ITRE

Utilizing GIS to Evaluate Base Schedules in Paratransit Operations

Final Report

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director

A joint activity
of North Carolina
universities

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16. Abstract

With ready access to street file names and inexpensive GIS software, paratransit systems can take advantage of GIS technology to evaluate base schedules on a regular basis in order to maintain system efficiency at consistently high levels. This project will develop a methodology to allow frequent analysis of base schedules to update paratransit routes on a semi-annual or annual basis.

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1.0 INTRODUCTION

The Transit Operations Group (TOG) at the Institute for Transportation Research and Education (ITRE), North Carolina State University was awarded a research grant from the North Carolina Department of Transportation. The goal of the research was to develop a GIS methodology to enable public transportation operators to routinely evaluate their route schedules and to make route changes to achieve scheduling efficiencies.

The study team consisted of ITRE staff and a consultant with expertise in using GIS for transit route analysis.

Three transit operations were identified to participate as demonstration sites for this study: Greensboro Transit Authority (GTA), Kerr Area Rural Transportation System (KARTS), and the Transportation Administration of Cleveland County (TACC).

The study objectives were:

1. Design a methodology using GIS to evaluate the effectiveness and efficiency of paratransit system base schedules, or subscription trips;
2. Utilize data from three paratransit systems (one urban, one multi-county rural, one single county rural) to test the methodology;
3. Refine the methodology using GIS in validating base trip schedules; and
4. Transfer technology.

2.0 BACKGROUND INFORMATION

Paratransit operations have always been an important component of the North Carolina public transportation network. The efficient scheduling of trips in both urban and rural environments presents a challenge. The customer's needs must be met in delivering quality service and at the same time the transit operation must take into consideration the most cost effective and efficient method of scheduling and providing that trip.

Schedules are developed on the basis of subscription trip requests. Subscription trips may occur daily, two or three times per week, once every month, or at a greater time interval. For example, an elderly resident may require transportation to and from a congregate nutrition site on a daily basis. A dialysis patient may require transportation to and from a dialysis center three times per week. In these examples the trips are repetitive, taking place from one origin to the same destination at predictable intervals. This type of trip forms the basis for developing paratransit routes.

In addition to subscription trips, paratransit provides demand-responsive transportation real-time or advance reservation (typically 24 hours). Demand-responsive trips are trips that are made on an occasional, rather than a repetitive basis. Demand-responsive trips are often accommodated on subscription routes on a space-available basis. Because of the scheduling complexity, some transit systems in North Carolina operate separate vehicles to deliver demand- responsive trips and do not integrate those trips on existing subscription trips even though such a practice may be more cost effective.

With computer-aided scheduling software, there are new opportunities to better integrate demand-responsive and subscription trips. Some North Carolina transit systems are now using this type of software to accomplish that goal. This achievement, however, has given rise to a new problem. The software scheduling functionality operates from the base subscription schedule providing suggestions where to efficiently insert a trip within this base. As new trips are added the base trips are not reoptimized to create the greatest efficiencies.

Paratransit service is a dynamic rather than a static service. New subscription passengers are continually added to the system and the transportation needs of existing passengers change with time. Therefore, schedules need to be analyzed on a regular basis to maintain operating efficiency with changing trip demands.

Efficient base schedule routes maximize passenger convenience and minimize the expenditure of personnel, financial, and capital resources. There is no standard for periodically examining the effectiveness of base schedules. In addition to a lack of a well-defined methodology, many systems lack the tools and training to conduct such an analysis.

Verifying the quality of base schedules can be very time consuming. A manual method typically used by paratransit system operators is to place pins in a wall map to identify trip origins and destinations. While some paratransit systems in North Carolina use automated scheduling and routing software to schedule and dispatch trips, most systems are not evaluating the efficiency of their base schedules. Unless optimal base schedules are used with scheduling software, the resulting daily runs may not be the most effective way to deliver paratransit services.

3.0 STUDY APPROACH

The purpose of this study was to develop a methodology, utilizing low-cost and affordable technology, GIS, to create an effective approach to analyze paratransit subcription schedules.

Given the dynamic nature of paratransit service, a simple method for analyzing and updating routes on a regular basis is needed in order to maintain overall system efficiency and effectiveness. With ready access to street name files and inexpensive GIS software, paratransit systems can take advantage of GIS technology to evaluate base schedules on a regular basis. A semi-annual or annual review of base schedules would allow most systems to consistently maintain their efficiency at a high level. This study utilizes Geographic Information System (GIS) to plot and display trip origins and destinations for base schedule route analysis.

The ITRE team (ITRE staff and a private consultant) conducted the core work with review by an advisory group consisting of staff from the North Carolina Department of Transportation Research, Public Transportation, and GIS units and the Federal Highway Administration. ITRE made three presentations to the advisory group at the beginning, mid-point, and at the end of the study (refer to Appendix A for an outline of the August, 1998 presentation).

Two demonstration sites (with different service characteristics) were identified at the onset of the study. The transit managers at these sites expressed an interest in utilizing this technology tool and agree to provide data and to participate in at least two meetings; a kick-off information meeting and an assessment of route performance. The latter meeting was also an opportunity for the transit managers to give input to the study on the usefulness of the GIS tool and evaluation process and to recommend improvements. ITRE also visited the sites as needed to gather data.

Since the first two sites represented a rural multi-county and an urban paratransit operation, for purposes of diversity the third study site was intended to be a small rural single county transportation system. To limit effort on data collection and refinement, the study team sought to identify a smaller system that did substantive post trip data entry and had 911 compliant addressing. Another criteria was that the manager needed to demonstrate an interest in utilizing GIS as a planning tool. ITRE also obtained input from NCDOT staff. It was difficult determining a site to meet these criteria. A third operation was identified after the project start up.

Data were plotted and refined and scripts (programs) developed in the GIS application by ITRE GIS Program area staff. The study consultant was responsible for developing an evaluation process. After these tasks were completed, the study team met with the managers of the three study sites for purposes of demonstrating the application, obtaining corrections to the data, providing an assessment of some route patterns, and obtaining input from the operations staff on potential improvements.

To transfer this technology to other North Carolina public transportation systems, guidelines were developed for using this GIS application. These guidelines should assist planners and operations managers on how to use the product and process developed in this study to optimize base schedules.

4.0 STUDY TASKS

The study consisted of the following tasks.

Task 1: Obtain a Base Map.

MapInfo was the GIS software initially selected for use in this study. Due to problems associated with the conversion of the base map information from another GIS package to MapInfo, a decision was made to use another GIS product, ArcView, for the analysis. This software was also selected because the ITRE research assistant working on this study was most familiar with ArcView.

The City of Greensboro provided a base map that was produced by the City staff. Maps from ITRE's Pupil Transportation Group (TIMS Maps) were used as the base maps for KARTS and TACC. The reasons for using TIMS maps were that the service area counties could not provide adequate coverages and the Tiger files (census bureau data) did not provide the accuracy level desired.

Task 2: Create or Obtain a Master Database.

A master database was compiled for the three demonstration sites:

1. GTA– data was readily available in an electronic format since the City of Greensboro staff had already imported route data into the GIS database and initiated analysis; minimum data refinement required
2. KARTS – data refinement required
3. TACC – data refinement required

The data distilled included: last name, first name, middle initial, trip origin (exact address), scheduled appointment, day of week, trip destination (exact address), pick-up sequence, drop-off sequence, trip purpose, and x-y coordinates or other GIS links. The GIS database was compiled for schedules for a typical three-day period for each site.

Both GTA and KARTS data were downloaded from scheduling and routing software database. The KARTS data were originally in dbf format and TACC data were provided in a spreadsheet. The study team requested that the three sites carefully review their data for accuracy and for updated addresses to limit errors.

Data development work for GTA was the smoothest since their data already had assigned GIS coordinates. Unlike the GTA data, the KARTS data were not geographically referenced and therefore geocoding was required. Geocoding refers to the process of taking tabular data and geographically identifying a physical location for database entries based upon their street address. This geocoding needed to occur before the data could be refined further by the transit systems.

Task 3: Refine Data.

The process for correcting non-matched addresses essentially involves identifying the non-matched records, finding their location and then correcting the error. The data files from all three days were compiled into one file for further correction. The purpose of compiling the data was to avoid correcting a single error multiple time for each day. Because each record has a DATESTAMP value, separating the data again following correction is not a problem. Once the data was compiled a frequency table was generated to show the number of times a particular non-matching address occurred in the database.

Because the expertise regarding the locations and correct addresses of the non-matched sites lied with the transit system staff, the study team required the assistance of the transit agencies in ensuring the accuracy of the data. An additional site visit was made to KARTS to provide assistance with updating the data.

Data refinement was a time consuming process. In order to achieve an acceptable match ratio over 90 percent, the transit managers were provided with a list of addresses that did not successfully geocode (i.e., P.O. box address and incomplete addresses are not acceptable). Some origins or destinations were listed as agencies or points of interest and required assignment of a street address. For example, the Department of Social Services needed to be listed as a street address instead of an agency name.

The final match ratio for GTA and TACC was over 90 percent.

For KARTS, the initial match ratio was well under 70 percent. Following the site visit, the overall match rate improved to approximately 76 percent. Although the 76 percent rate was a significant improvement, it was determined that a higher rate was required for the analysis. It was decided at this point to print a large format street map of each county, which was sent to the KARTS office. This task was not completed due to KARTS staff time constraints.

With KARTS, only a 76 percent match rate was achieved due to the fact that some addresses could not be resolved. Also one of the counties in this regional system service area, Warren County, has not yet completed 911 addressing. Because of the low match rate and the smaller number of trips relative to the other counties, Warren County was excluded from the analysis.

Task 4: Plot Trip Origins and Destinations

Files were created for three typical weekday(s). Trips were plotted according to time periods throughout the day. At least three time periods were utilized: morning, midday, and afternoon. This reflects the operation of a typical paratransit system, which transports passengers to destinations in the morning, provides nutrition routes and primarily demand-responsive medical or shopping trips during the midday, and transports passengers home in the afternoon. Trips were plotted as straight lines between origins and destinations, not following particular streets.

Again, data refinement also helped to plot a more accurate display of trip flow in the time periods.

Task 5: Generate Routes.

Passenger pick-ups and drop-offs for each route were placed into the most efficient sequence.

Scripts or programs were developed to facilitate navigation in the GIS. Five scripts were written and compiled for the study in the ArcView programming language, Avenue.

Each script performs a specific function and is associated with a button located in the button-bar of the *View Window.* The first acts as a 'clear screen' function and is only used for deleting graphics once one or more of the other scripts are run. Four scripts call for an interactive dialog for user-input. The scripts are as follows:

Script 1: Cut Graphics

This non-interactive tool allows the user to gut graphics previously drawn by one or more of the other scripts. The script is written in the Avenue programming language and is located in cleveland.apr as *Graphics.Delete.*

Script 2: ODLineV1

This is the first of the four interactive scripts. ODLineV1 is an analytical tool that creates lines depicting the travel between paired origin and destinations. When issued, the program allows the user to define both a route and time interval he or she wishes to view. There is also an option to show all routes during a specific time-block at once. The script can be broken into two parts; the selection process and the drawing process. The first objective of the script is to create a selected set from the active theme's attribute table (a database). A first selection is made after the user inputs a time interval of interest. Once that selection is made, a second dialog box is displayed giving the user an option to show all of the routes during that time interval. If "Yes" is chosen the selected set is complete and the script continues on to the second segment. If the user chooses "No", a second dialog box is displayed listing the optional routes. Once a route is chosen, a *reselect* takes place, selecting those particular records whose route is defined by the selection from the previously selected set. Once the selected set is narrowed to only those records that meet both the time and route requirements, the script continues on to the second segment.

Only records that are paired, i.e. those with the same **ID** and different **PD** values, are used in creating origin-destination lines. The second segment of the script finds these pairs and creates a solid line between the points of origin and destination showing the direction in which each customer traveled. This script is stored as *ODLineV1* in cleveland.apr.

Script 3: ODLineV2

ODLineV2 is a second version of ODLineV1. The analysis is essentially the same, except no time interval is required. Instead, the entire selected route(s) display when this script is issued. The script is stored as *ODLineV2* in cleveland.apr.

Script 4: RouteV1

The fourth script in the project creates a dashed line between all of the selected points showing the straight-lined route in question.

The selection process is the same as ODLineV1, with the exception that there is no option to choose all of the routes at once. The user again chooses a time interval and route from interactive dialogs. Once the selected set is in place, a series of straight lines are drawn between each point, whether it be a client's origin or destination, creating an analytical view showing the flow of a particular route within a given time. The script is stored as *RouteV1* in cleveland.apr.

Script 5: RouteV2

The fifth script (fourth interactive script) is identical to RouteV1, except no time interval is required. Once chosen, the route is displayed for the entire day. This script is located in cleveland.apr as *RouteV2.*

5.0 STUDY RESULTS

5.1 Evaluation

The maps displayed the origin and destination for each route. Additionally, the sequence of the run, showing the path of the vehicle (using straight-line distance between points), was plotted. Overlays were used to develop a picture of the entire system's scope of operation on the sample day(s). O/D paths were connected to create paratransit travel flow maps.

The grouping and sequencing of existing schedules was evaluated using the following techniques:

- Visual analysis of the clustering of pick-ups and drops offs assigned to a given tour – use of GIS allows the researcher to look at the entire system's activity in a manner not typically available to the scheduler or dispatcher. Additionally, by plotting a path between pick-up and drop-off points, the ITRE team assessed passenger assignments that resulted in excessive vehicle mileage.
- Time-series analysis – using the database functions of the GIS, the researcher was able to examine several tours/runs at particularly time periods in the day.

The ITRE study team met with transit system representatives to evaluate the data generated from the GIS plots of existing base schedules. The participation of the staff from the three demonstration sites was critical to successfully evaluating origin and destination plots.

The plots revealed those trip origins or destinations which do not occur within the area of most trip origins and/or destinations for each route. Such outlyers were analyzed to determine if they could be better served by another route to increase efficiency. An iterative process was used to refine existing base schedule routes. Potential deficiencies in existing schedules were noted. The study consultant provided input to the operators in on how trips could be grouped more efficiently.

The transit managers noted some discrepancies in the data. Some of these were due to data entry error on the part of the transit system and others occurred in the geocoding process. The evaluation meeting also included a discussion on how to use the GIS as a tool for conducting regular route analysis.

5.2 Lessons Learned

Although the ITRE technical staff have extensive experience in GIS training and technical assistance, this is the first time that ITRE staff have worked with applying GIS to transit operations. The study consultant was a necessary addition to the team as he had already begun applying GIS as a tool for evaluating route productivity.

This was an opportunity to work with North Carolina operators who were enthusiastic about this technology tool but had limited GIS knowledge and technical expertise. The three transit managers involved in this study recognized the potential that GIS can have in their operations as a tool for assessing route productivity.

The study team recognized some deficiencies in the study approach and data collection. These include:

- Data refinement required more effort than originally anticipated.
- Unanticipated delays occurred in converting data into the GIS program.
- A third study site was not readily identified.
- Instead of geocoding three individual days, all active subscription trips could have been geocoded into one large file with little extra effort.
- Address files are subject to data entry problems so a unique ID should have been given to each pick-up and destination.
- The analysis could be improved by going beyond just connecting routes by introducing network analysis and showing the route network along a road system. Program extensions to ArcView (network analyses) could be used. This would have required more level of effort from ITRE GIS and paratransit operations staff.
- The trips were broken up into timeblocks, analysis would have been better on the route level.
- A format should be provided to each of the three sites instead of relying on the format provided through the scheduling and routing software. This would streamline the conversion into the GIS database.

6.0 CONCLUSIONS/RECOMMENDATIONS

GIS can be a very powerful analytical tool, especially for urban and multi-county rural paratransit operations. This study was a first step in organizing client trip information, displaying the routes in various layers, and developing a process of visual evaluation of those routes.

The three demonstration sites were very actively engaged in the development of the GIS databases and map layers.

As indicated previously there were some deficiencies in this study. The data collection phase and error corrections consumed more time and effort on the part of ITRE and operations staff than originally intended. This demonstrated the importance of consistency in data entry and exact street names.

Origins and destinations were plotted for three typical days for each of the demonstration sites. The analysis was conducted by examining blocks of time, origin and destination points, grouping of trips, and outliers. This evaluation process was determined by the study consultant. An alternative method of evaluating the data would have been to introduce network analysis and show the routes network along a road system. ArcView has an extended network analysis program that could be used in the future for plotting the trips along a route.

Another potential improvement could be made by plotting all standing order trips for a given year instead of using a three-day period. This would permit a more detailed analysis of route patterns and help with reconfiguring routes to create more efficiencies.

The data from the three sites were transferred onto CD ROMs for use by each transit system. With the exception of GTA, the other operations are not adequately prepared to utilize the GIS. First, staff at these sites are not trained in ArcView. Second, they have limited staff time to devote to refining data and to begin utilizing this tool. GIS is a powerful tool but it does require ongoing maintenance to be an effective planning tool. Similar to KARTS and TACC, other rural North Carolina transit operations may not find it cost effective to procure, install, and maintain the GIS software directly. This decision would depend greatly on the computer skill level of staff, time available to devote to maintaining the software, and the ready availability of quality base maps and technical support. Rural systems associated with a local government may have more direct access to quality base maps and technical support through the GIS departments at these local governments.

For smaller transit systems, it may be more practical to contract for technical support for maintenance and analysis of GIS data. Since the technology plan developed for NCDOT/PTD by ITRE recommends the initiation of a GIS service bureau to provide a service to such systems, we recommend that these two sites could be the initial sites to use such a service. Within six months of completion of this study their data could be refined and routes put into a street network. An update could then be given to the sites.

This will serve several purposes: 1) the data would not just be sitting on a shelf, 2) the analysis process could be refined using these two sites, 3) this would allow sufficient time for the two study sites to train one or more of their staff on ArcView.

In the long term, the use of GIS to plot trip origins and destinations will facilitate route analysis and allow for base schedule analysis at regular intervals. Additional benefits from this method of analysis will be increased productivity from more efficient use of resources, an increase in passenger convenience, a reduction in travel time and vehicle route miles, and the ability to serve additional passengers without adding personnel or capital resources.

To assist in transferring this technology, Appendix B contains steps for utilizing GIS and the scripts developed for this project. This is intended to provide guidance to novice transit operators and planners.

APPENDIX A:

Guidelines for Implementing GIS in North Carolina Transit Operations

These guidelines were developed to assist North Carolina transit operators in implementing the processes that need to occur to set up GIS applications and to provide a review of some of the applications that were designed in this GIS demonstration project. The GIS novice is the audience for this step by step overview.

Step 1: Obtain the Transit Service Area Base Map

The base map is the coverage of the service area, typically a locality, county, or multiple counties. This map should be the most up-to-date map available and should also be, if possible, compatible with the selected GIS program for use in the transit operation. If the most current base map is in a GIS program other that what is to be used in the transit system, recognize that a software conversion package will be needed to translate the data into the desired GIS format.

There are a variety of sources for North Carolina base maps. Below is an overview of sources with potential problems identified:

- U.S. Census bureau Tiger files - this is a nationwide inventory of roads, updated every 10 years. It can be downloaded from the Internet or obtained from a state or local government office. The benefits of this source is that it can be readily downloaded into any GIS program.

  Problems: maps are updated only every 10 years with some interim updates (the last interim update was 1995). Streets are named in a particular format and the data being entered needs to follow that format. Massaging of data (blvd. may be used, bl may be used in Census data), lot of spatial editing due to 10 year problem. So street need to be added and spatial accuracy evaluated.

- Revised Versions of Tiger files - local or state government offices (North Carolina Center for Geographic Information and Analysis or the Institute for Transportation Research and Education). Usually maintained by local government for other base map applications.

- ITRE TIMS Maps – these maps are maintained and updated by ITRE's Pupil Transportation Group. This program area provides technical support on a scheduling and routing software package in use in North Carolina schools system transportation departments. One advantage is that these maps are more current than the census files and locally government maintained programs (e.g., Cleveland County was updated in 1997).

  Problems: TIMS is in a proprietary GIS. Most North Carolina GIS state and local agencies have their geographic coverages in ArcInfo. ITRE can provide an export coverage (.e00 or .e01) of any base map that can then be translated to a shape file. An export coverage can be imported into

Also, use this opportunity to clean up your data files, i.e., delete former passengers, etc.

Refer to the ITRE Winston-Salem network analysis on ITRE's web page. This is an example of a routing program instead of the straight line distance approach for this study.

Step 3: Import Data into GIS and Geocode

Importing may occur from one GIS program to the other. All have a table reading functions (for example ArcView can read certain format tables: Dbase files, INFO files, tab- or comma- delimited ASCII format files). If data not in one of these formats (i.e., Excel) the data must be converted first.

Geocode: run batch match file and interactively rematch: fixing problems. Problems include: spelling errors; consistency errors AV or AVE (base data may have one way), N. Main and S. Main; addresses out of range (squeeze them in); no address (must have full address not P.O.); if all letters are in upper case in one and lower in the other.

The match ratio to effectively analyze data is in the range of 90% - 100 %.

Early on in the process, review how your input matches with what is written in the base match.

Step 4: Write or Import the Program Scripts

For scripts to work, the data must be input into your GIS using a defined structure: last name, first name, middle initial, trip origin (exact street address), scheduled appointment, day of week, trip destination (exact street address), pick-up sequence, drop-off sequence, trip purpose, and x-y coordinates or other GIS links. The GIS database was compiled for schedules for a typical three day period for each site.

Scripts are text files written in a program specific language and are used to perform a function. Programs are compiled of one or more scripts.

Scripts were essential to our GIS computing operations. To operate your GIS program effectively specialized program scripts need to be developed to be able to manipulate the data to get results needed.

Five scripts were created to modify the ArcView GIS program in order for it to function the way we wanted to. Five Avenue scripts have been developed for this study for use in ArcView. The scripts would be need to be translated into the GIS programming language for your specific GIS packages (i.e., MapInfo's programming language is MapBasic).

The existing scripts can be edited and expanded on by a local programmer or through ITRE. The scripts are available though ITRE's Transit Operations Group (amn@unity.ncsu.edu). These can be sent electronically upon request and loaded into a GIS system from the program's windows interface.

APPENDIX B:

Utilizing GIS to Evaluate Base Schedules in Paratransit Operations

presented to and sponsored by the

North Carolina Department of Transportation
Research and Development
Public Transportation Division

prepared by the

Institute for Transportation Research and Education (ITRE)

August 28, 1998

Study Objectives

- ☆ Design a Methodology Using GIS to Evaluate the Efficiencies in Paratransit Base Trip Schedules
- ☆ Utilize Data from 3 Transit Systems to Test Methodology
- ☆ Refine Methodology
- ☆ Transfer the Technology

ITRE RLS

Study Tasks

☆ Master Database Was Created

- Subscription/Standing Orders
  - Paratransit Scheduling is Based on the Creation of Routes Based on Standing Orders, Then Insertion of Daily Demand Response Into Schedule "Slots"
- Selected Sample of Days
  - Drawn from Recent Operating Data -- Three (3) Sample Used

ITRE

Study Tasks

☆ Trip Origins and Destinations Were Plotted

- Sourcing the Base Map
  - Issues
    - Up-to-Date Address Ranges
    - Up-to-Date Street Information
    - Data Conversion
- Geocoding "Hit" Ratios
  - Varied from 75% to 100%
  - Necessitated Development of an Iterative Process with the Study Sites to Locate Trip Origins/Destinations That Could Not Be Geocoded

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Study Tasks

- ☆ **Scripting Tools**
  - ◆ Route Paths Are Created (Straight-Line Distance) Between Points
    - Not Street Networked
    - Street-Based Path Movements Not Available from the Case Study Sites
    - Resulted in Evaluation Process that Compared Straight-Line Actual with Straight-Line Proposed

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Study Tasks

☆ **Data Was Evaluated**

- **Researchers Successively Generated Route Plots for Given Time Periods of System Routes**
  - Example: Vehicle Movements on System Route 1, 6:00 A.M. to 8:00 A.M.
  - Route Plot Resided on Top Layer or Theme of the Map
  - All P/U and D/O Points Could be Displayed in Another Layer in Order to Demonstration Other Possible P/U or D/O Sequencing
  - Other Routes Could Then be Generating That Incorporated Candidate P/U or D/O Points

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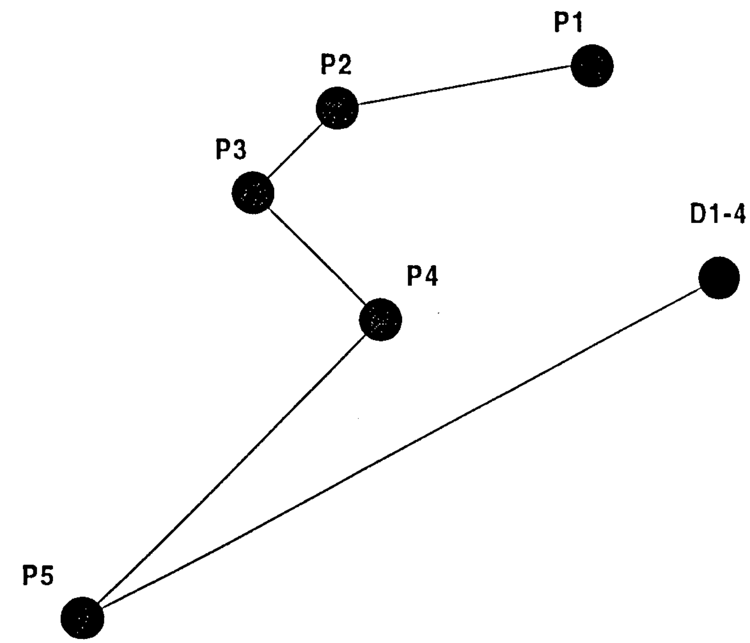
Study Tasks

- ☆ In the Illustration, a Typical Vehicle Sequence is Depicted
- ☆ Whereas P1 - P4 are in Close Proximity, Indicating a Well Designed Route, P5 Appears Well Off the Route Path
- ☆ P5 Creates the So-Called Starburst Effect



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Study Issues

- ☆ Starbursts Represent Time and Mileage
  - ◆ Added Operating Costs to the System
  - ◆ Added Passenger Inconvenience
    - Longer Ride Times
- ☆ Goal: Eliminate Starbursts and Backtracking

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Greensboro Evaluation Results

- ☆ Research Found 98 “Starbursts” Among the Sample Data
- ☆ At Least 46 “Alternative” Route Assignments Resulted in Estimated Straight-Line Distance Savings of Approximately 58.2 Miles

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Cleveland County Results

- ☆ The Location of the Operations Base Created Additional Level of Analysis
- ☆ Some Illogical Pick-Up Sequencing

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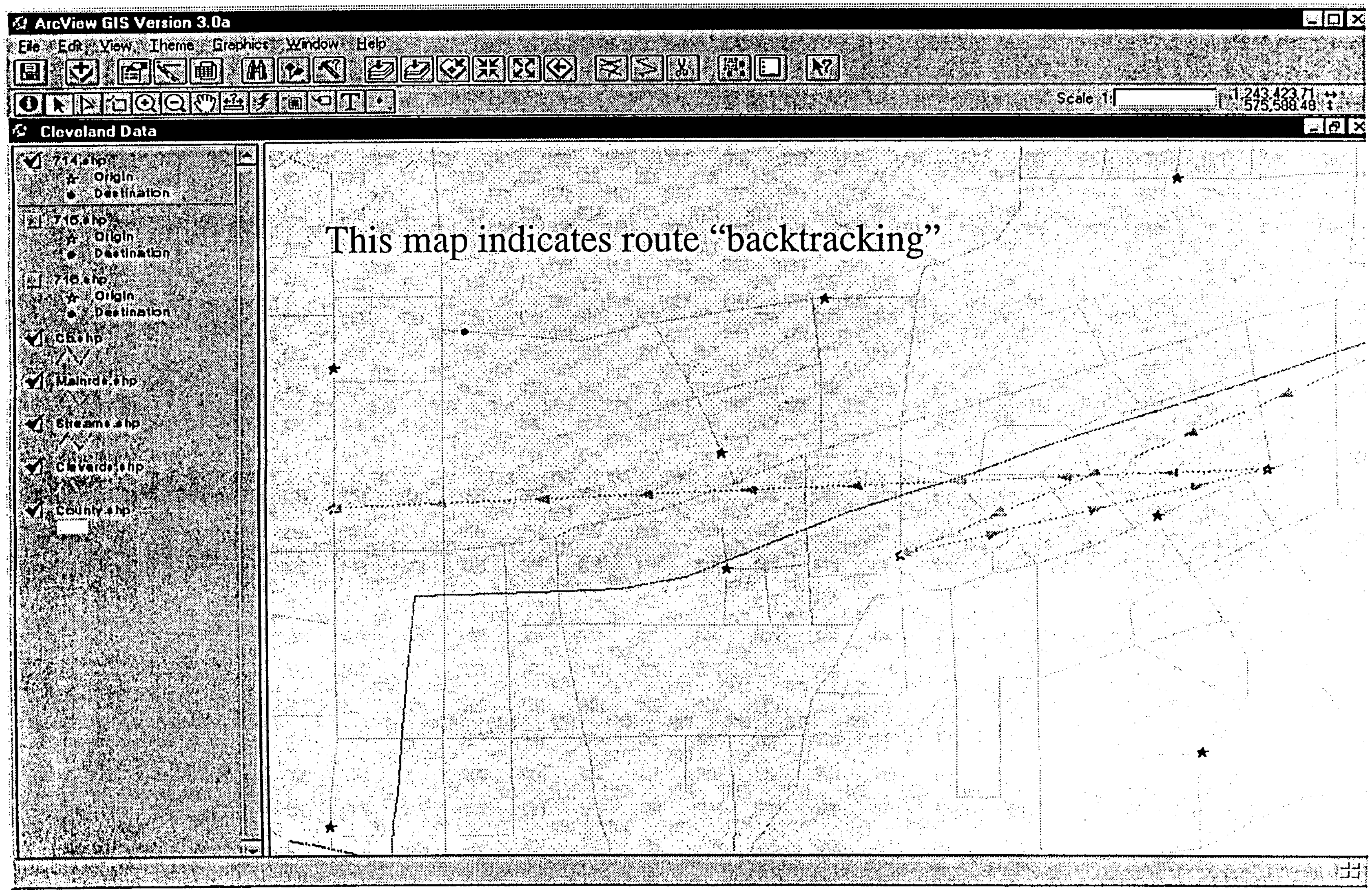
Finding Potential Problems



Other Barriers

- ☆ Lack of Street Addressing for All Highway Network Segments
- ☆ Use of Surrogate Addressing
- ☆ Data Provided With Incomplete Address Information
- ☆ Consistent Time Formatting in the Database
- ☆ Source Maps Not Current

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Conclusions

- ☆ Additional Research is Required to Eliminate Subjectivity in the Recognition of Starbursts
  - ◆ Additional Programming Could Produce Automatic Recognition of Starbursts and Automatic Calculation of Distances Between Segments
- ☆ Additional Local Parameters Must be Added to the Equation to Strengthen Research Conclusions
  - ◆ Pick-Up Windows
  - ◆ Maximum Travel Times

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Conclusions

- ☆ Low Cost GIS Desktop Products Can be Used to Conduct Comprehensive Evaluation of Complex Paratransit Schedules
- ☆ Work Conducted in the Project is Software Independent
  - ◆ ITRE Used Both MapInfo and ArcView to Conduct the Analysis