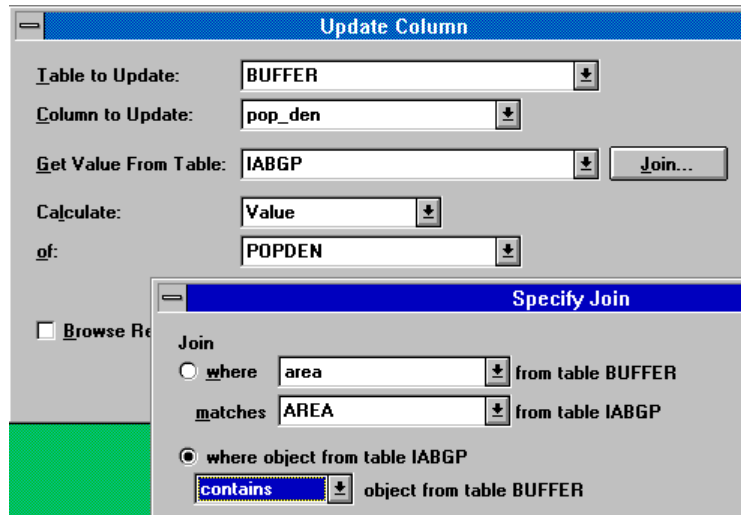the block group. See Figure 10-4.

Figure 10-4. Updating population density values.

7) Use TABLE - UPDATE COLUMN
 Table to Update: select *buffer*
 Column to Update: select *pop*
 Get Value from Table: select *buffer*
 Value: select the *Assist* button and type "column area * column population density."
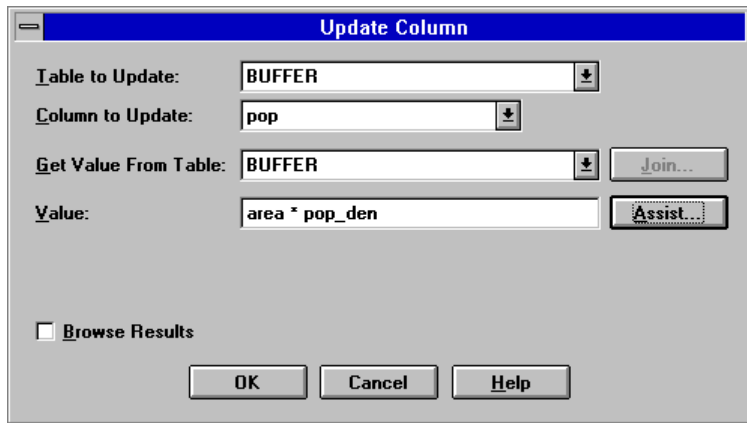This populates the <u>pop</u> column with the population of the subarea.
See Figure 10-5.

Figure 10-5. Calculating the population.

Step 4. Populate Buffer Table

1) Make buffer layer editable
2) Select all the subareas
3) Use OBJECTS - COMBINE to combine the subareas. The <u>area</u> and <u>pop</u> columns of each subarea should be summed together. The other columns may be neglected. See Figure 10-6.
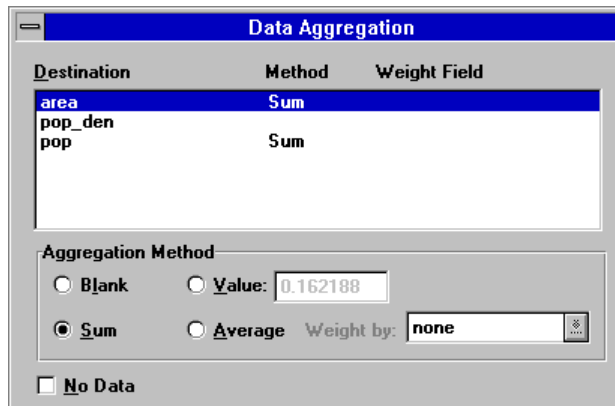

Figure 10-6. Combining the subareas.

CHAPTER 11.
RESOURCES AVAILABLE ON THE
WORLD WIDE WEB

OVERVIEW

The World Wide Web (WWW) provides a vast amount of information that can be utilized in a desktop mapping geographic information system (GIS). This data can aid transportation planners in alternatives analyses and decision making. Due to the ever increasing ease of use, and availability of large data files, the WWW has become a very useful tool in the applications of GIS. There are many sites on the WWW dealing with Global Positioning Systems (GPS), Tiger Files, GIS Software, and GIS data files.

The WWW works for any person with a modem or ethernet access, a personal computer, a web browser and an account with one of the many corporations that offer access to the WWW. Once the access to the WWW has been established, a user can browse through an endless number of websites or homepages. These locations are established and maintained by individual people or groups, such as clubs and corporations. Each of these websites contain information in one or more of the following formats: text, documents, programs, and pictures. Also included in most websites are highlighted portions of text which can be used to connect the user to other locations. These portions of text are often referred to as hotlinks or links. To connect to another homepage by using the links a user need only to click on the highlighted text once with the mouse. Another form of WWW navigation is through keyword searches.

OBJECTIVE

To access resources and information on the WWW.

REQUIREMENTS

1) WWW Browser (Netscape, Mosaic, America On Line...)
2) Modem or Ethernet access

PROCEDURE

This section explains how to locate and download information from the WWW.

Step 1. Locating Desired Information

There are two ways to locate GIS information on the WWW. One way to locate the information needed is to have the Uniform Resource Locator (URL) or web address. The second method is to use one of several search engines to perform world wide keyword searches.

Method 1. URL

A URL is typically in the form: **http://www.mapinfo.com**. Entering the URL of a known website in the location field and pressing "enter" will take the user directly to the homepage.

Method 2. Keyword Searches

To search for a homepage on a specific topic, the user must select the 'NETSEARCH' button (in Netscape). There are similar functions in all netscape browsers. Once you have clicked on the 'netsearch' button a new page will appear with a text box and a 'search' button. Enter the keywords for the given subject and press the 'search' button. Each search engine is different and will have many different options available. It is also very common to have vastly different results from different search engines. Therefore it is important to try several different engines if the desired page or subject matter is not found on the first attempt. Trying different keywords may prove to be more effective if the first chosen keywords are not returning satisfactory results.

Example: a useable keyword search for the Iowa Department of Natural Resources is: keywords: Iowa DNR

Step 2. Downloading the Information

Once a useful document or file has been located on the WWW, it must be downloaded. There are generally two methods for downloading data from the WWW. The first possibility is that the link selected will automatically begin the download. The second possibility is to save the selected information to a hard drive.

Method 1. Automatic Downloading

Some hotlinks are set up so that clicking on them will give the user a choice of either saving the information to a disk or canceling the data transfer. When this occurs the user may either cancel the operation or select the save to disk button. This will then bring up a dialogue box of all available drives and directories. Select the appropriate directory and save the information.

Method 2. User Directed Downloading

Some hotlinks will connect the user to the information, but will only display that information on the screen until otherwise instructed. For hotlinks of this nature it is necessary to select the appropriate link. Choose FILE - SAVE AS... This will bring up a dialogue box of all available drives and directories. Select the appropriate directory and save the information.

USEFUL UNIFORM RESOURCE LOCATORS TO WEBSITES

1) Tiger Home Page
http://www.census.gov/ftp/pub/geo/www/tiger/
2) Tiger Map Server Browser
http://tiger.census.gov/cgi-bin/mapbrowse-tbl?infact=2&act=out&outfact=2&tlevel=-&tvar=-&
mlat=&mlon=&msym=bigdot&mlabel=&murl=&lat=38.890&lon=-77.020&wid=0.360&ht=0.1
30&iwd=300&iht=400
3) Nebraska Natural Resource Commission Data Bank
http://www.nrc.state.ne.us:80/mainmenu/dbindex.html
4) Nebraska Offices with data
http://www.census.gov/ftp/pub/sdc/www/nesdc.html
5) Iowa Geological Survey Bureau Homepage
http://www.igsb.uiowa.edu/
6) IDNR/GSB-NRGIS Library
http://www.igsb.uiowa.edu/htmls/nrgis/gislib.htm
7) WSDOT - Seattle Met Traffic Flow
http://www.wsdot.wa.gov/regions/northwest/NWFLOW/
8) The US Department of Transportation
http://www.dot.gov/
9) Southern California Traffic Report
http://www.scubed.com/caltrans/transnet.html
10) Center for Transportation Research & Education
http://www.ctre.iastate.edu/
11) Census Bureau Home Page
http://www.census.gov/
12) Iowa Geographic Information Council
http://www.drake.edu:80/drakegis/igic/

CHAPTER 12.
RESOURCES AVAILABLE FROM THE
DEPARTMENT OF NATURAL RESOURCES

OVERVIEW

  Statewide and county population coverages can be obtained from two separate locations. The first location is the Iowa Department of Natural Resources (DNR) World Wide Web (WWW) homepage. The Iowa DNR homepage consists of line file data that covers the entire state of Iowa. These line files are not associated with population data except for a block group file which covers the entire state. There are also a limited number of files with information at the county level. This information is available for all 99 counties and include: rivers, roads, public land survey system, and topography. These files do not have associated population data.

Statewide coverages can be accessed at **http://www.igsb.uiowa.edu/htmls/nrgis/gisstate.htm** and county coverages can be accessed at **http://www.igsb.uiowa.edu/htmls/nrgis/county.htm**

Available coverages consist of:

   Cultural and Political Geography
    1990 census blocks
    Airports
    Boundaries of incorporated cities and towns
    Hospitals
    Iowa house of representatives district boundaries
    Iowa state senate district boundaries
    Land owned or managed by the Iowa DNR
    Major highways
    Political or civil township boundaries
    Populated places
    State and county boundaries
    Stream gages
    U.S. house of representatives district boundaries

   Environmental Geography / Geology
    Groundwater vulnerability regions
    Land use, 1975 - 1984
    Levees for the USACE, Rock Island District
    Permitted animal waste control facilities
    Permitted underground storage tanks
    Registered agricultural drainage wells
    Registered agricultural drainage well areas
    Registered, plugged wells pre 1989
    Registered, plugged wells 1989-1991

Registered private wells since 1987
Sanitary disposal site updates
Waste water treatment facilities
Wells & intakes: > 25,000 gpd
Wells & intakes for public water supplies

Geographic Reference
30 X 60 Minute Quadrangle Boundaries (1:100,000)
7.5 Minute Quadrangle Boundaries (1:24,000)
1 X 2 Degree Quadrangle Boundaries (1:250,000)
Public land survey system, township & range
Zip code areas

Physical Geography / Geology
Alluvial aquifers / alluvium
Bedrock Geology (1969)
Bedrock topography for 93 counties
Drainage basins
Geologic sampling points in Iowa
Landform regions
Lakes, designated for use
Major rivers
Mines: entrances for underground coal mines
Mines: identifiers for surface and underground mines
Mines: surface and underground coal mines
Sinkhole locations
Surface topography

The second location from which population coverages can be obtained is the Geographic Information System (GIS) Support Facility at Iowa State University. Available from this source are population coverages for each county in the state. Coverages that are available include, road, block, block group, and tract coverages. These files are available in ArcInfo format, and can be translated into MapInfo format through the MapBasic program ArcLink.

TO CONVERT ARCINFO FILES TO MAPINFO FORMAT

To convert the DNR files from the current *.taz format to a MapInfo format, two steps must be taken. The first step is to convert the files to an ArcInfo format (*.e00). The second step changes the *.e00 format to a MapInfo format (*.tab).

Note: The "" symbol represents the name of the desired file.*

Requirements

     1) the file to be converted (*.taz)
     2) u16.exe
     3) tar.exe
     4) untarz.bat
     5) MapInfo desktop GIS
     6) Arclink.mbx

Procedure

Step 1: Download the Files

Download the desired *.taz files from the DNR homepage as listed previously. To do so click on the FTP icon. When the computer reads file done, select FILE - SAVEAS... This will create a dialogue box of all available drives and directories. Select the appropriate directory and save the information. Download the three files, u16.exe, tar.exe, and untarz.bat. To download these files from the WWW simply click on the appropriate link and select FILE - SAVEAS... Place these files in the same directory as the downloaded *.taz files.

Step 2: Running UNTARZ.bat

Once the required files and the *.taz file are in the same directory, go to the DOS prompt and change to the directory containing the information.

At the DOS prompt type: c:> untarz FILENAME
where FILENAME = the name of the *.taz file without the .taz attached.

Example: if the file to be converted was county.taz, the command line would be:
          c:> untarz county

Two files are created. The two files are *.e00 and *.doc. The *.doc file contains documentation on the file that has been converted, and the *.e00 file is a useable ArcInfo file.

Step 3. Getting ARCLINK.mbx

Place the program ArcLink.mbx into the mapinfo directory on the hard drive. For further information on obtaining ArcLink please contact the GIS Laboratory at the Center for Transportation Research and Education at Iowa State University.

Step 4. Running ARCLINK

Enter MapInfo and select FILE - RUN MAPBASIC PROGRAM - ARCLINK. Running this program will create an ArcLink menu which is added to the MapInfo menu bar.

Step 5. ARCINFO to MAPINFO

   Once the ArcLink menu is on the menu bar select ARCLINK - ARCINFO->MAPINFO from the pull-down menu. This will produce a dialogue box which contains all the input parameters needed to run the program.

Step 6. Proper Directory

   Once the dialogue box is showing, change directories until reaching the directory where the desired *.e00 file is located.

Step 7. Dialogue Box

   Once the correct directory is chosen, all *.e00 files in that directory will be displayed in the EXPORT FILES window. These are the files which may be converted. There are two recommended options for the conversion process.

   Option one: This option is for the conversion of all the *.e00 files listed in the directory.
     1) Click the SELECT ALL FILES box.
     2) Next select the SAVE AND SET OUTPUT box.
   Option two: This option is for the conversion of specific files only.
     1) Select the desired files by highlighting the filename.
     2) Once the files have been selected click on the SAVE AND SET OUTPUT box.

Step 8. Save and Set Output

   Selecting the SAVE AND SET OUTPUT box creates a second dialogue box. In this box there are several options which may be adjusted. These options are:

   1) output filename
   2) directory for the output file
   3) file type
   4) allocation of tabular data
   5) complex polygon partitioning
   6) map projection

   Output file name: This is an optional setting. The filename can be named whatever the user wants, however the name will remain the same if no other name is given.

   Directory for the output file: This is also optional. If no other directory is selected the file is placed in the same directory as the file being translated.

File type: Files can be saved in either the MapInfo Tabular form (*.tab) or the MapInfo ASCII text file form (*.mif). One of these options must be selected. The default setting is the tabular format.

Complex polygon partitioning: When MapInfo encounters polygons which are too complex to handle, they are broken down into simpler components. These components may be either split polylines, or smaller polygons. The default choice is split polylines.

Allocation of tabular data: When complex polygons are broken down into simpler forms the data associated with the given polygon may be allocated to all of the new objects or just one. The default setting is to allocate the data to all of the new objects.

Map projection: The map projection must be set to the proper coordinate system for the map to be aligned properly. The correct projection is usually provided with metadata for the file. To change the coordinates from the default setting of non-earth coordinates, the user must choose a projection from a coordinate system file. One such file is, MAPINFOW.PRJ.

> 1) Select the PROJECTION FILE... button
> 2) Select MAPINFOW.PRJ
> > A dialogue box appears which lists possible projections.
> 3) Choose the correct projection
> 4) Click OK

Step 9. Optional Extra Files

> 1) Once the output settings have been saved the user has the option to select an additional *.e00 file and set different output parameters.
> 2) Clicking the mouse on the VIEW PROCESS LIST box will inform the user of the files which have been selected for conversion.

Step 10. Translation

Select the TRANSLATE box and the program develops a MapInfo table.

Step 11. Viewing the new MapInfo Document

To view the new MapInfo tables, select FILE - OPEN - *.tab.

CHAPTER 13.
RASTER IMAGES

OVERVIEW

Raster images were scanned and imported into MapInfo to examine the use of these images within a geographic information system (GIS) environment. An aerial photo was scanned and imported into MapInfo for the development of an urban transportation planning (UTP) model for the city of Ames. Other aerial photos were utilized to determine access locations along a specific corridor in Dubuque. The purpose of this project is to establish a procedure for the scanning and importing of aerial photos or maps into a GIS environment.

Ames

This project consisted of scanning a large aerial photograph of Ames. The photo consisted of two sheets, each with approximate dimensions of 22" x 30". The maximum scanning surface of the desktop scanner utilized was 9" x 12". Due to the small size of the scanning surface, it became necessary to break the photo down into scanable portions. There were two options available. The first option was cut the sheets into 8" x 11" pieces resulting in 16 sections. The second option was to leave the sheets intact and outline 8" x 11" sections on the back of both sheets. In this case the photo was on loan from the City of Ames and was kept intact.

The two pictures were scanned using a flat bed scanner, Power Macintosh computer, and Adobe Photoshop 3.0 software. The image format was changed from a Macintosh format to an IBM compatible format. Each of these images were imported in MapInfo under a specific map projection and coordinate system.

Dubuque

The Dubuque project consisted of scanning several 9" x 9" photographs. These photographs were taken such that a curving roadway was always centered in the photograph. When all the separate photos were aligned to produce a layout of the road, the road was skewed at several different angles.

The Dubuque photos were scanned in without regard to the angles mentioned previously. This in turned caused problems during the import process. For images to import properly in MapInfo it is important they be scanned in such a position that north is always upright. If the photos are not scanned in such a way, MapInfo will twist the digital map to fit the raster images. The images can not be rotated by MapInfo, and will therefore appear on the screen exactly as scanned. In this case each photo was scanned such that north was skewed.

There are two methods which may be used to correct these difficulties. First, Adobe Photoshop can be used to rotate the photo to the desired angle. Second, the photo can simply be

rotated to the desired angle on the scanner bed. The latter solution will cause some portions of the photo to be lost as the image will no longer completely fit on the scanner.

OBJECTIVE

To scan a photograph into a digital image (raster image) and import that image into MapInfo.

REQUIREMENTS

1) flatbed digital scanner
2) Adobe Photoshop 3.0 (or related software)
3) MapInfo 3.0 or better
4) Maclink Plus (only needed for Macintosh to PC format)

PROCEDURE

Step 1. Setting the Scan Options (Using Adobe Photoshop 3.0)

Select FILE - ACQUIRE - SILVERSCAN

This will open a dialogue box for scanning the photo. There are several options in the dialogue box. The important options are:

1) color
2) resolution
3) filesize
4) format
5) preview
6) scan

Color

Select one of the option available. For black and white images the recommended choice is: bw256 (black and white with 256 shades of gray). For color images the recommended choice is color256 (color with 256 hues). Color photos can easily be scanned in as black and white images.

Resolution

Resolution defines the clarity of the image. The higher the resolution, the sharper the image. However, file size is directly related to resolution. If the resolution is too high, then the file becomes far too large. For a file size of approximately one megabyte a resolution of 250 to 300 ppi (pixels per inch) is recommended.

Filesize

If so desired the filesize can be set to any value. This will in turn automatically set the resolution.

Format

The file format can be chosen from many possible choices. It is important to choose one of the formats that is compatible with the MapInfo software. The compatible formats are: *.gif, *.jpg, *.tif, *.pcx, *.bmp, *.tga, and *.bil. Any of these formats will work.

Preview

Clicking the preview button will cause a scaled down view of the picture being scanned to appear in the dialogue box adjacent to the options. From this preview the user may use the mouse to draw a box around a certain portion of the photograph. This selected area will then be the only portion of the image scanned.

Scan

Clicking the scan button will scan either the entire image, or the selected area in the preview window, if such an area has been chosen.

Step 2. Scanning the Photo

Once all the options have been set as desired:

1) Click SCAN
        The image will be scanned and displayed on the screen.
2) Select FILE - SAVE AS
        A dialogue box will appear.
3) Enter the name of the image and click OK

If the image has been scanned using a PC it is now ready to be registered into MapInfo. If the image has been scanned using a Macintosh it must first be converted to a PC format.

Step 3. To Convert Mac to IBM

1) Open the software program Maclink Plus
        A dialogue box will appear
2) Select the file to convert
3) Select convert from "Mac 'format' " (where format is the file format *.tiff, *.jpg, etc)
4) Select convert to "PC 'format' " (where format is the file format *.tiff, *.jpg, etc)

5) Click OK

6) save the converted file to a disk and copy to your PC or ftp the file over the local
network (if system is running on single network)

Once the file is copied to the PC the image is now ready to be registered into MapInfo.

Step 4. Importing the Image

To import a photo image into MapInfo you must first open the image file (*.gif, *.tif,
*.bmp, etc.), as a table in MapInfo. To do this select FILE - OPEN TABLE. A menu box will
appear. In the menu box change the file format to 'raster image'. Choose the appropriate file and
select open.

If the Control Point Coordinates are Known

1) Specify the map projection by choosing the projection button.

2) Click on a point in the preview image. The 'Add Control Point' box will appear.
Under the areas marked 'map x:' and 'map y:' Enter the coordinates of the selected point.
Enter at least three more points, or more if the projection is not known, or there is no
projection.

If the Point Coordinates are Unknown

1) Specify the appropriate projection, MapInfo selects Longitude/Latitude as a default.

2) To add points, click on points on the preview image. The 'add Control Point' box will
display the pixel coordinates of the point. Click 'OK' The point is then displayed in the
'Image Registration'

3) Choose at least three more points. Choose more than three points if the image is
without a projection. Choose points that are spread out if possible and easily identifiable.

4) Open a corresponding map.

5) Choose TABLE - RASTER - SELECT CONTROL POINTS FROM MAP

6) Highlight the first point in the 'Image Registration' box , and click on the equivalent
point in the map window. If the point is an intersection of two links or the end of a link,
it is often useful to turn on the 'snap' option by pressing '**S**' The 'add control point' box
again appears. Click ok to accept the coordinates.

7) Repeat step 6 for the other points, and click 'ok' on the 'image registration' box when
all control points have been defined.

It is important to keep in mind that the importation of the raster image will be more accurate as more points are selected. Typically six or seven points is sufficient, however in aerial photographs or other images where there is no projection you may wish to enter as many as 20 or more control points.

PROBLEMS WITH IMPORTING MAPINFO RASTER IMAGES

A problem can occur when importing Raster images into MapInfo. The problem occurs when the photo image is not lined up with the street file that is being used as a base reference. A raster image that does not have a projection (such as an aerial photograph) will cause MapInfo to twist the street map to fit the photo rather than rotate the image to fit the street map.

This may occur, for example, if photographs are aligned in such a way that a road is always in the middle of the page, and somewhat aligned with the edges of the paper. This is only a problem if the road is not straight. As it bends and turns, the photographs will align at different angles, not always with north being perpendicular to the photo. Because of this, MapInfo has difficulty correctly importing the image.

Since a raster image must be aligned with the street map for proper importation, likely solutions are to rotate the image using the Adobe Photoshop software used to scan the photo, or to set the photo in the scanner so that north is up.

CHAPTER 14.
UTILIZING CENSUS SUMMARY TAPE FILES
FOR TRAFFIC FORECASTING

OVERVIEW

Traffic forecasting models estimate future traffic volumes based in part on productions from, and attractions to, a traffic analysis zone (TAZ). Production and attraction equations require zonal attributes such as population and household income as inputs. This data is available in the census Summary Tape Files (STF) on the block level for population data and the block group level for household income data. However, TAZ boundaries often do not coincide with census boundaries. TAZs are typically smaller in size than block groups and larger than blocks. The Census Department will tabulate statistics using TAZ boundaries for metropolitan areas, however smaller cities are not offered this service. When these cities attempt to establish their own TAZs for traffic forecasting purposes, difficulties arise in aggregating or disaggregating census data to the TAZ level. This project seeks to identify methods, using geographic information systems (GIS), of aggregating census block data and disaggregating census block group data to the TAZ level.

OBJECTIVE

To develop a method, utilizing desktop GIS, for aggregating and disaggregating census block and block group data to a level useful for transportation planning purposes.

REQUIREMENTS

1) Census STF for blocks (STF1B) and block groups (STF3A)
2) GIS coverage of TAZs
3) Census block group GIS coverage, available from the census bureau.
4) All TAZ lay completely within a census block group; that is, block group boundaries do not split TAZs.
5) Census blocks lay completely within a TAZ; that is, TAZ boundaries do not split any census blocks.
6) MapInfo Desktop GIS

PROCEDURE

Aggregating Census Block Data to the TAZ Level

Step 1. Import Census STF Table into MapInfo Table

Use FILE - OPEN. Open the .dbf file containing the block data.

Step 2. Create Point Coverage

Create a point coverage of census block centroids from the x and y coordinates provided in the STF. Use TABLE - CREATE POINTS. Choose the proper filename and symbol style. Get x coordinates from "lntptlng" and y coordinates from "lntptlat." Multiply these coordinates by 0.000001 to handle the census' six implied decimal points. The projection is "Longitude/Latitude." Refer to Figure 14-1.
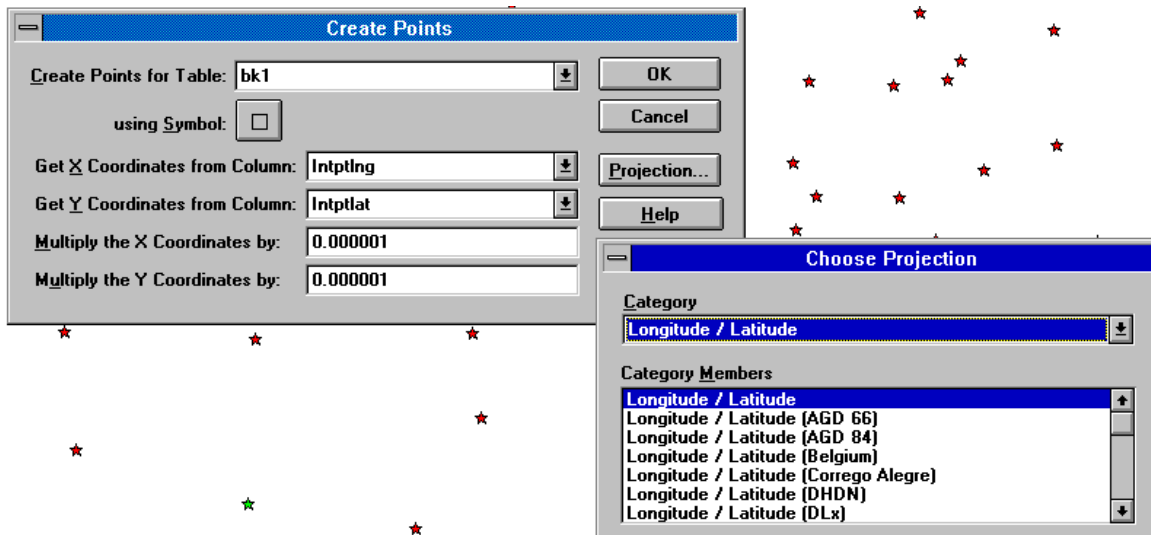

Figure 14-1. Creating a Point Coverage

Step 3. Sum STF Fields into a New TAZ Column

Use TABLE - MAINTENANCE - TABLE STRUCTURE to add a new column to the TAZ file. It is important to have the proper field type. Most census fields contain either integers or characters. Use TABLE - UPDATE COLUMN to sum the STF fields into the TAZ column. In Figure 14-2, TAZ is the TAZ MapInfo table; tot_pop is the new field added to the TAZ file; BK1 is the name of the STF block table; and Pop100 is the name of the STF field containing population data. This should update the TAZ column with the sum of block data in each TAZ.

Disaggregating Census Block Group Data to the TAZ Level

The block group STF contains information which is not available in the block level data. Unlike the block data, block groups are generally larger than TAZs and the information must be disaggregated to the TAZ level. One possible way to accomplish this is to develop proportions from the block group data and applying the proportions to a quantity known from the block data. The following is an example of disaggregating household income information from the block group level to the TAZ level. It is assumed that the trip generation model requires the number of households in three income brackets. The block group data contains the number of households in approximately 25 income brackets.
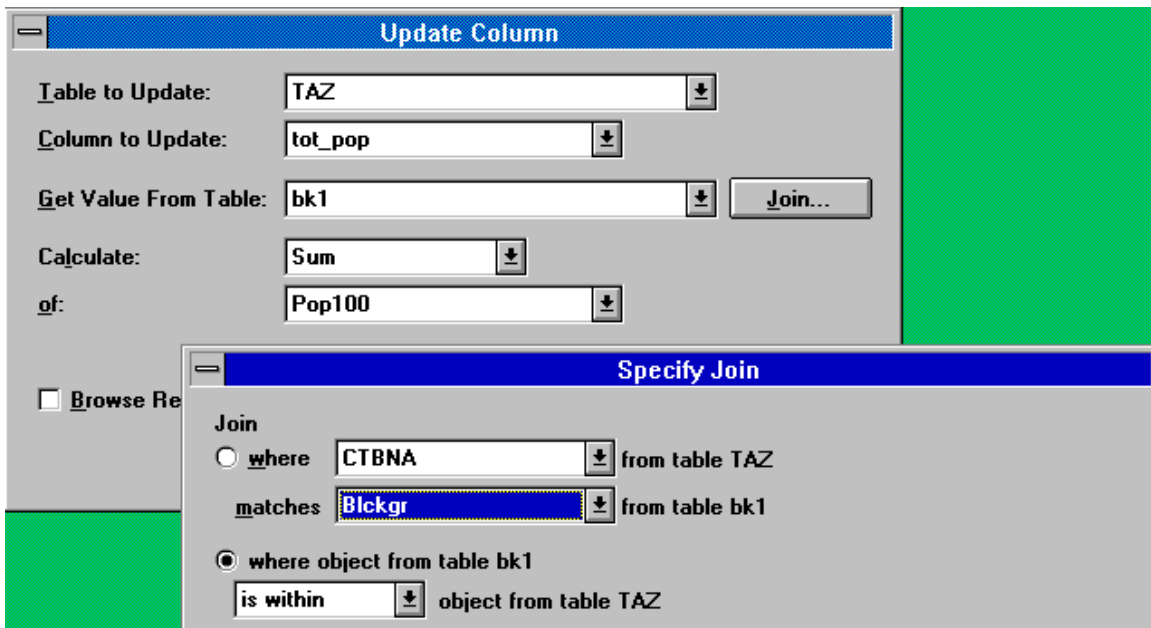
14-2

Figure 14-2. Summing STF Fields into a New TAZ Column

Step 1. Add New Fields to Block Group Table

Add new fields to the census block group table file for the number of households in each of three categories (see step 3 above for adding a field).

Step 2. Populate New Fields

Populate the first three new fields by summing the appropriate census columns. Use TABLE - UPDATE COLUMN. In Figure 14-3, "blkgroup" is the name of the block group file; "_0_20k" is the name of a new field; P80v1....P80v8 are names of the block group fields containing income information; and the "Expression" box is accessed by the "Assist..." button.

Step 3. Add New Fields to TAZ Table

Add seven new fields to the TAZ table. These fields should include three files for the number of households in each category, one for the total number of households in the block group, and three for the percentage of these households to total households. The latter fields should be a decimal type as they will contain decimal percentages.

Step 4. Populate New Fields

Sum the number of households in each category and for the entire block group. Use TABLE - UPDATE COLUMN. In Figure 14-4, "BLKGROUP" and "Blckgr" are the common

identifiers in each table; "hhgroup" is the column being updated; "Hu100" is the column in the census block table containing the total number of households in a block group.
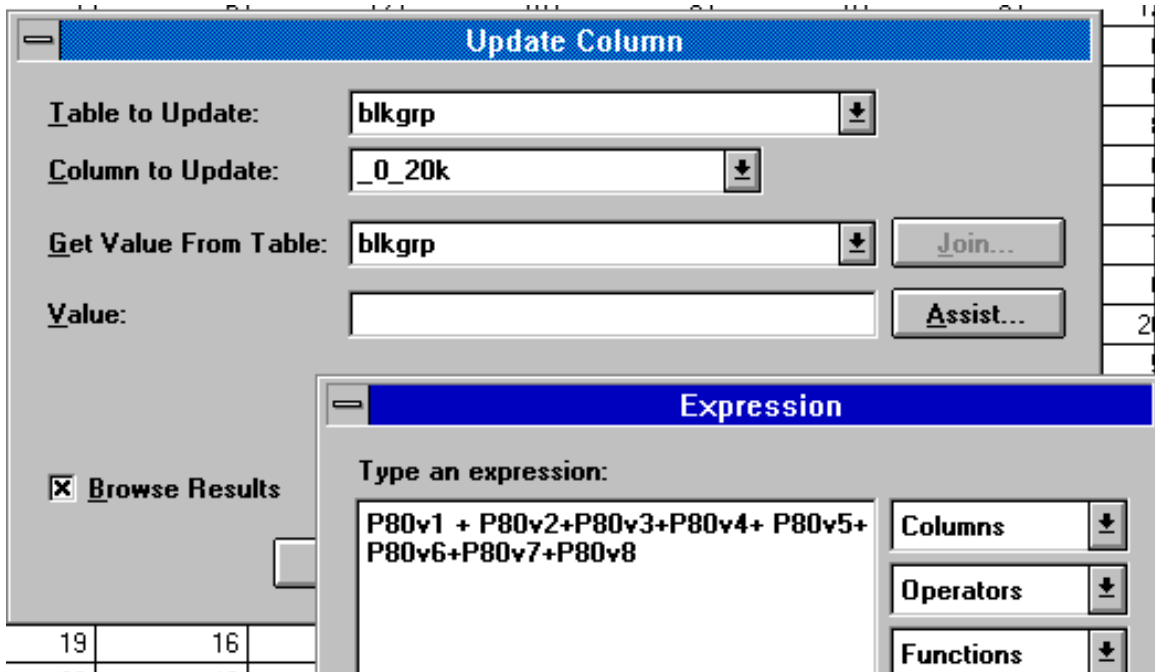

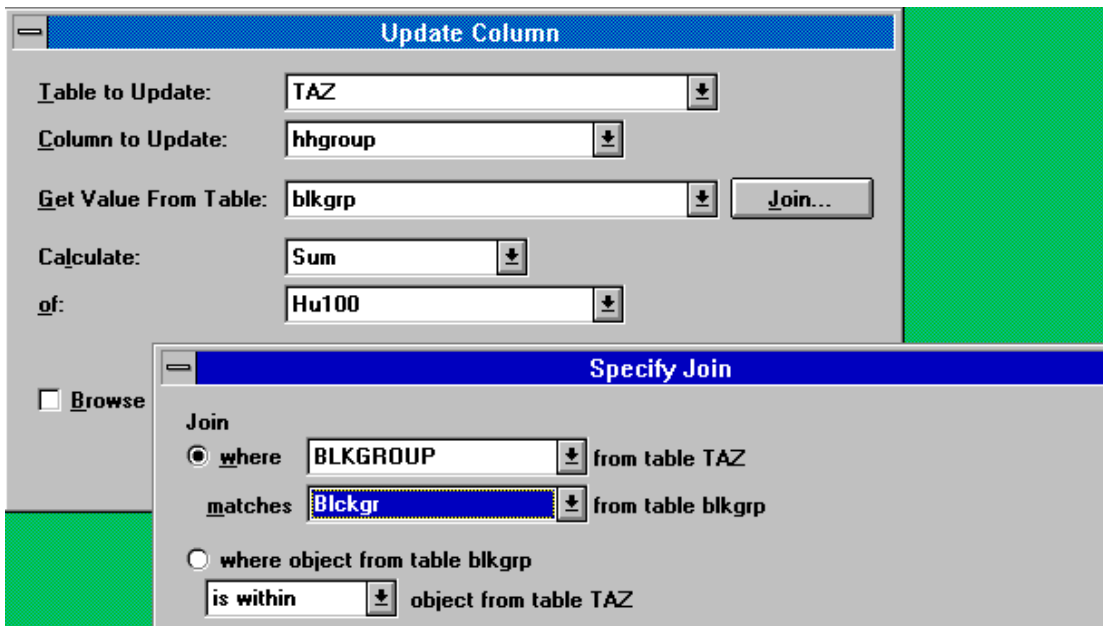Figure 14-3. Populate New Fields in Block Group Table
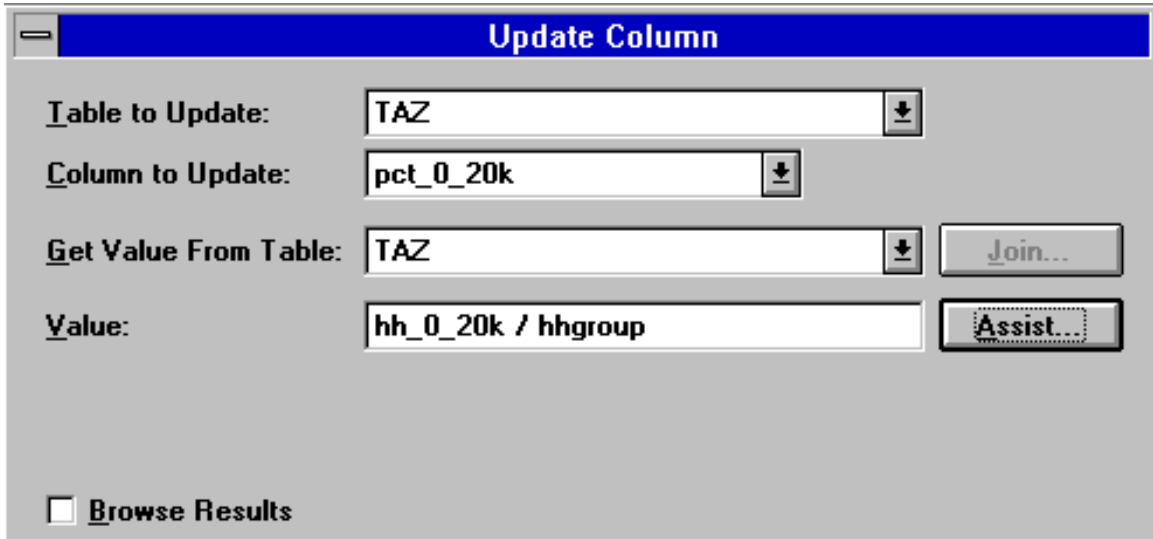
Figure 14-4. Populate New Fields in TAZ Table

Step 5. Calculate the Percentages

Calculate the percentage of households in each income category. Use TABLE - UPDATE COLUMN. In Figure 14-5, the column "pct_0_20k" contains the percentages; "hh_0_20k" contains the households in each category; "hhgroup" contains the total households in the block group.

Figure 14-5. Calculating the percentages.

Step 6. Recalculate Number of Households

Recalculate the number of households in each income category. Use TABLE - UPDATE COLUMN, multiplying the percentage to the number of households in each TAZ. The number of households in each TAZ can be calculated using the steps from **Aggregating Census Block Data to the TAZ Level.**

APPENDIX A

A GIS-QRS METHODOLOGY TO DEVELOP TRAVEL MODELS
FOR SMALLER URBAN AREAS

ABSTRACT

Personal computer implementations of urban transportation planning (UTP) packages have resulted in a proliferation of modeling efforts. The proliferation has generated a need for improved access to spatially referenced data and enhanced graphical interfaces and visualization tools, particularly for agencies with dwindling or limited resources. A geographic information system (GIS) for transportation modeling can meet these needs. In this paper, a set of recommended "steps" is described for developing UTP models using desktop GIS tools. Using the City of Ames, Iowa as a case study, the methodology improves data integration, allows for cost-effective and timely model development, and provides GIS visualization tools for enhanced model calibration and validation.

INTRODUCTION

Urban transportation planning (UTP) models have found wide spread use among urbanized areas. Large scale urban models, running on mainframe computers, were first developed in the 1960s. Throughout the 1970s, many jurisdictions deployed travel models, but decreasing resources for studies eventually slowed their development. In the late 1970s, quick response system (QRS) techniques were developed to facilitate modeling in smaller urbanized areas and to update existing models. During the 1980s, personal computer based UTP packages allowed for a further proliferation of modeling efforts.

Today, analysts using state of the practice travel model software face challenges of effective data management, analysis, and presentation of results. Data, much of which is spatially referenced, are collected and maintained by multiple agencies and available in diverse formats and coordinate systems. Many agencies lack the computational resources and experience required to acquire and manage spatial data in a common reference environment.

Modeling efforts are required of all Metropolitan Planning Organizations (MPOs); however, smaller urban areas could also benefit from cost effective modeling efforts. Application to these areas would enhance long range planning and examination of transportation infrastructure impacts and/or land-use changes. However, agency resources may prohibit conventional model development.

Most travel model software packages have limited graphical user interfaces (GUI) for visualizing networks, analyzing alternatives, and displaying data. Efforts to improve GUI of forecasting software yielded packages such as Caliper Corporation's TransCAD and other developers have improved systems in the works. However, agency resources and previous investment generally prevent immediate acquisition of one of these packages.

These modeling problems, though significant, are surmountable through recent technological and methodological developments. Geographic information systems (GIS) are

efficient, computer based tools used to capture, store, manipulate, analyze and display spatially referenced data. GIS can import multiple data formats and overlay data in a common reference environment. As mentioned, QRS techniques reduce resource requirements for UTP model development. A combined QRS-GIS model development methodology would therefore seem to promise efficient UTP model development in small urban areas. A QRS-GIS methodology would provide an environment to acquire and manage spatial data and should include visualization tools assisting model calibration and validation.

This paper's goal is to address current modeling issues by defining a QRS-GIS model development methodology. Its main focus is developing improved data integration and visualization tools. The QRS-GIS methodology and environment attempt to replicate and improve existing capabilities found in various foercast software and GIS programs along with examining new GIS capabilities. The scope ranges from integration of existing digital and non-digital data to GIS-based QRS techniques for operating within the GIS environment. The paper briefly examines previous GIS model development applications, outlines recommended data collection procedures, defines the QRS-GIS model development methodology and describes an application of this methodology to a case study: developing a validated UTP model for Ames, Iowa, population 50,000.

BACKGROUND: APPLICATIONS OF GIS IN MODEL DEVELOPMENT

Previous studies show GIS advantageous in developing travel models. Hans outlined three transportation applications of GIS, including model development (Hans, 1994). Barrett used GIS to update the Minneapolis/St. Paul UTP model by developing an interface between Intergraph's MGE GIS package, a UTP model, and PlanPAC (the FHWA's 1970s computer-based highway planning package) (Barrett, 1994). Bennion studied the development of Traffic Analysis Zones (TAZs) using GIS (Bennion, 1994) and O'Neill used GIS to define optimal urban area TAZs (O'Neill, 1991). Caliper Corporation's TransCAD package, a commercial GIS/travel forecasting model, has been used in many areas such as the re-calculation of trip generation values in Clinton, Iowa (Raber, 1994) and in Charlotte for super-regoinal transportation modeling (Hartgen, 1992).

SELECTION OF PLATFORMS

Although many GIS and planning model software are available, MapInfo GIS (MapInfo Corporation, Troy, NY) and Tranplan modeling software (Urban Analysis Group, Danville, CA) were used to prototype the QRS-GIS methodology described in this paper. With over 110,000 users, MapInfo is the most widely used desktop mapping program (GIS World, 1995). Many small agencies are concerned about selection of software to assure compatibility with other agencies. MapInfo has extensive operator-friendly capabilities which also make it attractive to many small government agencies. While its data structure is not based on topological relationships, like more powerful GIS programs, MapInfo attaches graphical features to a database containing attribute information. MapInfo also provides an ability to perform complex SQL (Structured Query Language) queries on multiple databases.

Tranplan is a personal computer implementation of the Urban Transportation Modeling System planning process: trip generation, trip distribution, modal split, traffic

assignment (UAG, 1995). The Iowa DOT is one of several states which has purchased a statewide Tranplan license allowing local government agencies free access to the software. Powerful and flexible modeling capabilities, the availability of state DOT assistance, and an active regional users group make Tranplan the choice of many planning agencies in the midwest.

DATA INTEGRATION

Not surprisingly, the proposed QRS-GIS model development methodology begins with data collection. Subsequent steps also resemble conventional techniques such as establishing traffic analysis zone (TAZ) boundaries, generating trips, defining an attribute model network, running the model, calibration, and validation. However, this methodology combines QRS techniques and a GIS environment which reduces resource requirements and improves data integration. Figure 1 outlines this methodology (areas shown in gray depict GIS processes).
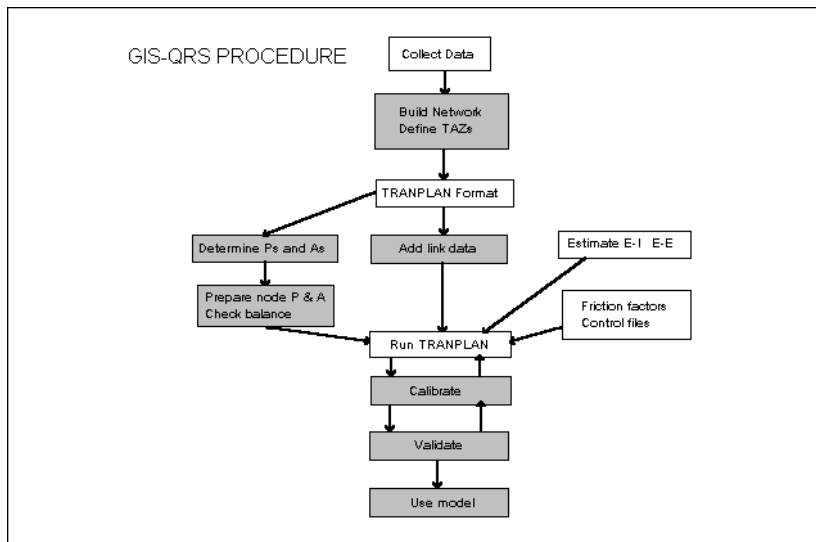
Figure 1. Flowchart of the system.

Spatial data useful for network modeling are available in a multitude of formats and coordinate systems. As data are collected and maintained by many organizations, local agencies may have difficulty acquiring and utilizing these data.

Although spatial data are plentiful, analysts in smaller agencies may have little or no experience in spatial data acquisition. For use in the QRS-GIS methodology, street network data were obtained from DOT CAD and TIGER street files. Socio-economic data were obtained from census data at the block and block-group level, employment statistics from the Department of Employment Services (DES), and parcel information from the local assessor/auditor. Data collected also included aerial photography, land-use maps, traffic signal locations, and traffic counts.

Upon data acquisition, the multiple data formats are imported into the GIS through the following procedures:

    • DOT design files in DXF format are directly imported into the GIS. Design files are generally developed in a known coordinate system and can be correctly placed within GIS. If not, they can be transformed into proper coordinates before or after import.

    • TIGER and census data, depending on the GIS package, can be imported directly, imported then translated from another GIS package, or imported using shareware programs. TIGER files are provided in geographic coordinates (lat-long) that any GIS can reference.

    • Raster images, aerial photography and other digital images, are registered through control points at known locations or point coordinates.

    • Point data with previously defined X-Y coordinates (e.g., assesor/auditor information) can be placed explicitly using the coordinates. This is sometimes the case when a GIS or CAD program was used to create the file but direct import is not possible. If point coordinates are unknown, street addresses permit goecoding to street files (e.g., DES data).

    • Other data, such as land-use maps, traffic signal locations, and traffic counts, can be developed through "heads-up-digitizing" and manual database updates enhanced by querying graphical elements and the associated database.

GIS allows placement of data in a common reference environment which becomes the basis of QRS-GIS analysis and presentation

QRS-GIS METHODOLOGY

Census block-groups provide a convenient starting point for traffic analysis zone definition. As with conventional development, modifications may be warranted if non-homogeneous land-use exists within a block-group. GIS's ability to overlay land-use maps, aerial photography, blocks and block-groups coverages assists identification of non-homogeneous block-groups and GIS's spatial analysis and manipulation capabilities facilitate appropriate zone definition.

In the QRS-GIS, trip generation equations are selected and independent variables identified after defining zone boundaries. GIS is used to assemble the required socio-economic data. Useful data sets include census data (number of households and income ranges), employment data (business location, type, and number of employees) and tax assessor data (dwelling unit locations, number of rooms, and year constructed). Data aggregation to zone levels through summing or a weighted average is a simple process in GIS as is calculating productions and attractions and associating such values with appropriate zones.

Creating a link-node network (required by Tranplan) begins with an existing street files. Data sources include the TIGER files, DOT CAD files, or local area CAD files (TIGER advantages include street address ranges and block and block-group overlays while disadvantages include some errors of omission and inclusion). GIS display of the street file, signal locations, link functional classification, and TAZs facilitates network development. After removing local streets, GIS is used to combine the remaining linework into network links.

The next step is placement of centroid connectors. GIS display of the existing street network, hydrography, aerial photos, and model network facilitate locating natural boundaries and defining access location. After placing centroid connectors, link attributes are added to the network and QRS-GIS programs outside GIS prepare the data into Tranplan format. Running the UTP package determines loaded link speeds and volumes and additional QRS-GIS programs incorporate the new speeds and volumes into GIS for analysis. These programs were written to be nearly transparent to the user and the whole process (modifying and running the model, once built) takes less than five minutes.

Future networks or modified networks can easily be developed in GIS. Exporting the new network and running the model produce new volumes and speeds, which can be brought into GIS for analysis, further modification, or display.

The Tranplan program requires additional data files to perform a model run which can be generated by the GIS. These include friction factors, external trips, and model control files (parameters, options, etc.). Friction factors are required to use the gravity model and are typically obtained by quick response techniques. An external trip matrix depicting flows through the network can be obtained through travel surveys or other quick response techniques.

Re-calibrating the model requires modifying key model parameters and checking input data (Ismart, 1990). Validating the model involves comparing the average annual daily traffic (AADT) to the predicted model volume (Ismart, 1990). To assist re-calibration and validation, GIS based visualization tools were developed to concisely display loaded volumes and flow patterns in meaningful ways, turning movement counts in familiar formats, and shortest paths between nodes based on travel time or other measures.

CASE STUDY: QRS-GIS FOR AMES, IOWA

The population of Ames is slightly less than 50,000, consequently, no MPO is designated and no model has been maintained for the area. Ames largest generator is Iowa State University (25,000 students) and the city is currently considering the development of a new highway interchange. The case study's goal was to implement the QRS-GIS methodology to develop a validated UTP model and evaluate the placement of the interchange in a cost effective manner (using project funds available for the traffic forecasts - a relatively small budget).

Initial data collection included the TIGER street file for the study area. The TIGER street file was imported via a second GIS package (Arc/INFO and ArcLink). The TIGER street network is shown in figure 2. An aerial photo of Ames, scanned into GIF format, was registered into MapInfo using control points placed at intersections located on the TIGER street network and on the rastor images.
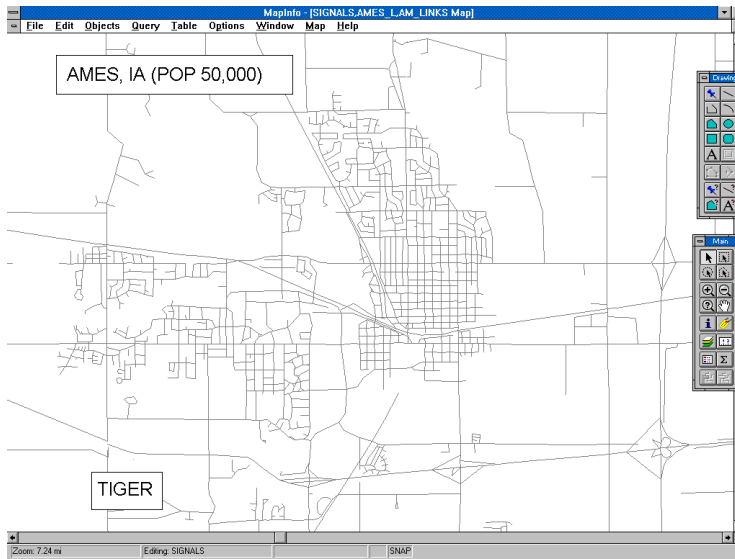
Figure 2. TIGER Street Network for the Study Area.

Following the methodology, model network development involved removing extraneous streets. Displaying the TIGER street network in MapInfo, together with the block-groups and traffic signal locations, allowed identification of model links (some local knowledge is required here). Streets coded by functional classification is helpful but not required. Figure 3 shows the TIGER street network and traffic signal locations.
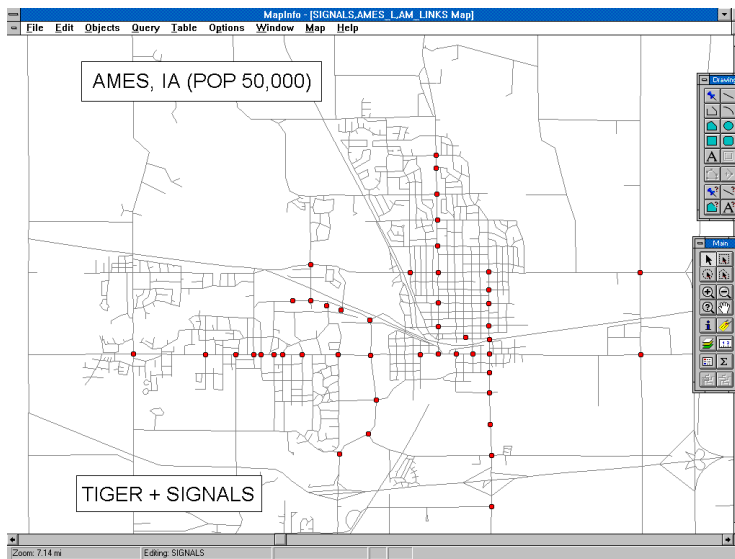
Figure 3. TIGER Streets with Traffic Signals.

The remaining street segments were combined into links by manually redrawing certain links and using MapInfo's Combine capability. The model network is shown in figure 4. While viewing the TIGER street file, area rivers, and aerial photos in GIS, centroid connectors were added to the network (see figure 5). The GIS was used to split existing links at centroid connectors (required by Tranplan). External connectors were also added at this point.
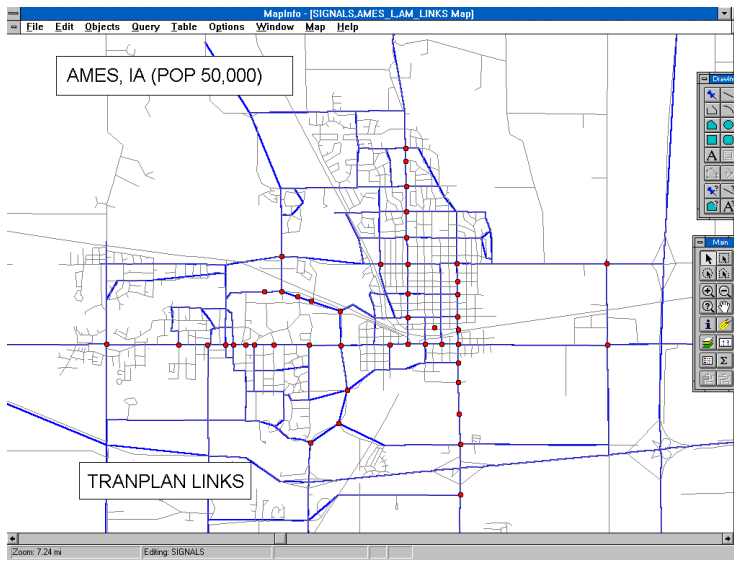
Figure 4. Tranplan Links.
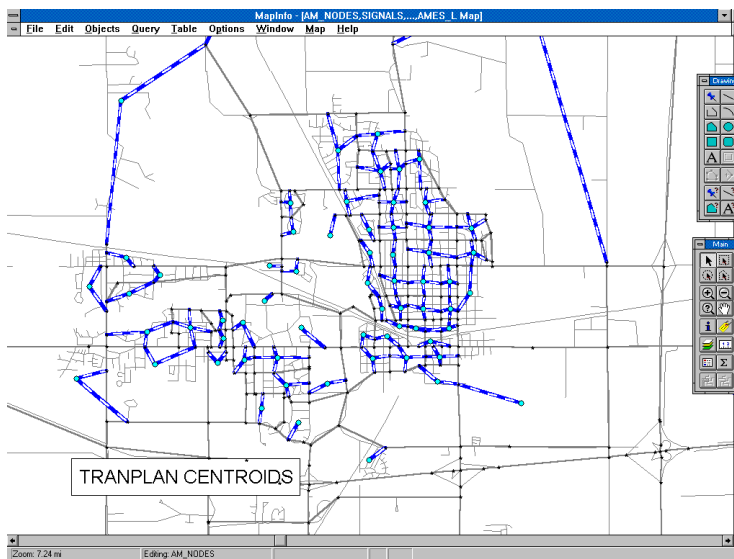
Figure 5. Tranplan Centroids.

The next step was to add link attributes and format the data sets. This step included assigning node numbers, determining coordinates, and adding attribute information (e.g., link speed and volume). GIS facilitated this process by updating tables, retrieving coordinate values, and querying links and updating attributes simultaneously. A file was also developed to contain node data (node numbers and X-Y coordinates, also required by Tranplan).

During network development, the block and block-group data were brought into GIS (shown in figure 6). Trip generation equations were selected and the necessary data inputs assembled in GIS. Number of households by income level and household occupancy were obtained from the census files. STF1 provided the number of households (by block) and STF3 provided income and occupancy ranges (by block-group).
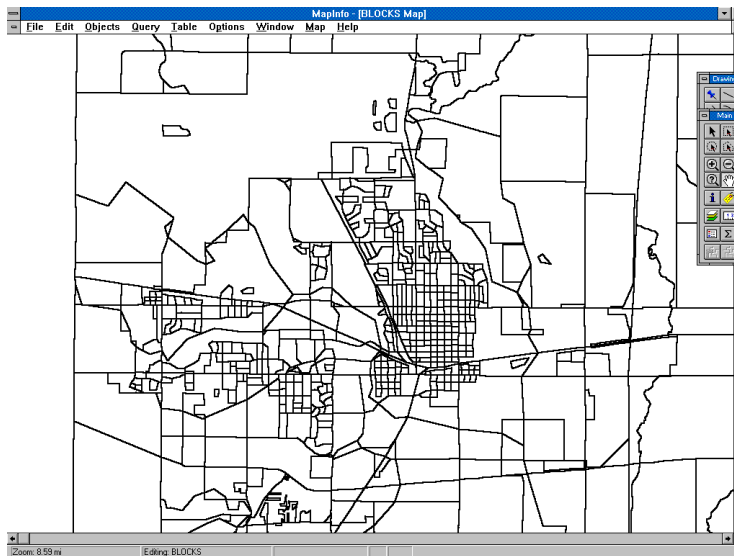

Figure 6. Census Block Data.

Employment data were obtained from the Iowa Department of Employment Services (DES) in ASCII format. These data included the name, address, SIC code and number of employees for all businesses in the study area. Goecoding the businesses to the TIGER street network using MapInfo resulted in an employment coverage. Some manual enhancement was required for each data set to ensure placement of most businesses. After file manipulation, 95 percent of the businesses were successfully placed. The remaining 5 percent were placed manually. An analyst from the city engineering department supplied corrected address ranges (to modify TIGER and DES), and helped in locating streets. For the study area, this took about eight hours. The MapInfo DES data are shown in figure 7.
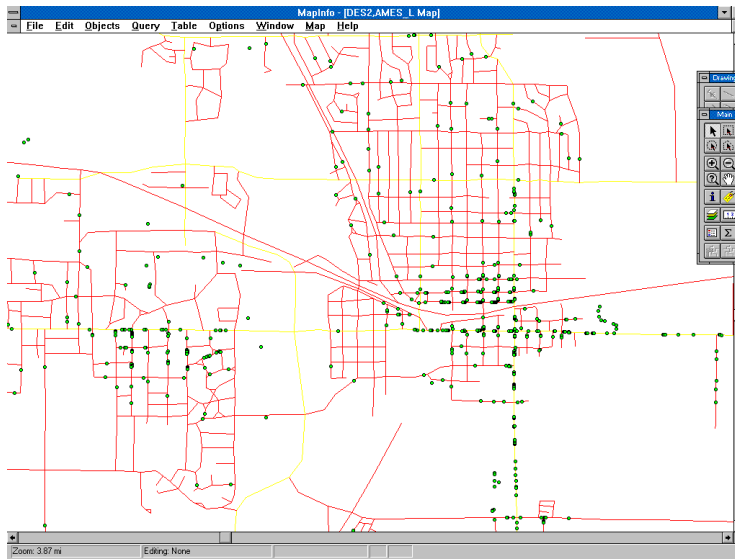
Figure 7. Employment Data Goecoded to TIGER.

The starting point for TAZ definition was the census block-groups. A GIS-based land-use map was developed and is shown in figure 8. Zones were modified after examining the street network and land-use characteristics. MapInfo was used to aggregate employment data (by specific SIC code ranges) and census data to the zone level. Trip generation equations were used to calculate productions and attractions with the GIS and results were stored in the node table.
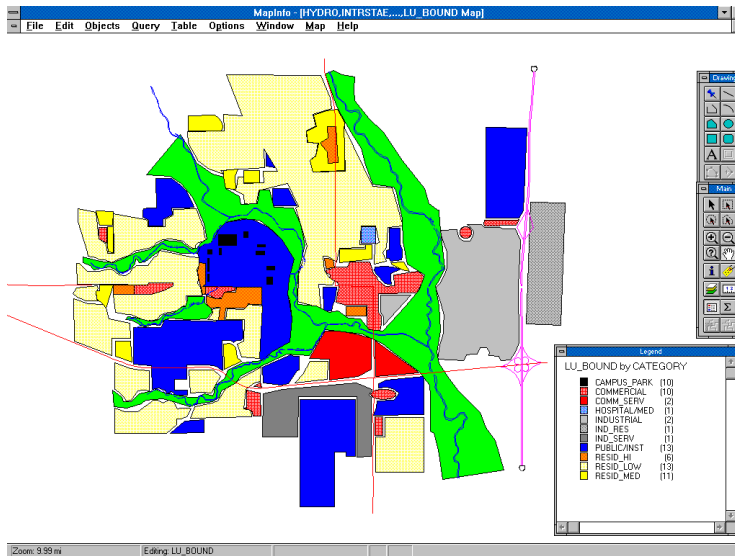
Figure 8. Land-use Map for Ames, Iowa.

The external to external (E-E) trips and external to internal (E-I) trips were calculated in a spreadsheet. The E-E trip exchange matrix was converted into an ASCII file for input to Tranplan. The E-I productions and attractions (by trip purpose) were then inserted into the node table. Productions and attractions were then summed in the QRS-GIS by trip purpose to check balance.

Other files required to run the Tranplan model include a friction factor table and control files. Friction factors used were taken from secondary sources (no data were collected to calibrate friction factors for the study area). Tranplan control files were created exogenously.

After data integration, network definition, demand analysis, and file preparation, files were exported and Tranplan was run to determine the loaded link volumes and speeds (see figure 9). The new link volumes and speeds were then imported into GIS for examination.

RE-CALIBRATION AND VALIDATION

Re-calibration and validation involved examining the loaded network to pin-point coding errors, comparing ground counts to model volume, and modifying the model to better replicate traffic. An iterative process, modifications were made, results compared to ground counts, further modifications were made, etc, until the model closely replicated traffic. Additional checks included the examination of volume to capacity ratios, the difference in counts and percent difference in counts.

VISUALIZATION TOOLS

Visualization tools were developed in the QRS-GIS to improve calibration techniques and enhance validation. A tool was constructed for visualizing network validation. Network links were buffered with model volume and labeled with model volume and percent difference from the ground count. Color was incorporated to quickly identify non-validating links. Red was used to identify links where the loaded volume exceeded the ground counts by a specified limit and blue identified links where the loaded volume was below the ground counts by the same limit. The red and blue color scheme provides analysts efficient problem recognition and information related to the problem's magnitude. An example (shown in black and white) is displayed in figure 10.
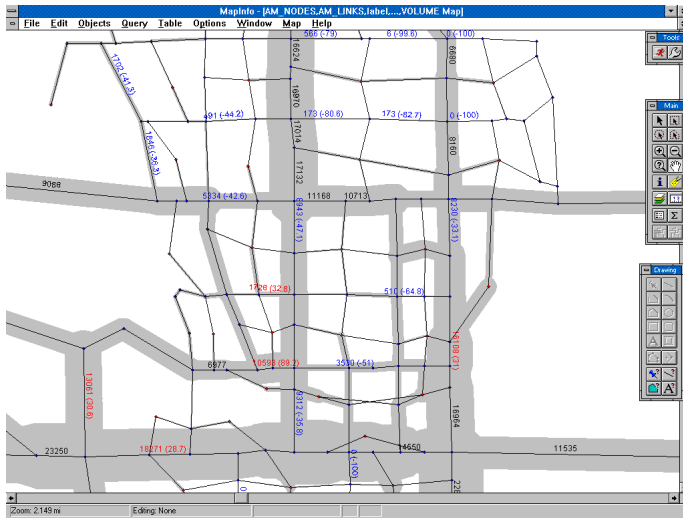
Figure 10. Visualization Plot.

Another tool displays turning movement counts for specified intersections. Turning movement diagrams in an easy to read format were automatically drawn and labeled with the turning volume. Turning movements were used to determine flow patterns through a specific intersection or a corridor. A turning movement example is shown in figure 11.
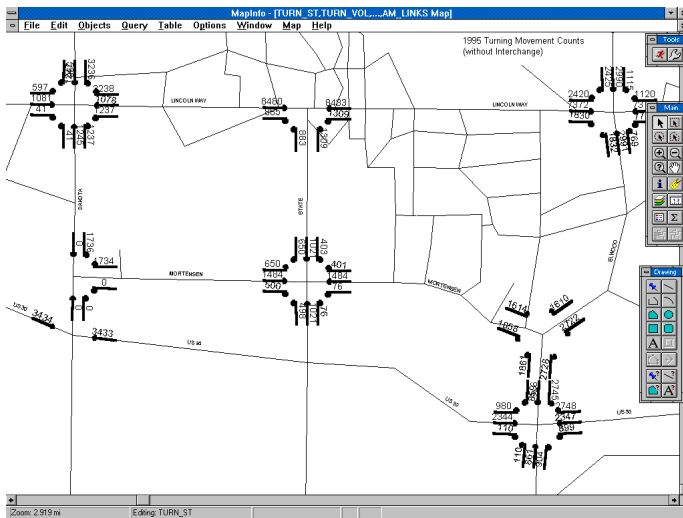
Figure 11. Turning Movement Visualization Tool.

Another tool displays the shortest path between specified nodes. Displaying the shortest path is not novel, as other GIS programs have built-in shortest path capabilities;

however, MapInfo lacks this ability. This tool calculates the optimal path through the network to facilitate checking flow patterns. A shortest path example is shown in figure 12.
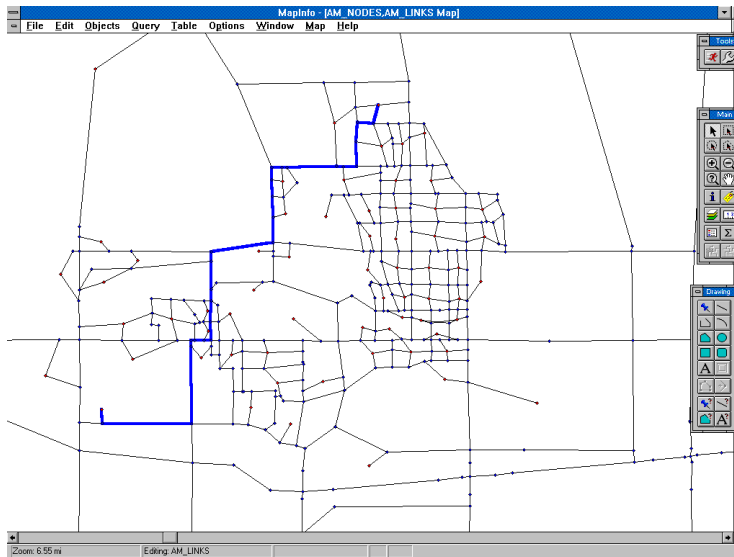
Figure 12. Shortest Path Visualization Tool.

In addition to the tools mentioned, the QRS-GIS environment provided many additional feature absent of most forecasting programs. Using the visualization plot during the validation phase, it was determined that the Iowa State University dormitories were not included in the socioeconomic data. To rectify this problem, MapInfo was used to draw a polygon around one of the dormitories determining the area. ITE Trip Generation software was then incorporated into the QRS-GIS environment and used to calculate the number of trips. This value was then inserted into to the node table.

A similar procedure was used to verify the productions and attractions for a special generator (local shopping mall). The area of the building in the mall's TAZ were determined using MapInfo and the number of trips was calculated using ITE Trip Generation software. These trips were compared with the trips generation equations results for verification (all within the QRS-GIS).

Another tool developed during the validation phase was a tool showing the effcts of a speed change on a cooridor. A selected corridor had the loaded volumes determined for two different speeds (free flow speed and a modified speed). A comparison of the two volumes was made using different colors and buffering styles. Using the free flow speed scenario, the corridor was intially buffered with the difference between loaded volume and ground count using a hollow buffer. These buffers were color coded (red where the model volume exceeded the ground count, blue where the model volume was below the ground count). Then, using the modified speed scenario, additional buffers showing the difference in loaded volume to groung counts were added with filled pattern buffers (also color coded in a similar

fahion). Using the display, an analyst can determine locations where speed modifcations are warranted to improve validation.

After re-calibrating and validating, a base year network for the study area was complete.

DEVELOPMENT OF NEW SCENARIOS

An alternative scenario was developed which included a network with the proposed interchange. For the alternative, in the QRS-GIS a new node was placed at the proposed interchange location links were realigned to connect with the node. After the modifications, the information was exported and another model run was performed. The new volumes and speeds were then brought back into GIS for analysis. Analysis included examining before and after volumes, turning movement counts, and traffic flow patterns.

To assist in analyzing the before and after counts, another visualization tools was developed showing the changes in model volume between the two scenarios. The tools calculates the difference in model volume and buffers each link proportional to the difference using the familiar color scheme (red showing the model volumes have increased and blue showing the model volumes have decreased). The buffers are labled with the difference in model volume, the percent differnce in model volume, or a combination. This tools provides an analyst efficient means to compare multiple scenarios.

Two future scenarios were also developed, with and without the interchange. The future data, provided by the city, showed where growth was expected. The data were used to re-calculated productions and attractions and additional links. New traffic volumes were determined and compared to the base network with and without the interchange.

CONCLUSIONS

The QRS-GIS model development methodology provided an effective means to incorporate existing data sources, integrate the data in a usable method, create a UTP model for an urban area, and visualize results which improves model calibration and validation. All data sources used for the project were compiled and maintained in various formats and projections by different organizations, and are available to interested agencies. The data were brought into the GIS environment and placed in a common reference environment through address matching, registering GIF images, translation from another GIS, use of X-Y coordinates, and direct importing. The GIS provided a means to analyze, manipulate, store and display the data to complete the requirements of model development.

Outputs of the project not only include a UTP model for the city of Ames, but programs developed to create new models, modify existing models, and analyze scenarios. Ames engineers were provided with a manual documenting program use for developing alternatives. The project created models depicting the base year with and without the interchange and future networks with and without the interchange. The GIS environment was used to handle the information required to develop a model and the linkage provided a quick means to analyze alternatives.

The results of the case study demonstrate that a UTP model can be efficiently developed using the QRS-GIS methodology (in a matter of a few weeks). The total cost for

developing additional models is far below the cost for a model developed using more conventional methods. The results showed that a model can be produced using existing data sources without surveys producing reasonable results. Local assistance was used for some steps of the model development but manual effort was minimized. The methodology also demonstrated the advantage of integrating data from a variety of sources for use in the development of a model.

Most importantly, the GIS-based visualization tools provide analysts with an efficient means of network evaluation. The QRS-GIS display and plots convey large amounts of information efficiently. Turning movement diagrams allow analysis of specific intersections and corridors. The shortest path algorithm provides the ability to examine traffic flows through the area. These visualization tools not only assist in model development, re-calibrating and validating, and comparing multiple scenarios, but increase the accuracy and functionality of the UTP model.

ACKNOWLEDGEMENTS

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**A GEOGRAPHIC INFORMATION SYSTEM - BASED TRANSPORTATION
FORECAST MODEL FOR USE IN SMALL URBANIZED AREAS**

ABSTRACT

GIS has been shown to be an effective tool for transportation forecasting and scenario analysis. Previous efforts have linked full function GIS packages with transportation forecasting models. The goal of this paper is to describe tools developed to provide a modeling environment more appropriate for the technical knowledge level and budget requirements of small urban or rural areas. Specifically, the needs of Metropolitan Planning Organizations (MPOs) and Regional Planning Affiliations (RPAs) in Iowa were considered in the system design. In the work described in the paper, a desktop mapping package MAPINFO (MAPINFO Corporation, Troy, NY) is integrated with an Urban Transportation Planning (UTP) model TRANPLAN (Urban Analysis Group, Danville, CA) to provide an interface for network analysis. With the system, network modifications and changes representing alternative demand scenarios are made in the GIS environment, data are exported to the TRANPLAN format, and, after analysis, returned to the GIS for effective presentation of results. User tools were tested and a case study demonstrating alternatives analysis and display capabilities is presented. Although developed and tested for Des Moines, the system can easily be transferred to other agencies to enhance transportation planning capabilities.

INTRODUCTION

Urban transportation planning (UTP) forecast models had their beginnings in large-scale urban transportation studies of the 1960's. By then, the digital computer allowed for the storage and manipulation of large amounts of data required to perform the modeling process. Today, transportation modeling is performed in most of the nation's urban areas. Practice has been shaped not only by technological developments, but by legislative directives.

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) has expanded planning and modeling activities by requiring programs at the state and Metropolitan Planning Organization (MPO) level to manage data systems in a coordinated and efficient way (1). ISTEA legislation includes several factors MPOs are to consider when developing transportation plans and programs including evaluation of all transportation projects within the metropolitan area and preparation and periodic update of long range plans (2).

Conventional applications of models to support planning activities result in one or several "views" of things to come. However, the models are capable of much more - of investigations of many alternatives.   Limited capabilities for data and scenario management, and lack of tools for visualization of results and sensitivity of outputs to changes in inputs limit the effectiveness of such models. With the intent of using GIS to provide some of these capabilities, efforts have been undertaken to link GIS to travel models. In fact, one commercial software package, TransCAD (Caliper Corporation) has GIS and UTP modeling features built-in.

In the GIS-based UTP modeling environment, each software is used for the purpose which it was develop and optimized. GIS is used to store, retrieve, analyze, modify, and display data required or produced by the UTP model. This provides analysts the ability to quickly and graphically evaluate several alternatives, such as changes in the network (e.g., additional links, increased/decreased speed on links, realignment of links) or modifications in land-use characteristics of the study area (e.g., altering socioeconomic data or growth scenarios).

As mentioned, a linkage between UTP models and GISs is not novel. Development of planning tools using GIS was introduced as early as 1986 (3). Since, there have been a number of efforts examining how GIS can be integrated with and/or enhance transportation modeling. The advantages of integrating GIS and UTP modeling was studied by Lewis, Blewett, McAdams, Replogle (3) (4) (5) (6) (7), and interactive transportation planning was studied by Choi (8). Geo/SQL (Generation 5 Technology, Denver, CO) and TMODEL2 (Metro Transportation Group, Bloomington, IL) were combined in a study by Niemeier (9). Integration of GIS with QRS II (AJH and Associates, Milwaukee, WS) was performed by Kriger (10). In another study, the seven county Minneapolis/St. Paul area rebuilt its regional planning model using a GIS (11). TRANPLAN (Urban Analysis Group) and Arc/INFO

(ESRI) have been combined using UAG's DBC (database capable) interface (12). Finally, a working linkage was developed between TRANPLAN and Intergraph's MGE (modular GIS environment) (13).

The benefits of combining GIS and travel models motivated Caliper Corporation's development of TransCAD software. TransCAD is able to store, display, and analyze transportation data (14) and model UTP networks (15). Among other areas, TransCAD was used in Charlotte for super-regional transportation modeling (16).

UTP models are spatial and data intensive, and while spatial-based queries and modifications can be made in the UTP model environment, GIS software is better suited to performing such analysis. In a GIS, for example, data for nodes or links within a particular geographic area can be efficiently selected, modified and displayed. GIS provides powerful graphical database query capabilities useful in examining the effects of changes of network attributes on demand, or, of the impact of demand changes on network performance. In small agencies, however, complex, full function, and typically more expensive GIS packages are likely to be beyond technical and financial resources.

This paper describes procedures for developing an effective, accessible modeling environment by linking a popular transportation planning model with a low cost GIS package. The emphasis herein is placed on accessibility of the system to smaller agencies. The platforms chosen are TRANPLAN (Urban Analysis Group, Danville, CA) and MAPINFO (MAPINFO Corporation, Troy, NY). TRANPLAN is a personal computer implementation of the Urban Transportation Modeling System four step planning process: trip generation, trip distribution, modal split, traffic assignment (17). The Iowa DOT and several other states have purchased statewide TRANPLAN licenses, which covers all state and local government agencies. Software capabilities, low cost (none to local agency), availability of state DOT assistance, and a regional users group provide powerful incentives for these agencies to use TRANPLAN. Currently, the software is being used at five of eight Iowa MPOs and is available for all Iowa RPAs and cities to perform regional transportation analysis.

MAPINFO is the most widely used desktop mapping program, with over 110,000 users (14). Its extensive operator-friendly capabilities make it attractive to many small government agencies. While its data structure is not based on topological relationships like more powerful GIS programs, MAPINFO does attach graphical features to a database containing information about the features. MAPINFO provides an ability to perform complex SQL (Structured Query Language) queries on multiple databases. It is currently being used or expected to be purchased by the majority of the MPOs and RPAs in Iowa. TRANPLAN and MAPINFO are both available for the Windows platform.

The system developed in this research was tested for functionality, as described in the sections to follow. A case application is also investigated. The paper concludes with a comparison of the system with conventional transportation forecasting procedures.

DESIGN OF SYSTEM

TRANPLAN provides a flexible travel modeling environment. For this study, a TRANPLAN model was provided by the Des Moines MPO, which included data files for node and link information, trip productions and attractions, information on turn prohibition, friction factors, and control of model execution. These files are stored in ASCII text format, which can easily be imported and exported from GIS.

Key information for developing graphics is included in the node and link files. In TRANPLAN, node data consist of unique node numbers and X -Y coordinates. Link data include beginning and ending nodes, distance, speed, direction, group designation (e.g., number of lanes, functional classification, etc.), and capacity.

MAPINFO stores data as point, line or polygon attributes. Nodes are represented by points while traffic links are represent as lines. Polygons are not used by the modeling environment at present, but could be used to aggregate socio-economic data for trip generation. Polygons could also be used to represent background information for display or checking for network coding errors. Figure 1 shows a flowchart of the modeling environment.

UTP MODEL / GIS INTEGRATION

In order to use the GIS modeling environment developed in this project, a user must first start with a complete set of TRANPLAN data files. The first step in use of the system is to convert data from TRANPLAN format to MAPINFO. In TRANPLAN, only the nodes file contains explicit geospatial information (x-y coordinates). Links, turn prohibitors and trip generation outputs (productions and attractions - Ps and As) all make reference to node numbers but do not contain X-Y coordinates. Therefore, geospatial data are added to these files by a FORTRAN program (TP_MI.EXE) before being imported into the MAPINFO environment. To display links, MAPINFO requires starting and ending X-Y coordinates. Therefore, coordinates are added by the FORTRAN program. The FORTRAN program also creates a key field (a concatenation of the A and B nodes) for later use in updating tables. At this point, one text file contains node information (node numbers, x-y coordinates, and Ps and As) and another contains link data. (STEP 1: run TP_MI.EXE)

NODE AND LINK DATA IMPORT

The second step is to import the node and link text files into MAPINFO. This is accomplished by running a MAPBASIC program (REGISTER.MBX). This program creates two tables in MAPINFO, one for node data (points) and one for link data (lines). The program then imports (registers) the text files. (STEP 2: run REGISTER.MBX).

The next step is to create graphics for the node and link tables using the MAPINFO function UPDATE. Nodes are mapped from the table using the X-Y coordinates. (STEP 3: run UPDATE on the links and nodes tables)

WHILE IN MAPINFO

Now, in the MAPINFO environment, an analyst may make modifications of network (link or node) data. It is possible to change the location of proposed links, add or delete proposed links, or change network attributes (such as capacity, number of lanes, or speed). Changes in land-use, demographics or growth can be modeled by reflecting changes in centroid (node) productions and attractions. Aerial photos, assessor data, and other spatial information can also be brought into the environment. Structured Query Language (SQL) queries can be performed, and presentation quality maps can be produced by altering node and link symbology. Different scenarios can be represented and stored, and links or nodes with common attributes can be selected, modified and displayed. New columns may be added to store additional link information (e.g., calculated 2-way volume, street names, etc.). However, these columns must be added after all original columns (a requirement of the system design). Information is now ready to be exported back to TRANPLAN for network loading. (STEP 4: make modifications).

BACK TO TRANPLAN

After performing network modifications in MAPINFO, the tables are converted back into TRANPLAN format. First, the node and link tables are exported as text files. (STEP 5: run EXPORT.MBX) A FORTRAN program reads the information from the exported tables and prepares new files in TRANPLAN format. (STEP 6: run BLDNET.EXE) The BLDNET.EXE program combines the link and node data with some existing TRANPLAN control file information to produce a complete TRANPLAN "Build Highway Network" control file (NETWORK.IN). The program also takes production and attraction information from the exported node table and places the information into a separate file required by TRANPLAN's gravity model module. Running TRANPLAN on the modified network produces loaded link volumes and speeds. (STEP 7: run TRANPLAN with NETWORK.IN)

BACK TO MAPINFO

After running TRANPLAN, UAG's 'NETCARD' program is run to convert the standard TRANPLAN binary network output file into a text file. (STEP 8: run NETCARD). Then, another FORTRAN program is used to remove unnecessary information and reformat the remaining data for import to MAPINFO. (STEP 9: run LOADED.EXE) The output of this program is a file which contains new speeds and loaded volumes for the modified network. The key field (combination of A and B nodes) is also created by the program, allowing for joining the information to the existing MAPINFO links table. Finally, a MAPBASIC program is run to import the model outputs back into MAPINFO and update the volume and speed fields of the link table. (STEP 10: run UPDATE.MBX)

VISUALIZING THE IMPACT OF ASSUMPTIONS AND MODIFICATIONS

Turn prohibitors, penalties and turning movement counts are stored in TRANPLAN and referenced by a series of three nodes (from node, through node and to node). A FORTRAN program was written to accept this information and combine it with node coordinates which can be imported and displayed in MAPINFO. With this tool, an analyst can automatically display this information in familiar, "arrow" intersection diagrams.

To compare loaded volumes and speeds with existing or alternative conditions, maps and tables must be saved for each scenario. (STEP 11: analyze results) Some macros were developed to produce comparison maps for speed and volume differences to examine alternatives (e.g., what is the effect of a construction project closing two lanes on a freeway? Where will volume-to-capacity ratio increase?). GIS functions of buffering and thematic mapping played important roles in developing several visualization tools. The project team found that storing each scenario's tables and maps in a different, properly named subdirectory was crucial to data management. In fact, due to constraints imposed by system design, file names for different scenarios do not differ.   Figure 2 represents the process used for developing different scenarios from either a base network or from alternative scenarios.

SYSTEM TEST

A network for the city of Des Moines, Iowa was used to develop different scenarios to test the system. Following the system steps, initially, MAPINFO tables and maps were developed from TRANPLAN text files. The CBD section of the Des Moines network is shown in Figure 3. (centroid connectors are shown as dotted lines.)

Three types of modifications were tested. The first modification represented a change in the land-use of downtown Des Moines through an adjustment of production and attraction information. The second modification was a change in the operational characteristics of a freeway to simulate construction activity. The third modification was the addition of new links.

The land use modifications were modeled as a trip increase of 50 percent for CBD zones. The increase was reflected in all trip purposes. The effected zones (represented at their centroids, indicated as diamonds) are shown in figure 4.

A reduction in capacity due to construction on a segment of on Interstate 235 is modeled in the second scenario. Proposed improvements on Interstate 235 are being considered. Capacities of the highway links are reduced by 50 percent (four lanes reduced to two, each direction). The construction area and the links impacted by diverted traffic are shown in figure 5.

The third test scenario demonstrates adding links to the network. These links represent a proposed southern arterial. The addition is comprised of four links with a daily capacity of 25,000 vehicles and a speed of 58 kilometers per hour (35 mph). The location of the links and the resulting decrease in adjacent traffic volume are shown in figure 6.

TEST RESULTS

Each of the three test modifications were performed easily in the GIS UTP modeling environment. Including running all programs and displaying results using the visualization tools took less than twenty minutes on a 486 based personal computer (650 zone network). The system has superior visualization capabilities (compared to running TRANPLAN alone), decreases the time needed for scenario analysis, allows more varied spatial queries, facilitates evaluation and comparison of multiple alternatives, and improves quality control and scenario management.

CASE STUDY: DES MOINES, IOWA

To provide a practical application of the system, a proposed extension of Des Moines' Martin Luther King Jr. Parkway was examined. The goal of this extension is to provide additional north - south capacity for northwest - downtown commuters. The application examines and compares location alternatives for the extension of the parkway to Interstate 80.

A MAPINFO table and map depicting open spaces and hydrography in the city were provided by the Des Moines MPO. These were used to identify possible alignments for the extension. The study area is shown in figure 7.

The development of new links and nodes representing the alignments involves a series of steps:

1) identify the development area
2) after copying its attribute information, remove the interstate link where the extension will connect
3) place a node at the proposed interchange location

4) insert two new interstate links, paste attribute information
5) insert new nodes for the MLK extension
6) insert new links for the MLK extension

These steps were performed for two alignments and two design speeds (four scenarios). One of the alignments locates the interchange on the east side of the Des Moines River and the other places the interchange on the west side of the river. In an actual roadway alignment process there would be many more factors to examine, although most of which can be displayed in a GIS. Figure 8 shows the location of the east and west alignments.

The links which were developed were attributed with the information required by TRANPLAN. The addition of the new links added rows to the bottom of the links table. The rows were updated with the required information (A node, B node, speed, distance, capacity, link group information, etc.). For each of the two alignments, the operational characteristics for the new links on the interstate were the same as the original link (with the exception of distance). Speed of the first operational scenario replicates existing MLK attributes. Speed is increased in the second scenario from 46 kilometers per hour (27.5 mph) to 67 kilometers per hour (40 mph).

Next, the tables for the scenarios were exported and TRANPLAN was run to determine the new loaded volumes. The new volumes were then joined with the existing MAPINFO tables. Figures 9 - 11 compare existing and scenario traffic volumes.

CONCLUSIONS

The MAPINFO-TRANPLAN interactive system provides many useful features for small to medium sized planning organizations. The features include the use of a graphical interface for modifications and query analysis, enhanced presentation ability, enhanced alternative analysis, and a user-friendly, low cost, desk-top system.

The graphical interface for the modifications and query analysis allows analyst to use database capabilities linked to graphical elements. The graphical displays and macros allow analysts to better visualize network changes. The capability to perform spatial queries allows bulk update or display of links in ranges of attributes. An analyst can also compare multiple scenarios.

Enhanced presentation is important for effectively communicating the results of the model to the public and elected officials. Maps have a great impact and supplement good oral presentation. The system's quick query capabilities provide an ability to respond to questions that arise during meetings, and attention can quickly be focused on an affected local area.

Alternative analysis is enhanced with rapid scenario analysis. Traffic volumes of one scenario can be compared with traffic volumes of any other stored scenario.

Only the elementary capabilities of the system are demonstrated in this paper. The true power of such a system is revealed when applied by planners and analysts in the field. A system operating completely on a desk-top personal computer utilizing relatively low cost user-friendly software is very attractive to these users and several requests for the system have been made. (The system has been tested at two MPOs, one state DOT and one city).

The system took about three months at half time of one analyst to develop. Implementation and use of the system can be accomplished in less than one day, including training (assuming knowledge of TRANPLAN and some knowledge of MAPINFO).

Future development will include enhancements to the programs to operate quicker, in one environment (MAPINFO) and with less reliance on user input. (Currently a user is required to toggle between three windows programs).

The city of Des Moines was provided with the results of the case study along with the programs and information required to use the system and analyze different alternatives. The MPO is currently using the linkage to examine different future growth scenarios for the city.

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APPENDIX C
UTILIZING GIS TO FACILITATE BICYCLE ROUTE PLANNING

Introduction

This paper reports on the development and application of a GIS for planning the location of on-street bicycle routes. A multi-objective decision making process is used to identify and determine weights for criteria to be considered when planning these facilities. Criteria and their weights are integrated into programs that run within a GIS environment. The simple GIS based tools are shown to be useful to planners performing alternatives analyses to support a sound decision making process concerning bicycle route location.

In recent years the amount of attention focused on bicycle facilities is steadily increasing. The rise in attention is primarily due to federal programs that have been created to promote bicycling as a mode of transportation. More federal funding is available for communities to spend on bicycle facilities. Bicycling provides an alternative to the automobile for commuting, helping to reduce traffic congestion and enhance air quality. The popularity of bicycling for recreation has also dramatically increased (Burrell, 1994).

ISTEA-91 requires that all MPOs, in cooperation with the State, develop transportation plans and programs which incorporate the development of bicycle and pedestrian facilities (ISTEA, 1991). The Iowa Department of Transportation started bicycle facilities system planning efforts in response to increased facility usage and ISTEA requirements. Due to these requirements, there is an increasing need for an efficient and consistent method to identify alternative locations which would best suit a bicycle route. Many MPOs, COGs, cities, counties, and some Departments of Transportation (DOT), lack the time and resources to conduct in-depth bicycle planning studies. Planners, engineers, and decision makers can benefit from a tool that allows them to more efficiently manage the ever increasing amount of large data sets that are available for conducting analyses. Many data sets are too large to analyze with conventional methods. Utilizing a GIS in the planning process can also aid in the coordination of multi-jurisdictional planning efforts in regional areas.

Several guides exist to aid planners and decision makers when developing new bicycle facilities; however, an analytical process is yet to be integrated into a GIS environment for the same purpose. Many public agencies in Iowa currently use a GIS or desktop mapping system to varying degrees; however, based on experiences working with these agencies, the full potential of the GIS is not utilized. Particularly in the area of bicycle facility planning, the GIS is used as an inventory tool and for map making. The GIS should be able to utilize existing data, be flexible as to what criteria are used, provide visualization of alternatives, be affordable, be user friendly, low cost, and run on a desktop personal computer.

The Ames/Iowa State University Bicycle Committee is currently involved in an effort to update its *Bicycle Master Plan*. The committee has discussed incorporating into the plan a methodology for officials to follow when designating new bicycle route corridors. The methodology described in this paper was utilized in a case study of the Ames area to identify optimal bicycle facilities. For the purpose of this study, the term "optimal" is described as being the best or most desirable route based on link attributed and criteria weights obtained in a Delphi process.

Paper Organization/Methodology

We begin with the results of a literature review on bikeway planning. The literature review examines current and historical bicycle use in the United States, programs promoting the use of bicycles, current bicycle facility planning processes and guidelines, and physical elements that have an impact on route location. We also explore analytical processes that have been previously developed to evaluate the suitability of roadways for bicycle travel, determine the level of service a route will offer, and identify the level of stress a corridor may impose on a bicyclist based on the characteristics of the road. Following the literature review are sections detailing the steps used to accomplish the objectives of this study:

Step 1: Identification and Weighting of Criteria

To identify an optimal bicycle route, one first needs to identify criteria that are important to consider and then proceed with collecting data. A list of pertinent criteria can be generated by reviewing literature or conducting surveys. After the criteria are identified, their respective weights can then be obtained. There are many methods one can utilize to identify relative weights for each criterion, and for this study a Delphi process was performed.

Step 2: Route Optimization

The desktop mapping system chosen for this study has no built in routing capabilities. Therefore, an external routing code was written which is called from within the GIS. With this program, a user may identify optimal routes based on the sum of weighted link attributes.

Step 3: Analysis of User-defined Routes

In most planning cases, there are a limited number of feasible options for designating a bicycle facility corridor. In some instances bicyclists have desired routes of travel where they wish to have a bicycle facility constructed. In other situations, there may be barriers present that preclude or inhibit the development of a bicycle facility such as a lack of available right-of-way or public opposition.

An analysis of bikeway alternatives can be improved by including node and cross-street information in the assessment, which is possible when dealing with a smaller set of alternatives. This can be accomplished by including expert judgment in the process. In this case, the user has a limited number of user-defined routes to analyze. Links along user-defined routes can be selected together with intersections and cross street information. The weighted attributes associated with the links, nodes, and cross-streets are then summed to obtain a score for each route. The score of the alternatives can then be compared.

Step 4: Model Calibration and Validation

Before the model can be used in planning activities, the validity of the routes chosen by the model should be established. This is accomplished by showing the results of the model to bike planners and enthusiasts.

Step 5: Test Case: Ames, Iowa

In a case study, control origin and destination points are identified on existing bicycle routes. An optimal route analysis is conducted to identify alternative routes that may be suitable for bicycle facilities. A user-defined analysis is then conducted on the existing route. The scores are compared to determine how close the user defined route is to optimality. After the case study is conducted, a general analysis is performed to determine if the new methodology presents feasible alternative bicycle route locations. The new routes are evaluated to determine if they represent actual desired routes of travel for bicyclists.

LITERATURE REVIEW
Bicycle Facility Development Guides

AASHTO

Review of bicycle related literature indicates that increasing attention is being given to bicycle facility planning and design. AASHTO published its *Guide for the Development of Bicycle Facilities* in 1991. This document provides information on the development of new bicycle facilities. Provisions for bicycle travel are similar to and consistent with standard highway engineering practices. AASHTO states that this guide does not cover all aspects of developing safe bicycle routes and should be used in conjunction with other publications such as the Manual on Uniform Traffic Control Devices (MUTCD), and state and local facility construction specifications. (AASHTO, 1991).

Iowa DOT

The Iowa Department of Transportation published *The Bicycle Facilities Network Identification Handbook* in 1995. The purpose of this handbook is to provide a general set of guidelines that can be used by MPOs and other regional governments to identify a recommended bicycle facilities network. It is organized to assist planners, technicians and decision makers, who may have varying amounts of exposure to bicycle and pedestrian facilities planning, with the network identification process (Iowa DOT, 1995).

Legislation Affecting Bicycles

ISTEA

The US has undergone a period of change regarding the recognition of bicycling and walking as modes of transportation. ISTEA-91 recognizes the importance of bicycling and has several provisions that directly relate to bicycle and pedestrian systems. The legislation offers many opportunities for the development of bicycle facilities with federal funding. States and MPOs are required to develop bicycle and pedestrian elements which must be incorporated into respective transportation plans (ISTEA, 1991).

Additional Legislation

The US Congress (Appropriations Act of 1991) directed the Secretary of Transportation to conduct a National Bicycle Study. This study resulted in a final report and 24 case study reports that focused on expanding the options for personal transportation, particularly making the changes needed in the transportation system to encourage more use of human-powered travel modes. The Clean Air Act Amendments also recognize bicycling improvements as approved transportation control measures (Zegeer, 1994).

Bicycle Facility Analysis Methods

Several attempts have been made to develop analytical tools for bicycle facility planning, yet no one identified has attempted to couple these tools with the spatial and analytical power of a GIS. Since the middle 1960's, traffic engineers and planners have used level of service (LOS) measurement to evaluate the operation of traffic corridors. LOS standards have more recently been developed for evaluating roads for bicycle travel. Epperson, 1994 expanded upon a previous attempt to develop a measurement of the operational condition of roadways for cycling. The methodology is based on the "Davis Bicycle Safety Index Rating" (Davis, 1987). The "Davis Index" sought to develop a mathematical model for indexing bicycle safety to physical roadway features and other pertinent criteria with a final goal of the ability to predict major bicycling accidents. This model evaluated roadway segments and major intersections separately. Inputs to Davis' equation consisted of location criteria such as topography, lane width, and land use. Also included were pavement criteria, such as cracking, weathering, and potholes. A separate intersection evaluation consisted of inputs such as, actuated signals, clearance intervals, and number of lanes. (Davis, 1987). Epperson identified shortcomings with the "Davis Index" and developed a modified version which operated and expanded on the same principles (Epperson, 1994).

In an attempt to develop a LOS based operational condition measurement, Dixon focused on the development of a methodology that measures bicycle and pedestrian facility performance based on LOS measures (Dixon, 1995). This LOS performance measure employs a point system on a scale of one to 21, resulting in a LOS rating system of "A" through "F" to evaluate roadway corridors for bicycle use. Segment scores are weighted and summed to achieve a corridor LOS rating. The LOS ratings describe the level of interaction that a bicyclist may anticipate with motor vehicles. (Dixon, 1995).

A similar LOS measure methodology was developed which is specific to separated bicycle paths and does not deal with the mixing of bicycles and motorized vehicles. Hein Botma, 1995, focuses more on the methods used and less on the results obtained. He also states that "the results presented are based on first guesses of parameters and should be seen as an illustration of how the method can be worked out." In the Dutch manual on bicycle infrastructure, a measure of quality of facility operation was developed that measures the hindrance that path users experience due to their interactions or maneuvers. Botma simplifies the process to measuring the frequency of passing and meeting maneuvers on a two way bicycle facility. This approach is then extended to traffic operation on separate narrow paths used by pedestrians and bicyclists. Using this method the LOS can be determined separately for pedestrians, bicyclists, and the average user of

the path. The results obtained can then be used to determine requirements for path width and criteria for separation of bicycles and pedestrians (Botma, 1995).

Similar to the hindrance concept used by Botma, Sorton, discusses the development of a methodology for recording and analyzing key criteria affecting bicycle use(Sorton, 1994). Sorton's methodology focused on five differing levels of stress a bicyclist experiences when riding in differing traffic conditions. Stress level one indicates that the streets are reasonably safe for all type of bicyclists. On the other extreme, stress level five indicates the street may not be suitable for bicycle use. The variables that aid in determining the stress level consist of traffic speed, outside lane width, and traffic volume (Sorton, 1994).

It is argued by some that there is insufficient attention paid to quantitative modeling of bicycles. Katz, 1995, reported on the need for quantitative modeling of bicycle demand and reviews the techniques available for incorporating bicycles into existing transportation planning models. Katz states that traditional modeling techniques, and even more recent strategic modeling techniques that have evolved, have not been effective in modeling modes such as bicycling. He also states that the time is now right to pursue various modeling techniques in new areas such as IVHS and GIS (Katz, 1995).

Landis, 1996, suggests there is an increasing amount of pressure on transportation planners to use quantitative analysis for prioritizing projects within Transportation, Capital and Long Range Transportation Improvement Plans. Landis created two analytical tools to help planners to quantitatively evaluate, test, and prioritize on-street bicycle facilities. These tools incorporate a performance measure and a supply and demand measure for evaluating transportation facilities. The Interaction Hazard Score (IHS) model provides a measure of a bicyclists' perceived hazard of bicycle/motor vehicle interaction. The results are often translated into a LOS category for bicycle planning.

The Latent Demand Score (LDS) model provides an estimate of latent bicycle travel demand, a measure of the relative amount of bicycle travel that would occur on a road segment if there were no bicycle travel inhibitions caused by motor vehicle traffic. This technique incorporates a simple probabilistic gravity model to quantify the proximity and scale of bicycle trip productions and attractions. The model attempts to identify roads that should be candidates for bicycle facilities (Landis, 1996).

IDENTIFICATION OF BICYCLE ROUTE CRITERIA
Introduction

When attempting to identify an optimal bicycle route, several factors (such as topography, traffic congestion, and lane widths) should be considered. Similarly, when evaluating an existing bicycle facility and its location, the same factors will help to indicate how desirable the facility may be to bicyclists. The first part of this section focuses on identifying the various factors that have an impact on bicycle facility location. The second part of this section utilizes a multi-objective decision making method to establish weights for each of the factors relative to their importance. In a later section, these weights are utilized, in a case study, to aid in the identification of optimal bicycle routes within the city of Ames, Iowa.

Factors Influencing Mode Choice

Many factors influence a persons decision to choose the bicycle mode for a particular trip. This decision process identifies important areas that should be addressed when planning for new bicycle facilities. Most often, distance and time are given as reasons people do not choose to bicycle or walk for utilitarian trips. Nationwide Personal Transportation Survey (NPTS) study results show the average length of all travel trips is nine miles (Zegeer, 1994). Average work trips tend to be slightly longer, while shopping and other utilitarian trips are generally shorter. Individual attitudes play a major role in the decision to bicycle or walk. People may choose not to bicycle or walk because it is not popular, or that these activities are perceived as socially inappropriate for those who can afford personal motorized transportation. Other people have different perspectives, viewing bicycling as beneficial to the environment, healthful, economical, and requiring less exposure to traffic.

Trip Barriers

Bicycle Safety

One of the most frequently stated reasons for not bicycling or walking is the fear of not being safe in traffic (Zegeer, 1994). Even a community planned with excellent bicycle facilities can have problems with safety. Narrow travel lanes, high congestion, high vehicle speeds, lack of bicycle facilities, and high concentration of vehicle emissions cause many people who would otherwise bicycle to choose another mode because the safety risk is too great.

Facility Access

Access and connectivity can be another form of impedance to persons choosing to bicycle. A well designed and engineered bicycle facility is useless to the bicyclist who cannot access the facility or who cannot continue from one neighborhood to another on the same route. In the same way, facilities that do not connect neighborhoods to shopping centers or central business districts may never achieve their purpose of increasing the use of non-motorized modes of transportation. Direct routes are major considerations when making a decision to bicycle or drive.

Connectivity

Many cities and counties have taken a proactive role in constructing bicycle facilities within their local jurisdictions. Because most of the facilities have in the past been planned and constructed independently, often there is no connectivity between facilities. Facility connectivity is a major component to consider when developing an effective transportation system. Most facilities currently in place do not serve a utilitarian purpose because they do not link traffic generators together. They are typically constructed for recreation purposes. The current challenge to transportation officials is to integrate existing facilities into a continuous utilitarian based system and to include multimodal access facilities (Iowa DOT, 1995). An example showing a lack in connectivity between bicycle routes is illustrated in Figure 1. Several
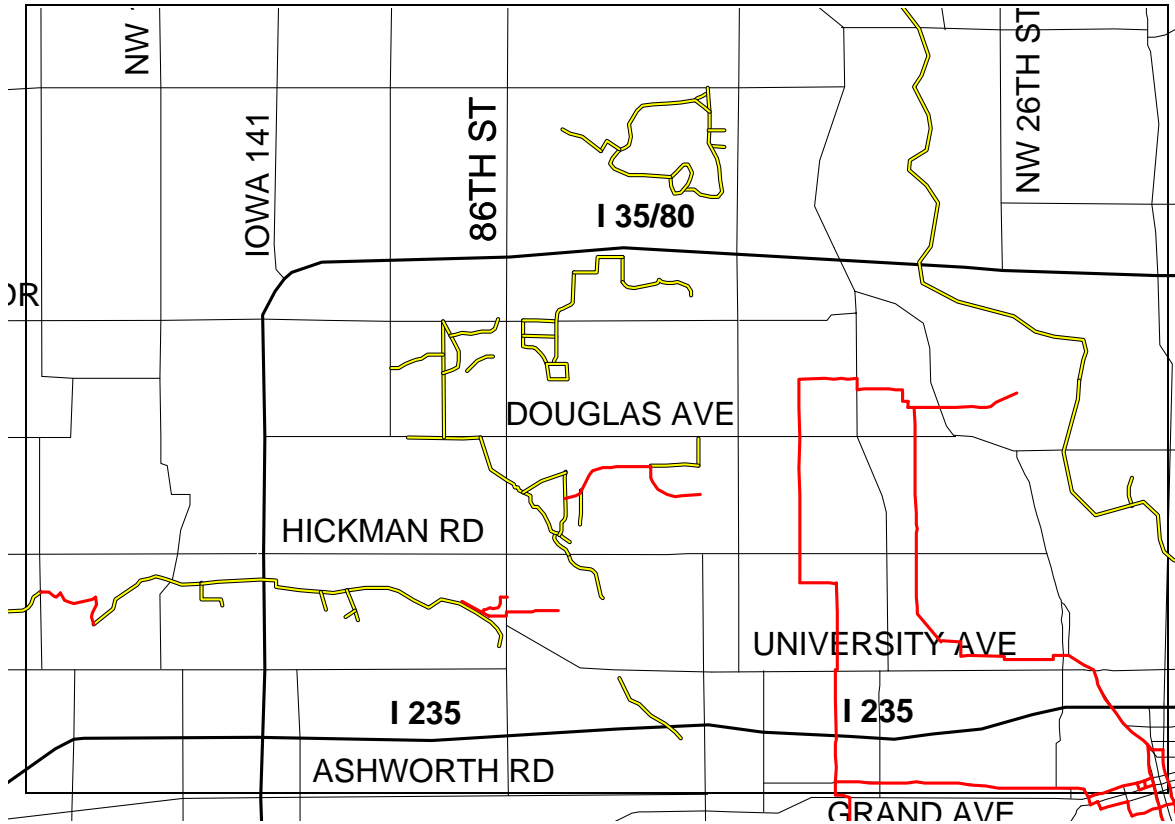
Figure 1: Lack of Bicycle Route Connectivity

independent facilities were constructed within the same general area, however they were not connected, thus decreasing the effectiveness as a transportation facility.

Destination Barriers

Facility needs and infrastructure do not stop when arriving at work or other destinations. Many people are discouraged from commuting by bicycle because once they arrive at their destination they have no place to safely park their bicycle or to shower if needed (Zegeer, 1994). There is a need for secure parking facilities to protect bicycles from the weather and from theft or vandalism. A survey conducted in Baltimore, Maryland, reported that 25 percent of the sample had experienced a bicycle theft, causing 5 percent of the sample to give up bicycling. In large cities where bicycling is a popular mode of transportation such as New York City, theft rates are extremely high each year. For many commuters to consider bicycling as a mode of transportation, secure facilities for parking are needed.

Bicycling Stress Levels

Bicyclists often choose routes that require the least amount of physical effort. They tend to choose routes which are flat and offer the least amount of stopping. Bicyclists also tend to choose routes which avoid high volumes of traffic traveling at high rates of speed. Traveling in

hazardous environments causes mental and physical stress. Sorton, 1994 has defined stress levels for bicyclists' ranging from 1 to 5. A stress level of 1 (very low) suggests that traffic conditions are appropriate for all levels of bicyclists (not applicable to children under age 10). A stress level of 2 (low) indicates that traffic conditions are appropriate for casual and experienced riders and only under certain conditions for youth bicyclists. A stress level of 3 (moderate) indicates traffic conditions are appropriate for experienced riders and only under certain conditions for casual riders. These traffic conditions are not appropriate for youth riders. A stress level of 4 (high) indicates traffic conditions are favorable for experienced bicyclists only under certain conditions and not favorable for casual or youth riders. A stress level of 5 (very high) indicates that traffic conditions are not favorable for any bicyclist under any conditions (See Figure 2, Sorton, 1994). Typical improvements which can make conditions favorable for lesser experienced bicyclists may consist of street widening to include wide curb lanes, paving of shoulders, and separate bike lanes.

Criteria Identification

One of the more important challenges to planners or engineers when developing new bicycle facilities is the identification of factors that should define route location. There are several methods that can be used to identify the factors such as literature reviews and surveys. For this study, a Delphi process was utilized over the internet to identify these criteria.

The Delphi Approach

Utilizing groups of experts as consultants when problem solving or brainstorming for criteria can prove to be very beneficial; however, there can also be many disadvantages. A committee of experts can bring together a wide variety of information and can often agree on decisions, although the agreements may be the result of strong social pressure to conform to the majority's viewpoints. Many times decisions are made based on the number of pros or cons for a position and not their validity. Those who are more vocal or have a dominant personality or have ulterior motives may also have a large influence on decisions. The Delphi technique has three distinct features that distinguish it from other committee methods. First is the element of anonymity, the second consists of iteration with controlled feedback, and the third is a statistical response.

During a Delphi procedure the expert committee members remain anonymous and their interaction is handled using surveys or questionnaires. This is done to avoid the possibility of identifying an opinion with a specific person and also enables an individual to change their position on an issue without publicly admitting it and therefore possibly loosing integrity. Any ideas can now be considered on their merits, no matter what stature the originator is held in by other members of the expert committee.

Committee interaction is controlled through responses to surveys or questionnaires. The administrator of the Delphi process extracts from the surveys or questionnaires only information that is relevant to the issue and presents them to the expert committee. Each individual member of the expert committee is informed only of the opinion of the committee as a whole and the arguments for and against each point of view. The committee members are not subjected to repetitive discussion of the same argument. All members can present their point of view to the
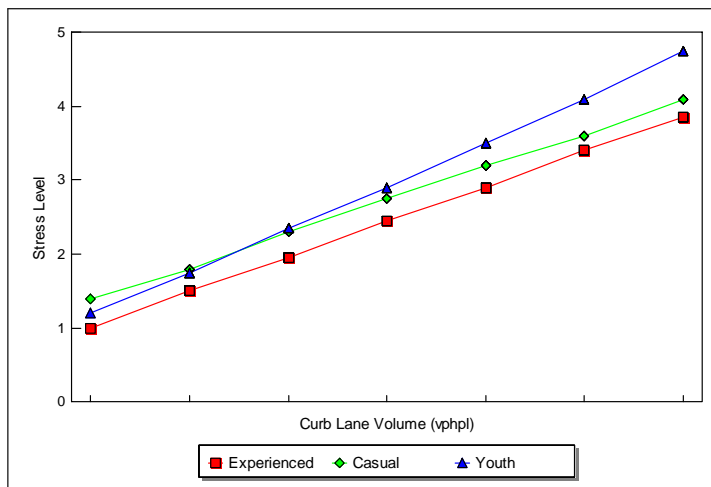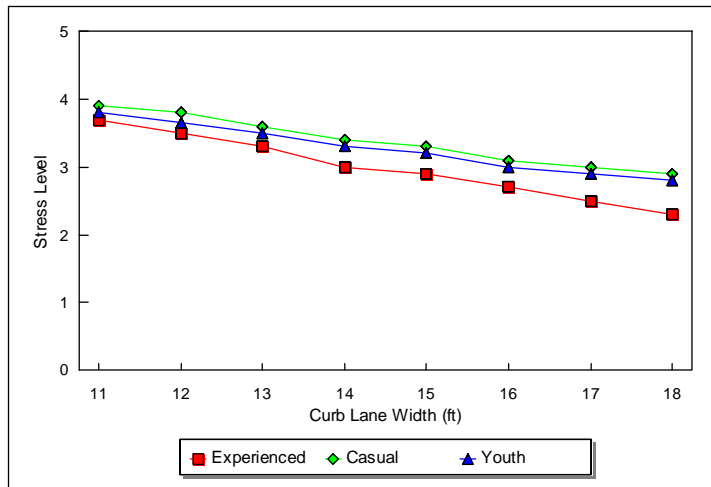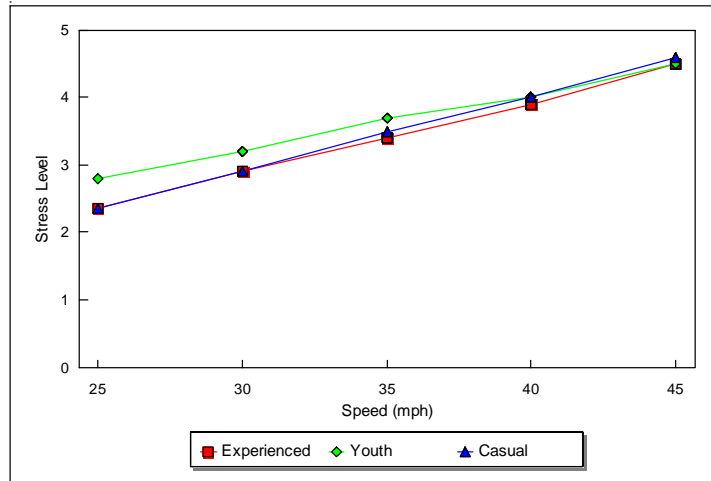
Figure 2: Stress Levels as a Function of Routing Criteria

committee, but not in such a way to allow an overwhelming influence due to repetition. The main effect the controlled feedback has is preventing the expert committee from making goals and objectives on their own. The committee can concentrate on the original purpose without being distracted by self-serving goals.

Typically, an expert committee will produce an outcome that is representative of the majority. There could be a minority report if the remainder of the expert committee felt strongly about the issue. However, it is unlikely there will be any indication of a difference of opinions that may be present within the committee. The advantage of utilizing a Delphi process is that a statistical response will be presented which includes everyone's opinions. For example, a single question's response is presented in terms of either a median and two quartiles or a mean and a standard deviation. This allows each opinion within the committee to be included in the median or mean, and the spread of responses is illustrated by the size of the inter-quartile range (IQR) or standard deviations.

Utilizing the Internet

Normally, the Delphi process involves gathering a panel of experts together in a workshop type of atmosphere and usually lasts for a day and on occasion more. For the purpose of this study, we utilized the internet and electronic mail to conduct a Delphi analysis. There are several news groups available on the internet that discuss transportation topics. The population selected consisted of subscribers to news groups that focused on bicycles as an alternative form of non-motorized transportation. When a message is sent to the news group it is forwarded to hundreds and often thousands of subscribers. They in turn have the choice to respond and everyone retains their anonymity. Responses to the surveys posted to the news group were on a volunteer basis. A total of nineteen people responded to the survey and returned information.

The Delphi Sequence of Events

Round One

When conducting a Delphi analysis, each submission of a survey or questionnaire is referred to as a "round." The survey or questionnaire not only asks questions but also provides information to the expert committee on the degree of consensus, and the arguments presented by committee members. For the purpose of this study, the expert committee members will be referred to as "panelists" and the person conducting the analysis will be the "administrator." A total of four rounds were conducted.

For round one, a questionnaire was developed to identify criteria that should be considered when planning for new bicycle facilities. The panelists are given background information on the objective of the study along with a list of example criteria such as traffic congestion, outside lane widths, and surface type. The panelists were then asked to add any criteria they feel is appropriate to consider when planning new bicycle facilities. The responses obtained from the panelists are very similar to the criteria that were identified in literature reviews and consisted of criteria such as topography, traffic volume, surface type, and traffic speed. A complete list of criteria are shown in Table 1.

Table 1: Delphi Round 2 Results

Panelist

Criteria Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Mean	Std. Dev.	LQ	Median	UQ	IQR
Hilly Terrain/Rolling	5	2	4	2	2	1.5	1	2	0.5	1	1	0	0	1	1	0	0.5	0	1	1.34	1.29	0.5	1	2	1.5
Mountainous	1	3	6	4	4	2.5	2	4	0.5	6	2	0	0.5	2	3	0	1	0	1	2.24	1.85	0.75	2	3.5	2.75
High Cross Street Traffic	7	3	3	2	2	3	1	2	0	1	1	0	0.5	2	9	1	1	1.5	2	2.21	2.2	1	2	2.5	1.5
Frequent Unsignalized	5	2	2	1	1	0.5	1	1	0	0	0	0	0	1	8	0	0	1.5	1	1.32	1.95	0	1	1.25	1.25
Frequent Signalized	5	2	2	1	1	0.5	1	1	0	1	1	0	0	1	8	1	2	1.5	1	1.58	1.85	1	1	1.75	0.75
Frequent Stop Signs	5	2	2	1	1	0.5	1	1	0	1	0	0	0.5	2	6	0.5	0	1.5	1	1.37	1.56	0.5	1	1.75	1.25
Industrial	7	0	0	1	0	0	0	1	0	2	2	0	0	1	4	0.5	1	0	0.5	1.05	1.72	0	0.5	1	1
Rough Pavement	0	0	0.5	0	0.5	0	1	0.5	0	1	0	2	0	0	3	1	0.5	2	0.5	0.66	0.83	0	0.5	1	1
Crushed rock/limestone	1	2	1	0.5	1	0.5	2	1	0	1	0	2	1	1	4	1	1	0	1	1.11	0.9	0.75	1	1	0.25
Loose gravel	3	3	2	1	2	1	3	2	0	1	0	2	1	1	5	2	3	2	2	1.89	1.17	1	2	2.5	1.5
Moderate	7	0	2	2	1.5	3	1	2	0	0	2	0	0	2	4	1	2	0	1	1.61	1.69	0	1.5	2	2
High > 35 mph	6	2	1	1	1.5	3	2	2	0	1	2	0	0.5	1	5	3	3	1	0	1.84	1.57	1	1.5	2.5	1.5
On-street parking	6	2	1	2	1.5	0.5	0	1	0	1	1	0.25	0	0	8	1	1	0	1	1.43	2.03	0.13	1	1.25	1.13
Many heavy vehicles	4	0	2	2	1	1	2	1	0	2	1	0	0	3	6	2	0.5	1.5	2	1.63	1.47	0.75	1.5	2	1.25
Narrow Lanes	4	2	1	1	1.5	2	1	0	0	2	1	0	0.5	0	5	2	1	1.5	2	1.45	1.28	0.75	1	2	1.25

Delphi Round 3 Results

Criteria Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Mean	Std. Dev.	LQ	Median	UQ	IQR
Hilly Terrain/Rolling	5	2	4	2	2	1.5	1	2	0.5	1	1	0	0	1	1	0	0.5	0	1	1.34	1.29	0.5	1	2	1.5
Mountainous	1	3	6	4	4	2	2	4	0.5	5	2	0	0.5	2	3	0	1	0	1	2.16	1.75	0.75	2	3.5	2.75
High Cross Street Traffic	5	3	3	2	2	3	1	2	0	1	1	0	0.5	2	7	1	1	1.5	2	2	1.66	1	2	2.5	1.5
Frequent Unsignalized	5	2	2	1	1	0.5	1	1	0	0	0	0	0	1	6	0	0	1.5	1	1.21	1.62	0	1	1.25	1.25
Frequent Signalized	5	2	2	1	1	0.5	1	1	0	1	1	0	0	1	6	1	2	1.5	1	1.47	1.51	1	1	1.75	0.75
Frequent Stop Signs	5	2	2	1	1	0.5	1	1	0	1	0	0	0.5	2	6	0.5	0	1.5	1	1.37	1.56	0.5	1	1.75	1.25
Industrial L	7	0	0	1	0	0	0	1	0	2	2	0	0	1	4	0.5	1	0	0.5	1.05	1.72	0	0.5	1	1
Rough Pavement	0	0	0.5	1	0.5	0	1	0.5	0	1	0	2	0	0	3	1	0.5	2	0.5	0.71	0.82	0	0.5	1	1
Crushed rock/limestone	1	2	1	0.5	1	0.5	2	1	0	1	0	2	1	1	4	1	1	0	1	1.11	0.9	0.75	1	1	0.25
Loose gravel	3	3	2	1	2	1	3	2	0	1	0	2	1	1	5	2	3	2	2	1.89	1.17	1	2	2.5	1.5
Moderate	7	0	2	2	1.5	3	1	2	0	0	2	0	0	2	4	1	2	0	1	1.61	1.69	0	1.5	2	2
High > 35 mph	6	2	1	1	1.5	3	2	2	0	1	2	0	0.5	1	5	3	3	1	0	1.84	1.57	1	1.5	2.5	1.5
On-street parking	6	2	1	2	1.5	0.5	0	1	0	1	1	0.25	0	0	7	1	1	0	1	1.38	1.87	0.13	1	1.25	1.13
Many heavy vehicles	3	0	2	2	1	1	2	1	0	2	1	0	0	3	5	2	0.5	1.5	2	1.53	1.24	0.75	1.5	2	1.25
Narrow Lanes	4	2	1	1	1.5	2	1	0	0	2	1	0	0.5	0	5	2	1	1.5	2	1.45	1.28	0.75	1	2	1.25

Round Two

        After the criteria to be included in the analysis were identified, a new questionnaire was drafted to determine the relative weights for each of the criterion. The panelists were asked to give a penalty (in miles) to an otherwise "perfect" 5 mile route that exhibits each characteristic. For example, a respondent may give a 3 mile penalty to a "mountainous" but otherwise perfect route, resulting in a score of 8 "equivalent" miles. Or, in other words, the 5 mile mountainous route is equivalent to an 8 mile flat route, in the opinion of the respondent. Thus, all penalties are in miles. The panelists were then requested to submit their weights for each criterion and supply statements or arguments supporting their choice, that is, why the weights should not be higher or lower. The results of round two, as illustrated in Table 1, show the initial responses to the round two questionnaire. The responses from panelists in this round were very similar. Although there was a high degree of consensus among panelists early on in the analysis, another Delphi round was conducted to determine if a higher degree of consensus among panelists could be reached. After the panelists returned their weights to the administrator, the data were compiled and a statistical summary of the weights was prepared. The statistical summary is comprised of the median weight and the upper and lower quartiles as well as the mean and standard deviation.

        Round Two Statistical Summary   The difference between the mean and median for approximately half of the criteria is less than 0.25 miles per 5 mile trip, the exceptions being mountainous terrain, frequent signalized intersections, land use, on-street parking, frequent stop signs and outside lane widths. The mean and median for each of these criteria has a difference exceeding 0.25. This suggests there may be significant outliers present in the data. The *frequent high cross street traffic* criterion has the highest standard deviation at 2.01 with the *mountainous terrain* criterion a close second with a standard deviation of 1.91. The goal for conducting the next Delphi round is to attempt to reduce the deviation from the mean and eliminate the extreme outliers. The statistical summary of round two is also illustrated in Table 1.

Round Three

        The panelists were presented with the criteria, their relative weights from the previous round, a statistical description of panelists' estimates, and summaries of arguments. The panelists were then asked to set a new estimate of the weights after reviewing the statistical summary and the comments presented. If their estimates fell outside the IQR from the previous round they were asked to give reasons to justify their views and to comment upon those in the opposite extreme. When the panelists' revised weight estimates were returned to the administrator, the same statistical work was done as in the previous round. If a general consensus was not reached, another round would have been needed. Otherwise the administrator can use each median weight for the model.

        Round Three Statistical Summary   The results of round three, also shown in Table 1, show the expected response in a Delphi analysis: the mean is now closer to the median in the categories of mountainous terrain, cross-street traffic, signalized and un-signalized intersections, on-street parking, and heavy vehicles. This is partly illustrated by the lower standard deviation; however, the IQR for all categories remained the same. This indicates that the outlier data in the previous round remains an outlier but at a lesser extreme. Panelist 15, who has unusually large

scores in the previous round, lowered his or her scores in five different areas. The scores were only lowered slightly, which accounts for the IQR remaining the same. In total, only four panelists adjusted their scores.   (See Table 1.)

Round Four

Round four was conducted in the same manner as the previous rounds. The response rate dropped from 100 percent (19 responses) in rounds one through three to 42 percent (8 responses) in round four. Each panelist that responded to the round four questionnaire did not make any changes to their previous responses and did not supply any arguments. The assumption was made that each panelist who did not respond did not wish to make any changes and a high degree of consensus was obtained. Therefore, no statistical analysis was needed and no further rounds were required.

Delphi Conclusions

The Delphi analysis was successful in producing the expected responses from the panelists. The overall goal of the Delphi analysis was to obtain information on how the criteria should be weighted relative to each other. The goal was not to identify exact values, only ballpark weights were sought because the model weights were altered in the calibration process.

Round one, coupled with a literature review, provided a complete list of physical criteria to be used in the bicycle route location and evaluation processes. Round two of the Delphi process was successful in providing relative weights for the criteria. Each panelist that responded submitted their weights and some added comments supporting their choice. A total of nineteen people responded to the round two questionnaire. Round three was moderately successful in that four of the nineteen panelists responded with new weights that more closely matched the median value from the previous round. In round three, the IQR remained unchanged and the standard deviations were reduced only slightly. Results from round four were less complete in that only eight of the original nineteen people responded. Also, the panelists who elected to respond in round four did not wish to make any changes from the previous round, therefore, another round was not warranted. The mean value was then utilized as the relative weight for each criterion. The criteria are listed below in order of importance based on the median weights (number one being most important):

1.	Mountainous Topography	(2.16)
2.	Frequent High Cross Street Traffic	(2.00)
3.	Loose Gravel Surface	(1.89)
4.	Traffic Speed > 35 mph	(1.84)
5.	Moderate Traffic Congestion	(1.61)
	Presence of Heavy Vehicles	(1.53)
6.	Frequent Signalized Intersections	(1.47)
	Narrow Outside Lane Widths	(1.45)
7.	On-street Parking Allowed	(1.38)
8.	Frequent Stop Signs	(1.37)
9.	Hilly or Rolling Topography	(1.34)

10. Frequent Unsignalized Intersections   (1.21)
11. Crushed Rock/limestone Surface   (1.11)
12. Distance   (1.00)
13. Industrial Land Use   (1.05)
14. Rough Pavement Surface   (0.71)

The experience gained with using a Delphi method via the internet has proven to be slightly less than expected, although anonymity was maintained at the highest level and the feedback was easily controlled. This was possibly due to the inability to hold the interest of all responding panelists when conducting more than two or three rounds. The other alternative is that a high degree of consensus among respondents was obtained much quicker than expected. After the third round, the majority of the panelists did not continue to respond. It is possible that if the panelists were gathered together as a committee, interest would be maintained longer and more results would be obtained.

After the initial weights were obtained they were input into an equation that calculates optimal routes. After the weights were input, the validity of the model was checked by running a test of the program to determine its accuracy in identifying an optimal bicycle route. If the validation process revealed that the model needed calibration, the weights would have been adjusted and the link scores would have been recalculated. Utilizing the display capabilities of a GIS aided in the process of determining if the model needed calibration and identifying the criteria that needed to be re-calibrated. The next step consisted of calibrating all the criteria weights so they produced an output that represented a route a bicyclist would likely choose.

DEVELOPMENT OF THE GIS

The next step after using the Delphi process to determine bicycle route criteria and their weights, was to use that information to identify optimal bicycle routes in a network. To facilitate this process, this section presents two GIS based route identification tools. The first of these analytical tools identified the optimal route within a network and sums link scores together to obtain an overall route score. The route score is the sum of link penalties (in equivalent miles) for an entire route. The other tool allows a user to select an alternative to the optimal route and compare its calculated score to that of the optimal route score.

Geographic Information Systems

GISs are becoming increasingly popular in transportation. The requirements set forth by the Intermodal Surface Transportation Efficiency Act, such as requiring States and MPOs to develop bicycle and pedestrian elements "which must be incorporated into the transportation plan" for the State or MPO, increase the need for analytical applications for determining where bicycle facilities should be located. When developing a new bicycle route network or expanding on existing facilities, planners, engineers, and decision makers can benefit from a tool that allows them to more efficiently manage large data sets and visualize the data spatially. Transportation agencies have historically been among the first to identify and utilize innovative computer technology (Loukes, 1991). State Departments of Transportation have usually taken the primary

role in the implementation of statewide GIS efforts (Vonderohe, 1993). However, the application of a GIS to bicycle facility planning is a relatively new concept.

Desktop Mapping GIS

Some GIS packages are "desktop mapping" systems that are designed to run on personal computers. MapInfo (MapInfo Corporation, Troy, New York) is one such package. Although MapInfo is somewhat limited in respect to topological functions, it remains a very powerful and affordable desktop GIS. GISs have recently been acquired by Iowa public transportation agencies. Most utilize affordable desktop (PC) mapping systems such as MapInfo (informal phone survey). In addition, many smaller agencies are currently in the process of conducting formal or informal feasibility studies on GIS implementation.

One of the main objectives of our study was to develop computer based analytical tools for planners, engineers, and decision makers to aid them in planning bicycle facilities. Much of this planning takes place at the local level. These organizations have chosen desktop mapping GIS software due to cost and learning curve considerations. MapInfo, a popular desktop mapping GIS among public agencies in Iowa, was chosen as the software development platform. A limitation of MapInfo is its lack of network analysis tools such as computing shortest routes or modeling traffic flow. In this study, the routing problem was overcome quickly by developing an external FORTRAN program (still on the PC) which computes the shortest route (lowest score path). MapBasic is used to transfer the results from the FORTRAN program into the MapInfo environment. Although MapInfo is limited by not having the ability to build topology, MapInfo has a limited ability to select objects on the basis of their spatial relationship to other objects by using special geographic operators.

Developing a Base Street Network

TIGER Line Files

TIGER line files were used as the basis for the routing network in this study. The TIGER files were downloaded from the Iowa State GIS Support Facility in ArcInfo format. The ArcInfo files were then converted into MapInfo format using the ArcLink MapBasic program. Many of the links in the TIGER line file for the Ames street network were combined to reduce the number of links in the network. After the network links were modified, a node was placed at the endpoints for each link to represent intersections. Figure 3 illustrates a TIGER line file that was translated from ArcInfo into MapInfo and the resulting Ames link/node network.

Data Processing

In this section, the inputs for this analysis are specified. The method allows use of any combination of criteria appropriate for data analysis. Criteria utilized by the analytical tools were identified from a panel of experts in a Delphi analysis.
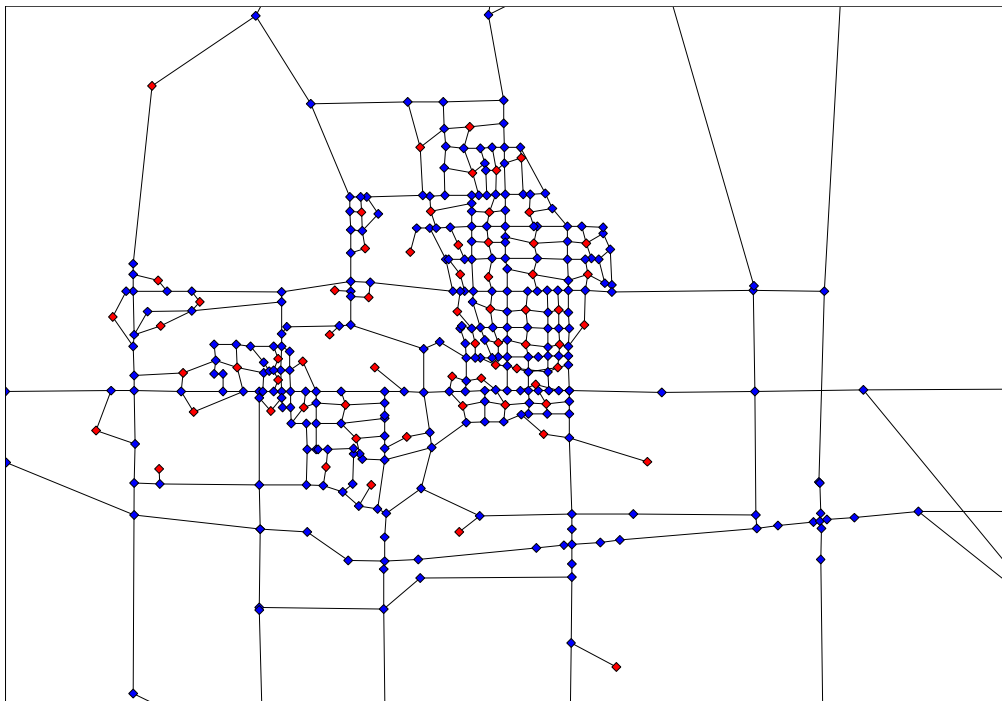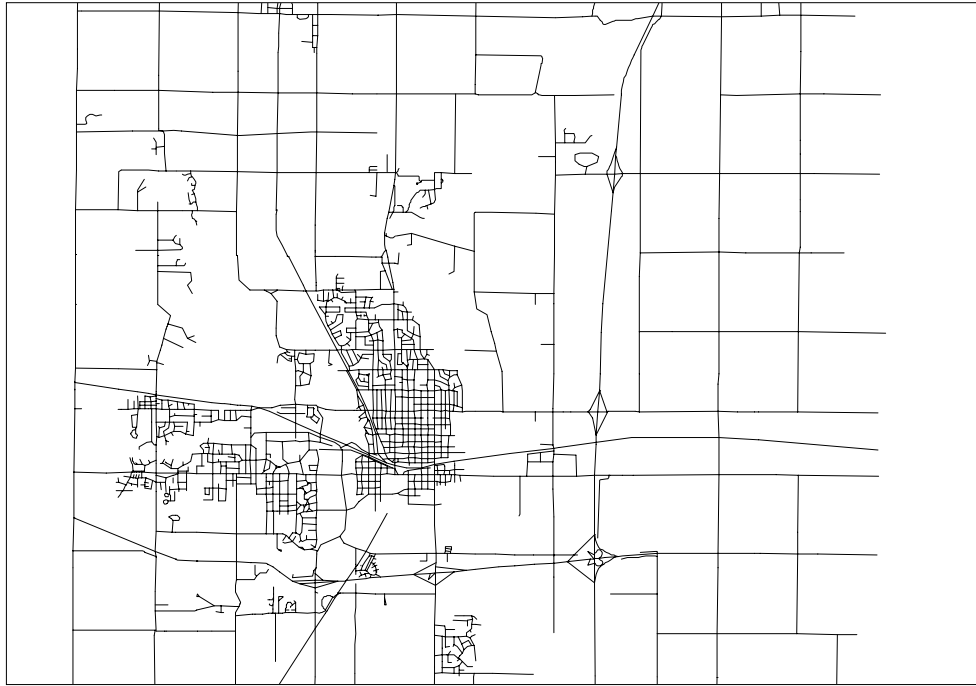
Figure 3: TIGER and MapInfo Link-Node Files

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Populating the Links with Data

Attribute data for the street network were obtained from various sources. Some of the data were obtained from the city of Ames. These include traffic volumes, capacity, intersection signalization, and posted traffic speed. Other data such as topography, land use, on-street parking, heavy vehicles, and surface type were obtained from city maps and windshield surveys. Derived data were calculated by MapInfo. These include link lengths and volume to capacity ratios. Each layer has a database table with attributes for each graphical element. New fields were added to the link table to represent each criterion identified in the Delphi process. Then, links in the street network with attributes such as mountainous topography or high traffic speed were assigned the appropriate penalty weight in the appropriate field.

Queries

Many GIS developers have integrated Structured Query Language (SQL) into their GIS software packages (Antenucci, 1991). Data can be grouped together into a selection by formulating questions or queries. Such a query may select all links within a network with a speed greater than 40 miles per hour. The results of the query are stored in temporary tables called *query tables*. The SQL command allows a user to formulate complex queries. Data records selected from previous queries have the same items as the base tables. Using the SQL command allows the user to select from multiple tables and also from existing query tables. With the SQL command a user can create query tables containing information that was only implicit in the base table(s) (MapInfo, 1994). When a query has retrieved a list of all links matching the query parameters, other fields in the table can be updated by multiplying by the appropriate penalty weight.

Penalty Assignment for the Ames Network

In this section, each set of criteria are assigned penalties. The penalties are then used to calculate link scores for the Ames case study.

1. Topography: A windshield survey was conducted to determine areas of hilly or mountainous terrain. Links having these characteristics were manually selected in MapInfo and penalties were assigned to the selected links.

2. Cross Street Traffic: The v/c ratio was calculated for each link in the street network utilizing data obtained from the city of Ames Traffic Engineering office. These data were saved in a new field within the MapInfo table. All links having a v/c of 0.3 or greater were selected and assigned the appropriate penalty. It should be noted that traffic volumes will be similar in both directions for a 24 hour model but may differ dramatically for a peak hour model.

3. Intersection Signalization: Traffic signal locations were identified from a windshield survey and plotted on a map layer in MapInfo. However, due to the wide disbursement of traffic signals, no penalties were assigned.

4. Stop Sign Frequency: Stop sign locations should be identified and plotted on a map layer in MapInfo. A corridor with a high frequency of stop signs should be penalized because bicyclists generally do not favor stopping frequently.

5. Land Use: Areas of industrial land uses were identified utilizing a land use coverage in MapInfo. A query was done selecting all links intersecting the industrial land use polygons. Each of these links were penalized accordingly based on survey results.

6. Surface Type: A windshield survey was conducted to identify roads or sections of roads that were comprised of a lane or shoulder with gravel, crushed rock, or rough pavement. These links were manually selected in MapInfo and penalized accordingly based on survey results.

7. Traffic Congestion: The volume to capacity ratio was calculated for each link in the street network utilizing data obtained from the city of Ames Traffic Engineering office. These data were saved in a new field within the MapInfo table. All links having a v/c ratio of 0.3 or greater were selected and assigned the appropriate penalty. It should be noted that traffic volumes will be similar in both directions for a 24 hour model but may differ dramatically for a peak hour model.

8. Traffic Speed: All links with a speed of 35 mph or greater were selected using a GIS query. These links were then penalized accordingly based on survey results.

9. On-Street Parking: A windshield survey was conducted to identify links where on-street parking was allowed. These links were manually selected in MapInfo and penalized accordingly based on survey results.

10. Heavy Vehicles: All links were surveyed to determine if they had higher than normal heavy truck traffic. Those that did were assigned the penalized accordingly based on survey results.

11. Outside Lane Widths: All links having outside lane widths of 12 feet or less were penalized accordingly based on survey results.

Development of Analytical Tools

Optimal Route

This section presents the process used to develop the optimal route planning tool. This tool works on the basis of a simple shortest path algorithm which minimizes the sum of link scores. MapBasic was utilized to convert differing data formats of FORTRAN and MapInfo during the process. A series of programs was utilized (available from the authors), as discussed in the following sections:

S-export

Programs and Processes: The node and link information associated with the network is exported into a text file format by using the MapBasic program *"s-export.mbx"*. The program *"s-export.mbx"* needs to be run only once unless changes are made to the node or link files. The file format of the node and link information is altered to enable the FORTRAN program to read it.

1st-path

After the network is exported into text format, two nodes were selected (in MapInfo) to be connected by the bicycle route. After the nodes were selected the MapBasic program *"1st-path.mbx"* is run to export the selected node information into text format.

S-path

The next step is to run the FORTRAN program "*s-path.for*". The program, which must be run from the DOS prompt, calculated the lowest score route between the selected nodes.

Showpath

The final step was to run the MapBasic program "*showpath.mbx*" which registered the output from the FORTRAN program into the GIS. The lowest score route was then illustrated on the map along with the cumulative route score (in equivalent miles). At this point the lowest score route between other nodes can be calculated. The same process and programs were used as before except the "*showpath.mbx"* program was replaced with the "*showmore.mbx"* program. The "*showmore.mbx*" program enabled MapInfo to show more than one optimal path at once.

User-defined Route

When planning for new bicycle facilities it may be desirable to analyze alternatives to the optimal route. The objective of this tool is to provide a means for comparing various corridors to determine the most appropriate route for a bicycle facility. The most suitable way to select one route over another is to compare their respective link sum scores. The user-defined tool makes this possible by enabling a user to sum the link scores along a chosen route. The tool can be utilized by selecting any number of connecting links within the GIS and then running the MapBasic program "*user_def.mbx*". This program sums the link scores (of the links selected by the user) and then illustrates the selected route. This tool enables the user to visualize and compare routes. The user-defined route will always have a higher score (penalty) than the optimal route.

Validation

This section presents the process of validating the route planning tools. The first step in the process was to utilize the optimal route planning tool with previously determined criteria weights as inputs to identify the best route between two nodes. An assessment was made as to the reasonableness of the route identified (based on general knowledge of route preferences of bicyclists and common sense - visualization through GIS makes this feasible). This process revealed that the distance criterion was not correctly weighted (it should not have been weighted, in fact, as distance is the base unit of comparison). Figure 4 illustrates the route identified as the optimal route when the distance was incorrectly weighted and then corrected.

Validation can also be accomplished by adjusting the criteria weights until the optimal routing tool replicates actual route choices of bicyclists. For example, if steep topography is a
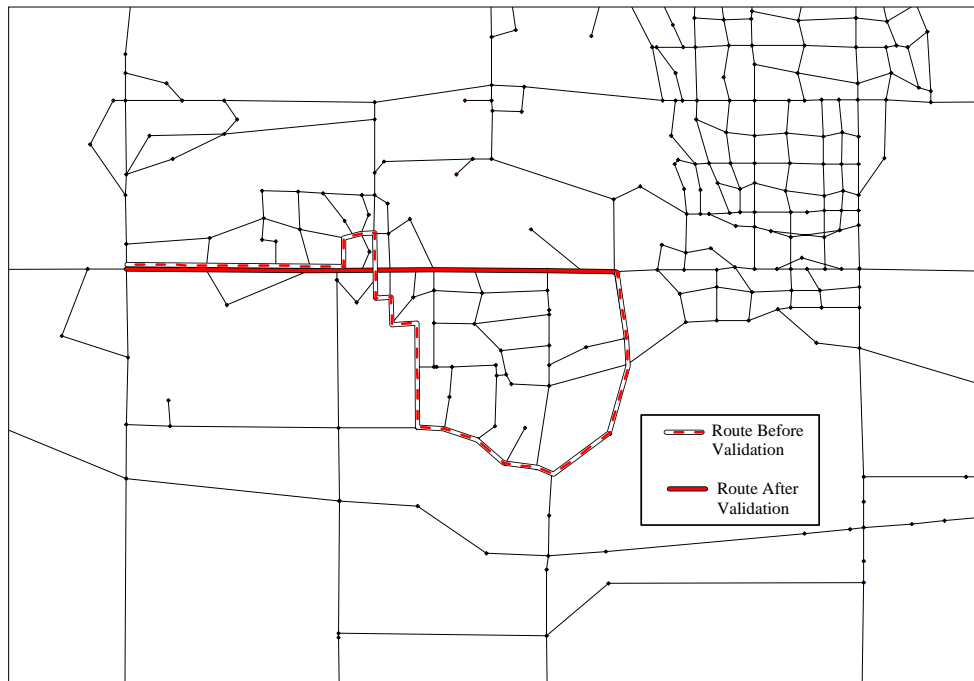
Figure 4: Visualizing Model Errors

major concern in the planning region, a higher than normal penalty can be assigned to links with hilly or mountainous characteristics. When identifying a route, the optimal routing tool is then more likely to avoid links with steep topography. This type of validation can be accomplished using any of the criteria.

It should be noted that what appears to be a reasonable bicycle route is extremely subjective and may drastically differ from one jurisdiction to the next. The route planning tools were designed to be flexible in the criteria and weights they utilize to accommodate various jurisdictions. The link scores can be easily recalculated using the MapBasic program "*newscore.mbx*". When new fields are created for additional criteria, modifications must be made to the equation in the "*newscore.mbx*" program to include the new criteria weights in the calculation.

CASE STUDY: AMES, IOWA

The Ames/Iowa State University Bicycle Committee is currently involved in an effort to update the *City of Ames Bicycle Master Plan*. The bicycle route planning tools were utilized in a case study of the Ames area to (a) identify optimal bicycle routes and (b) compare them to existing and proposed bicycle route locations. This section describes the case study which demonstrated the usefulness of the bicycle route planning tools which utilize data collected during this study. The results of this case study have been offered as recommendations to the Ames/Iowa State University Bicycle Committee concerning the evaluation of existing bicycle routes and the placement of future routes for the *Bicycle Master Plan* update.

Traffic Generators

The first task in the case study was to identify a sample of bicycle traffic generators that represent each section of the city. Traffic generators consist of schools, shopping centers, parks, residential areas, and business centers. Figure 5 shows bicycle traffic generator locations chosen for the case study and existing off-street routes, proposed on-street routes, and proposed off-street routes.
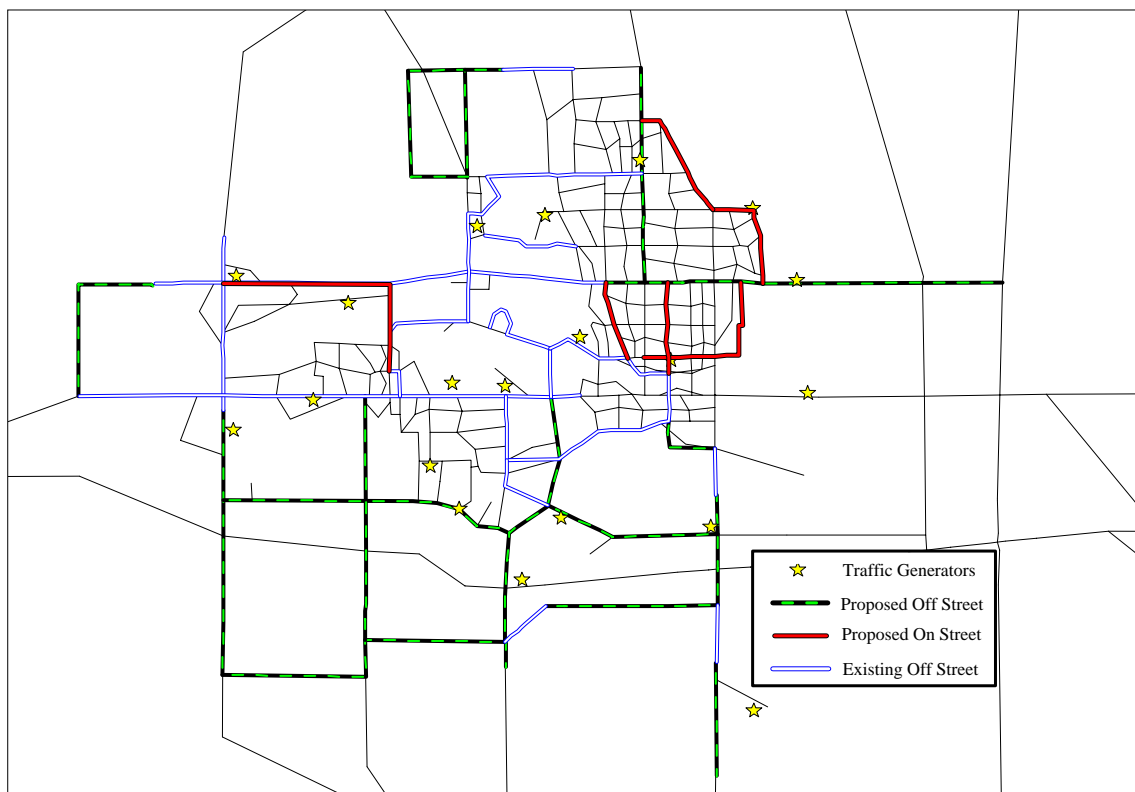
Figure 5:

Traffic Generators and Bike Routes in Ames, Iowa

Proposed and Existing Routes

The second step was to identify proposed and existing bicycle routes within the city of Ames. A map illustrating the locations of these facilities was obtained from the city Traffic Engineering Office. At the time of this writing, the only existing on-street routes in the city were located on the Iowa State University Campus. For this study, the university campus was treated as a traffic generator node, thus the existing on-street routes on campus were not included in the model.

Optimal Bicycle Routes

The next step in the case study was to determine the optimal routes between selected traffic generators. Bicycle traffic generators were selected that were connected by existing or proposed bicycle facilities. The optimal route planning tool was used to calculate the optimal route between the two traffic generators. The selected optimal route was then compared to the existing and proposed bicycle route locations.

Off-Street Route Test

Bicycle traffic generators with existing off-street routes between them were first tested to determine if the existing bicycle route would be selected as the optimal route as determined by the criteria weights obtained in the Delphi analysis. As an example, a pair of bicycle traffic generators with existing off-street facilities include the South Towers Residence Hall and North Grand Mall. Figure 6 illustrates the optimal and existing bicycle routes between these two traffic generators. The optimal route tool selected a route that utilized very few existing facilities. The user-defined tool illustrated the lowest scoring alternate route which utilized more existing bicycle facilities had a score which is 1.1 miles higher than the optimal route. A tradeoff can be made between utilizing existing off-street facilities and traveling further or choosing the overall best route. In this particular scenario, the lack of access through the Iowa State University campus may have an impact on the optimal route chosen.
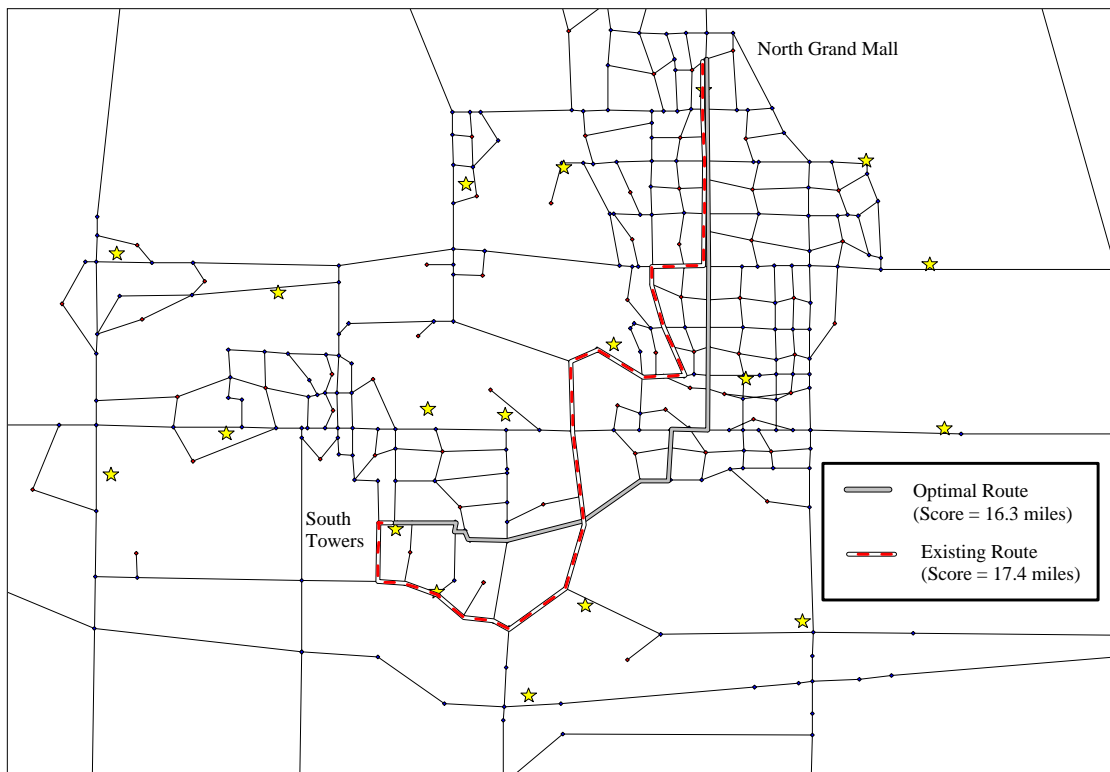
Figure 6: Off-street Bicycle Routes in Ames

A recommendation for future study is to add links to the network that offer access through the Iowa State University campus to determine their impact on the routes selected as optimal through the network.

On-Street Route Test

Similar to the off-street route test conducted previously, bicycle traffic generators with proposed on-street routes between them were tested. The test was to determine if proposed on-street bicycle routes would be selected as part of the optimal route. For this test, two bicycle traffic generators selected were Ames High School and the Ames Public Library. Figure 7 illustrates the optimal and existing routes between these two traffic generators. The optimal route tool selected a route between the high school and the library that follow routes that have been designated, by the *City of Ames Bicycle Master Plan*, for proposed on-street bicycle routes. For approximately two blocks along the optimal route there is no existing or proposed bicycle facility. An alternate route was selected which has continuous existing or proposed bicycle facilities. The user-defined tool was used to calculate a score for this route so it could be compared to the optimal route. The score for the optimal route is 2.3 miles shorter than the route with the existing or proposed facilities. The following section explains the success of the optimal route and the user-defined bicycle route planning tools.

Figure 7: On-street Bicycle Routes in Ames

SUMMARY AND CONCLUSIONS

This paper has discussed the development and application of GIS based bicycle route planning tools. It reviewed previous analytical work attempting to evaluate the suitability of corridors for bicycle travel. This review uncovered areas of deficiency and helped to identify new areas where research and development are needed, such as utilizing GIS for bicycle route planning. We explained the methodology utilized to determine the physical route characteristics that should be considered when planning new bicycle facilities or evaluating existing facilities. We also explained the process used to weight the characteristics as criteria for routing followed by a report on the development of GIS based routing programs. A case study was also presented demonstrating use of the routing tools in the City of Ames, Iowa. Existing and proposed bicycle routes were analyzed utilizing the route planning tools to determine if they represented the best possible location for a bicycle route.

A transportation planner, traffic engineer, or other user can utilize the bicycle route planning tools to provide them with the necessary information to make sound decisions concerning the placement of bicycle routes and facilities. The case study shows these tools can be useful in identifying the best or better location for a bicycle facility or simply comparing one route alternative to another using the route scores. Utilizing these route planning tools makes it possible to quantitatively assess a bicycle route and calculate a route score. This enables planners to rank various bicycle routes. Unfortunately, bicycle route planning can become a subjective process. However, GIS tools combined with a rigorous decision making methodology can lessen this subjectivity. The bicycle route tools have been designed to be flexible and adaptable to any city, county, or other jurisdiction. These methods can also be adapted to other types of fixed route planning such as transit planning.

As a result of the increasing popularity of bicycling and the adoption of recent legislation mandating a focus on multimodal transportation, professionals such as transportation planners and engineers are now demanding the development of quantitative tools that will aid them in their planning processes (Epperson, 1994). This comes at a time when utilizing GIS for planning is becoming common. This is especially true for smaller planning agencies because of affordable "desktop mapping" GISs that are designed to run on a PC.

The method developed for this study is designed for smaller planning agencies and intended to run on a "desktop mapping" GIS. Utilizing the resources and quick response time of the internet to conduct a Delphi analysis for the identification and weighting of criteria proved to be successful in producing valuable information in a short amount of time. The Delphi analysis for this study lasted only three rounds. The respondents attained consensus much faster than expected. Typically, a Delphi analysis requires more than three rounds to gain an acceptable degree of consensus among respondents. Utilizing the internet also allowed each respondent to maintain a high level of anonymity and feedback was easily controlled. The number of respondents in the sample population could have been increased if surveys were sent to multiple news groups. This study used only one news group because it was not known how many people would respond to the surveys.

This study shows that implementing a routing algorithm into a "desktop mapping" GIS that does not have routing capabilities was a relatively simple process. This process was simplified by using the "desktop mapping" GISs programming language. An external program (which also runs on the PC) was used to perform the routing analysis. By using the GISs

programming language, results from the routing algorithm were transferred back to the GIS where the results were displayed. The optimal route tool (which utilizes the routing algorithm) was designed to be flexible as to what information it uses to calculate the optimal route. This allows the routing tools to be adaptable to many different types of routing analysis. The user-defined routing tool makes it easy to display route scores which enable a planner to compare alternative routes on a quantitative basis.

The case study of Ames, Iowa provided a way to validate the routing tools. Utilizing the criteria weights obtained in the Delphi analysis, the results of the case study analysis illustrated that many of the existing and proposed bicycle routes were fairly similar to those identified by the optimal route tool. The tool supports current planning methodologies and provides an efficient method of identifying good routes in future studies. The user-defined tool was successfully utilized to assess alternative routes, as computer optimal routes are not always politically or socially feasible.

Recommendations for Future Study

During the course of this project, several topics surfaced that should be examined through future study. The set of criteria could be expanded to include considerations such as turning movement penalties, a more detailed account of topography, and bicycle accident data. Also, positive attributes could be implemented such as subtracting points if a route traversed a desirable land use such as a park or residential area. This study examined application to a small city with a population of 50,000 people. A possible next step is to implement the methodology and route planning tools in a larger metropolitan area or possibly on a statewide scale. Utilizing the Delphi approach via the internet to obtain criteria and weight information proved successful in producing the expected responses from the panelists in a quick and efficient manner. Although, after the third round in the Delphi analysis, the number of people responding to the questions started to decline drastically. This was either because the respondents loss interest or that a high degree of consensus was reached much faster than expected. After reviewing the statistical analyses, one can conclude the latter is more likely to be true.

Because data were not available for every street in the city of Ames, the network was simplified to include only roads with existing data. This was done to avoid time consuming data collection. Planners have the option of excluding certain roads from their network. However, by utilizing a more detailed link network, adding criteria, or integrating node information, results from analysis may become more accurate, or at least provide alternatives for decision makers

Bicycle route planning is only one of many areas the route planning tools may be of value. The flexibility and adaptability of these tools may allow them to be applied to areas such as transit route planning, hazardous waste routing, delivery route planning, or simply identifying the shortest distance route between two points. More work is needed to further demonstrate the benefits of the routing tools to planning bike routes, especially for agencies who utilize "desktop mapping" GIS software in other areas.

OPERATING INSTRUCTIONS AND PROGRAMMING CODE

Optimal Route Planning Tool

S-Export.mbx

Set Map CoordSys Earth Projection 8, 62, "m", -93, 0, 0.9996, 500000, 0

Commit Table LINKS As "G:_PROJECT\AMESBUS\PATH\P-LINKS.TAB" TYPE NATIVE
Charset "WindowsLatin1"
Open Table "G:_PROJECT\AMESBUS\PATH\P-LINKS.TAB" Interactive
Add Map Auto Layer P_LINKS
Alter Table "P_LINKS" (drop
a_xcoord,a_ycoord,b_xcoord,b_ycoord,ag,length,speed_option,speed1,speed2,dc1,lg1,lg2,lg3,ca
pacity1,capacity2,option,speed3,speed4,dc2,lg4,lg5,lg6,capacity3,capacity4,user_define,ID,total_
loaded_volume,traffic_counts_1992,traffic_counts_1994,vc_ab,vc_ba,TRAF_DIFF,TRAF_DIFF
_PCT,street_name,traffic_counts,loaded_volume_1000,pre_dak_model,change,speed_change,tra
vel_time)

INCLUDE "C:\MAPINFO\MAPBASIC.DEF"
        EXPORT P_LINKS INTO "p-LINKS.TXT" TYPE "ASCII" DELIMITER " "
        EXPORT NODES INTO "NODES.TXT" TYPE "ASCII" DELIMITER " "
Close Table P_LINKS Interactive

END PROGRAM

1st-Path.mbx

INCLUDE "C:\MAPINFO\MAPBASIC.DEF"
Commit Table selection As "PATH-IN.TAB" TYPE NATIVE Charset "WindowsLatin1"
Open Table "PATH-IN.TAB" Interactive
Add Map Auto Layer PATH_IN
        EXPORT PATH_IN INTO "route.in" TYPE "ASCII" DELIMITER " "
Close Table PATH_IN Interactive

S-Path.for

(note: portions of this code were developed by James Cardle, Shashi Sathisan and Reg
Souleyrette, University of Nevada, Las Vegas, 1989-90.)

```
CC
C
C    Program: PATH
C
CC
```

```
      PARAMETER (MNLnks=1000)
      PARAMETER (MNRtLnks=100)
      PARAMETER (MNRtNds=100)
      PARAMETER (MNNds=1000)
      PARAMETER (MNNbrs=6)

      CHARACTER*1 a1

      DIMENSION Nd(MNNds)
      DIMENSION NNbrNds(MNNds)
      DIMENSION NdLab(MNNds)
      INTEGER NdX(MNNds)
      INTEGER NdY(MNNds)

      DIMENSION NbrNd(MNNds,MNNbrs)
      REAL NbrScr(MNNds,MNNbrs) , score(MNRtLnks)

      DIMENSION time(MNLnks)
      INTEGER Lnk(MNLnks)
      INTEGER ANd(MNLnks)
      INTEGER BNd(MNLnks)
      INTEGER ANdLab(MNLnks)
      INTEGER BNdLab(MNLnks)

      INTEGER RtANd(MNRtLnks)
      INTEGER RtBNd(MNRtLnks)



CCC

      COMMON/SPATH1/NbrScr,NdStart,NdStop,
     *NNbrNds,NbrNd,RtANd,RtBNd,NdCount,NNds

      write (*,*)' finished dimension'
x


      OPEN(4,FILE='route.out',STATUS='UNKNOWN')


C    Read Node text File for Node numbers

      OPEN(1,FILE='nodes.txt')
      DO 4027 I=1,MNNds
```

```
      READ (1,*,err=1) a1,NdLab(I),NdX(I),NdY(I)


      Nd(I)=I
 4027 CONTINUE
  1   CONTINUE
      NNds=I-1
c     write (4,*) (Nd(I),NdLab(I),I=1,NNds)

C     Read Link text File for A node and B node for Links and travel time

      OPEN(2,FILE='p-links.txt')
      DO 4029 I=1,MNLnks
      READ (2,*,err=2) ANdLab(I),BNdLab(I),time(I)
      Lnk(I)=I

      do 15 j=1,NNds
      IF(ANdLab(I).eq.NdLab(J))ANd(I)=J
      IF(BNdLab(I).eq.NdLab(J))BNd(I)=J
 15   continue


 4029 CONTINUE
  2   CONTINUE
      NLnks=I-1

c     write (4,*) (ANd(I),ANdLab(I),BNd(I),BNdLab(I),time(I),I=1,NLnks)

C     Read Beginning and End Node Numbers

      OPEN(3,FILE='route.in')
      Read (3,*)a1,NdLStart
      Read (3,*)a1,NdLStop

      DO 13 I=1,NNds
      IF(NdLStart.eq.NdLab(I))NdStart=I
      IF(NdLStop.eq.NdLab(I))NdStop=I
 13   CONTINUE

c     write (4,*) NdLStart, NdLStop, NdStart, NdStop

C     Determine the number of neighbor nodes for each node

      DO 4039 I=1,NNds
      NNbrNds(I)=0
      DO 4039 J=1,NLnks
```

```fortran
      IF(Nd(I).EQ.ANd(J)) THEN
        NNbrNds(I)=NNbrNds(I)+1
        NbrNd(I,NNbrNds(I))=BNd(J)
        NbrScr(I,NNbrNds(I))=time(J)
      ENDIF
      IF(Nd(I).EQ.BNd(J)) THEN
        NNbrNds(I)=NNbrNds(I)+1
        NbrNd(I,NNbrNds(I))=ANd(J)
        NbrScr(I,NNbrNds(I))=time(J)
      ENDIF
 4039 CONTINUE
c     write (*,*)' finished 4039'

      CALL SPATH
      write (*,*)' finished SPATH'

C     Write the anode and bnodes for the links on the route

      DO 4054 I=1,NdCount-1
c      write (4,*)RtANd(I),RtBNd(I)


      DO 5039 J=1,NLnks


      IF(((NdLab(RtANd(I)).EQ.ANdLab(J)).and.
     1(NdLab(RtBNd(I)).EQ.BNdLab(J))).or.
     2((NdLab(RtANd(I)).EQ.BNdLab(J)).and.
     3(NdLab(RtBNd(I)).EQ.ANdLab(J)))) then
        score(I)=time(J)
      ENDIF
 5039 CONTINUE




      Write (*,780)NdLab(RtANd(I)),NdLab(RtBNd(I)),score(I)
  780 format(2i10,f10.2)
      Write (4,2070)NdLab(RtANd(I)),NdX(RtANd(I)),NdY(RtANd(I)),
     1 NdLab(RtBNd(I)),NdX(RtBNd(I)),NdY(RtBNd(I)),score(I)
 2070 FORMAT(6i10,F10.4)
 4054 CONTINUE

      END
CCC
```

```
C
C     Subroutine to calculate the optimum path
C
CCC

      SUBROUTINE SPATH
C
C     Calculates shortest path in nodal network
C     using 1st algorithm in G.F. Newell "Traffic Flow
C     on Transportation Networks".
C
C     Written by J. Cardle @ UNLV on 7/18/89
C     Modified by R. Souleyrette & S. Sathisan Jan. 1990
C
C     NdStart = The starting node for the route
C     NdSave = Temporarily saves the node number
C     NdStop = The ending node for the route
C     RtANd(I),RtBNd(I) = Beginning and end nodes of link I
C           on the optimal route.
C     Nd(I) = Number for Node I {I=1,MNNds}
C     TempNd(I) = A tempopary array that holds node numbers
C      on the optimal path, used to rearrange backwards to forwards
C     CumScore(I)...Cumulative score between StartNd and Nd(I)
C       {I=1,MNNds}
C     LLab(I)...True if Nd(I) is on the path, False if not
C       {I=1,NNds}
C     X(I)...The node being examined
C     MNNds = The maximum number of nodes
C     NNbrNds(I) = Number of Neighbor Nodes for Nd I
C       {I=1,MNNds}
C     NbrScr(I,J) = Score to neighbor J for Node I
C       {I=1,MNNds; J=1,NNbrNds(I)}

      PARAMETER (MNNds=1000)
      PARAMETER (MNNbrs=6)
      PARAMETER (MNRtLnks=100)

      DIMENSION NNbrNds(MNNds)
      DIMENSION CumScr(MNNds)
      DIMENSION Nd(MNNds)
      DIMENSION NbrNd(MNNds,MNNbrs)
      REAL NbrScr(MNNds,MNNbrs)
      INTEGER RtANd(MNRtLnks)
      INTEGER RtBNd(MNRtLnks)
      INTEGER X(MNNds)
```

```fortran
      INTEGER TempNd(MNNds)
      CHARACTER*1 CH
      LOGICAL LLab(MNNds)


      COMMON/SPATH1/NbrScr,NdStart,NdStop,
     *NNbrNds,NbrNd,RtANd,RtBNd,NdCount,NNds
CC
C    Initialize arrays
CC

      DO 4032 I = 1,NNds
       LLab(I) = .FALSE.
       CumScr(I) = 0.0
       Nd(I) = 0
       X(I) = 0
 4032 CONTINUE
c     write (*,*)' finished 4032 **********'

CC
C     Initialize variables for Node 1 (Starting Node)
CC

      K=1
      LLab(NdStart)=.TRUE.
      CumScr(NdStart)=0.
      X(1)=NdStart

c     write (*,*)' starting 4033'
CC
C    Find shortest path from node 1 (NodeStart) to the destination
C    node (NodeStop)
CC

      DO 4033 Kount = 1,10000
       IF((LLab(NdStop)).OR.(K.GT.NNds)) GO TO 3045
       KM1 = K
       K = K + 1
       DMin = 100000.

CC
C    Evaluate minimum function
CC

       DO 4017 I = 1, KM1
```

```fortran
       DO 4034 JJ = 1, NNbrNds(X(I))
        ndummy=NbrNd(X(I),JJ)
        IF(.NOT.LLab(ndummy))
     *   THEN
         Temp = CumScr(X(I)) + NbrScr(X(I),JJ)
         IF (Temp.LT.DMin) THEN
          DMin = Temp
          iisave = X(I)
          NdSave = NbrNd(X(I),JJ)
         ENDIF
        ENDIF
 4034    CONTINUE
 4017   CONTINUE
      LLab(NdSave) = .TRUE.
      CumScr(NdSave) = DMin
      Nd(NdSave) = iisave
      X(K) = NdSave
 4033 CONTINUE
c     write (*,*)' finished 4033'
CC
C     FILL ARRAYS 'TempNode','RtANode','RtBNode'.
CC

 3045 CONTINUE

C     WRITE ERROR MESSAGE IF THE DESTINATION NODE CANNOT BE REACHED &
STOP

      IF(LLab(NdStop)) GO TO 3072
      WRITE(*,2078)
 2078 FORMAT(//////////,' The destination cannot be reached from ',
     *' the starting node.',///' Probable cause:',
     * //,' Critical link(s) have been removed from routing',
     * ' consideration.',//,' Please start again. (Hit "Enter"'
     * ,' to continue)    ',\)
      READ(*,'(1A)') CH
      GO TO 3073

 3072 CONTINUE
      TempNd(1)=NdStop
c     write(*,*)' Beginning Node = ',NdLab(NdStart)
c     write(*,*)' Ending Node = ',NdLab(NdStop)
c     write(*,*)' TempNd(1) = ',TempNd(1)
      DO 4035 I=1,NNds
       TempNd(I+1)=Nd(TempNd(I))
```

```
c      II=TempNd(I+1)
c      write(*,*)' NdL(TempNd(I+1)) = ',NdLab(II)
       IF(TempNd(I+1).EQ.NdStart) GO TO 3046
 4035   CONTINUE
 3046   CONTINUE
       NdCount=I+1

       DO 4036 I=1,NdCount-1
       J=NdCount-I
        RtANd(I)=TempNd(J+1)
        RtBNd(I)=TempNd(J)
 4036   CONTINUE
 3073 CONTINUE
       RETURN
       END
```

Showpath.mbx

```
include "c:\mapinfo\mapbasic.def"
Register Table "ROUTE.OUT"  TYPE ASCII Delimiter 32 Charset "WindowsLatin1" Into
"RT.TAB"
Open Table "RT.TAB" Interactive
Commit Table RT As "ROUTE.TAB" TYPE NATIVE Charset "WindowsLatin1"
drop table RT
Open Table "ROUTE.TAB" Interactive
Create Map For ROUTE CoordSys Earth Projection 1, 0
Add Map Auto Layer ROUTE

set map redraw on
Set Map XY Units "m" CoordSys Earth Projection 8, 62, "m", -93, 0, 0.9996, 500000, 0
Set Style Pen (3,2,16711935)
update ROUTE set obj = CreateLine (_COL2,_COL3,_COL5,_COL6)
'COMMIT TABLE ROUTE
Select Sum(_col7) from Route into query1
Browse * From query1
```

Showmore.mbx

```
include "c:\mapinfo\mapbasic.def"
Register Table "ROUTE.OUT"  TYPE ASCII Delimiter 32 Charset "WindowsLatin1" Into
"RT.TAB"
Open Table "RT.TAB" Interactive
Create Map For RT CoordSys Earth Projection 1, 0
Add Map Auto Layer RT
```

```
set map redraw on
Set Map XY Units "m" CoordSys Earth Projection 8, 62, "m", -93, 0, 0.9996, 500000, 0
Set Style Pen (3,2,16711935)
update RT set obj = CreateLine (_COL2,_COL3,_COL5,_COL6)

Insert into ROUTE select * from RT
drop table RT
commit table ROUTE
```

User defined Route Planning Tool

User_def.mbx

```
set map redraw on
Set Map XY Units "m" CoordSys Earth Projection 8, 62, "m", -93, 0, 0.9996, 500000, 0
Set Style Pen (3,2,65280)
update Selection set obj = CreateLine (a_xcoord, a_ycoord, b_xcoord, b_ycoord)

Select Sum(score) from Selection into Selection
Browse * From Selection
```

Calibration Process

Newscore.mbx

```
Update LINKS Set score =
100*(length)+0.2*(topography+landuse+intersections+surface_type+congestion+speed+parking
+heavy_vehicles+lane_width)
```

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