Finding the Fastest Route

A GIS Network Analysis Project

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ABSTRACT:

Routes and networks are the interconnected features that are used for transportation and include highways, railways, and city streets. Networks are an important part of everyday lives and analysis of these networks improves the movement of people, goods, services and the flow of resources. To demonstrate the use of network analysis, this project focused on determining the best route between two destinations based on a specific travel expense. For the purposes of this project, travel cost would be based on the length of time required to travel between locations A and B. A Geographical Information System (GIS) determined both the quickest and shortest routes between these locations. Data used by this project included public data and data generated using a Global Positioning System (GPS). TIGER street data provided the vector data necessary to conduct the network analysis but several data formatting problems existed that required correction. Once analysis was completed, a route representing the shortest travel distance and a route representing the fastest travel time were developed. From this project, it is important to remember that the shortest route is not always the fastest route since travel times are generally faster on major highways instead of residential streets.

INTRODUCTION:

People everywhere need to get somewhere else and are dependent on automobiles, buses, trains, subways, or airplanes to arrive at a final destination. Most people would like to arrive at a destination in the least amount of time, least number of stops, and lowest cost. Not only do these transportation issues concern individuals, but businesses and governments as well. Routes and networks are the interconnected features that are used for transportation and include highways, railways, city streets, rivers, transportation routes (transit, school buses, garbage collection), and utility systems (electricity, telephone, water, sewage). Networks are

an important part of our everyday lives and analysis of these networks improves the movement of people, goods, services and the flow of resources (Lo and Yeung, 2002).

Network analysis in GIS is often used to find solutions to transportation problems by using either vector or raster models to represent the real world. There have been numerous studies done on which model is more effective for network analysis. The vector-based model appears to be more suited to analysis of precisely defined paths such as roads and rivers. The raster-based model seems best suited for analysis of problems where paths are not pre-defined (Husdal, 2003).

The Network Analyst extension for ArcView solves problems of network traffic on streets, rivers, railroads, pipes, or any interconnected set of lines. It can find the shortest or fastest route between your origin and your destination, including all the stops along the way. It can tell whether one place is or is not linked to another hundreds of miles away. It finds the closest facilities to a location, such as the closest hospital to a vehicle accident and it identifies service areas, such as areas serviced by a bank. Network Analyst can also build spatial models of traffic flow (Ormsby and Alvi, 1999).

PROJECT DESCRIPTION:

To demonstrate the use of network analysis, a project was developed that focused on determining the best route between two destinations that was based on a specific travel expense. Travel expense could be represented by travel time, mileage, operating cost, or some other factor depending on the goals of the project. For the purposes of this project, travel cost would be based on the length of time required to travel between locations A and B. Factors influencing the length of time such as school zones, traffic lights, and rush hour traffic would be considered in the determination of the fastest route. The use of GIS to determine the quickest route between locations A and B was the primary goal of this project.

Several steps were necessary to reach the primary goal of this project and included:

- Evaluation and selection of the software that may be used

- Review of literature to determine how to conduct network analysis
- Acquisition of the data necessary for analysis
- Development of procedures to gather actual travel times
- Processing of acquired data to facilitate analysis
- Conducting the analysis
- Presentation of the findings

METHODS:

To conduct the actual network analysis, an appropriate software package needed to be selected. ArcGIS and ArcView, both developed by ESRI, were evaluated to determine which one would be able to efficiently solve this network problem. ArcGIS required a cost surface to be developed that was based on raster topology. The cost surface would then be analyzed to determine which route would be the fastest by using the Cost-Weighted Distance function found within the ArcGIS Spatial Analyst extension. ArcView on the other hand required a vector based cost surface to be developed and then relied on an extension called Network Analyst to derive the quickest route. After conducting a literature review of similar projects, it was discovered that this project was best suited to be represented using a vector-based model; therefore, ArcView with Network Analyst would be the best GIS software solution for solving the project.

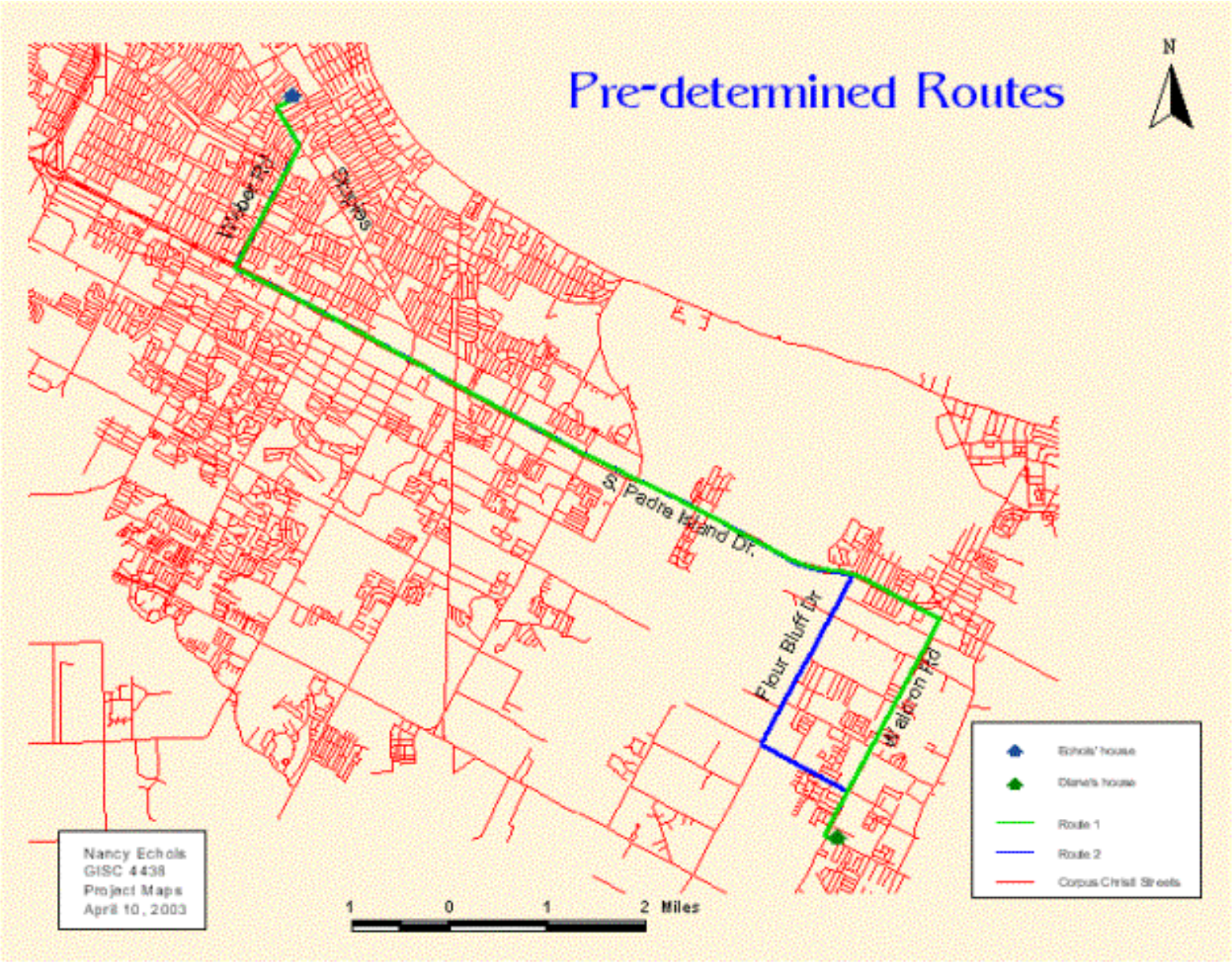

Figure 1. Pre-determined routes.

Originally, the proposed solution to this project involved the use of two pre-determined routes (Figure 1) that were thought to have similar travel time, which then would be analyzed using GIS in order to determine the quickest route. However, since one of the primary uses of the Network Analyst extension is to generate routes, the original project was modified so that the extension would be used to select the quickest route. The GIS selected route would then be compared to the travel time for the two pre-determined routes in order to assess the accuracy of the GIS route.

Data necessary for this project included data available from public sources and data that

needed to be gathered or generated. Public data was obtained through an Internet search of various federal, state, and private data clearinghouses including the U.S. Census Bureau, Texas Natural Resource Information Service, and ESRI. Road data was acquired from ESRI for Nueces County, Texas in the form of a TIGER file, which was based on the 2000 U.S. Census. The road data would be used to develop a cost surface for Corpus Christi, Texas, which would be used to develop the actual preferred route. U.S. Geological Survey Digital Orthophoto Quarter Quads (DOQQ's) for the city of Corpus Christi, Texas were obtained from the Texas Natural Resources Information Service, which were based on 1995 aerial photography. The DOQQ's would be used as a base file for overlaying other spatial data for the project. Metadata written for the TIGER file and the associated databases describing the TIGER data were acquired from the U.S. Census Bureau to help understand and utilize this type of data.

Data that needed to be gathered in order to facilitate GIS analysis included data for the pre-selected routes, locations of school zones, and beginning and ending locations for the route. A route data sheet for recording information pertaining to each route was developed and included:

1. A start time at point A and an end time at point B.
2. Any road conditions that would affect the analysis.
3. Number of miles traveled.

A data collection methodology was developed and included the speed to drive, time of day, where to drive, and the GPS file and system parameters. Each route was driven for 5 days and data was collected for each route.

A Trimble Pathfinder Pro XR GPS was used to collect the following point or line data:

1. Number of school zones and their locations, speed limit, distance, and times.
2. Distance and path of each route.
3. Location of point A and point B.

The standardized system parameters for collecting the GPS data included:

1. A single position collected each second for point files for a total of three

minutes. This generated 180 positions for a single location.

2. A single position collected every three seconds for line files.
3. A Position Dilution of Precision of less than six.
4. A satellite elevation mask of 15°.
5. Universal Transverse Mercator coordinate system and WGS84 datum

All GPS data was downloaded using the Pathfinder Office version 2.51 software and then exported as a shape file for use in ArcView GIS.

After researching other GIS projects that involved this subject it was determined that, most network analysis is done using TIGER street data. TIGER data included information for each street such as its type, travel speed, length, name, etc. One of the most important data fields in the TIGER file was the Census Feature Class Code (CFCC) (Figure 2). This three-digit code describes the purpose (highway, residential, etc.) and type (divided or undivided). For

Shape	Tlid	Fnode	Tnode	Length	Fedirp	Fename	Fetype	Fedirs	Cfcc	Fraddl
PolyLine	178519754	10291	10600	0.18270	S	Padre Island	Dr	W	A41	0
PolyLine	178519753	10225	10508	0.16466	S	Padre Island	Dr	W	A41	0
PolyLine	178519752	10225	10291	0.02797	S	Padre Island	Dr	W	A41	0
PolyLine	178519750	10085	10296	0.11040	S	Padre Island	Dr	E	A45	0
PolyLine	178520089	11371	11402	0.03122	S	Padre Island	Dr	W	A41	4786
PolyLine	178519747	9997	10085	0.04390	S	Padre Island	Dr	E	A45	0
PolyLine	178519746	9953	9997	0.02287	S	Padre Island	Dr	E	A45	0
PolyLine	178522621	13099	13120	0.25787	S	Padre Island	Dr		A35	7800
PolyLine	178519743	9998	9997	0.03149	S	Padre Island	Dr	W	A45	0
PolyLine	178546791	9998	10508	0.27478	S	Padre Island	Dr		A35	4200
PolyLine	178546795	10508	11162	0.47217	S	Padre Island	Dr		A35	4600
PolyLine	178546706	5730	5715	0.78539	N	Padre Island	Dr		A64	1998
PolyLine	178546708	5690	5722	0.22183	N	Padre Island	Dr		A64	0
PolyLine	178519739	10003	10035	0.02060	S	Padre Island	Dr	W	A41	0
PolyLine	178519757	10508	10296	0.10852	S	Padre Island	Dr	E	A41	0
PolyLine	178519742	9978	9998	0.01163	S	Padre Island	Dr		A35	0
PolyLine	178546804	11802	11513	0.37145	S	Padre Island	Dr	E	A64	4999
PolyLine	178519720	9910	10003	0.04972	S	Padre Island	Dr	W	A41	3966

Figure 2. TIGER CFCC table excerpt.

example, a U.S. Highway that is divided and without limited access has a CFCC code of A25. ArcView includes a CFCC table that gives each code a speed limit and an algorithm that will multiply that speed limit by the length of the road and give each road length a travel time

distance. After downloading the TIGER street data into ArcView, several problems were discovered that needed to be corrected. First, there were streets in the file that did not exist and had to be deleted from the file. If these streets were not eliminated, Network Analyst used them in its calculation for the quickest route, which would not be possible to drive since no road was actually present. Second, quite a few streets had CFCC codes that did not match the ArcView table. The streets that were lacking correct CFCC codes were primarily small private roads that actually existed but needed to have their appropriate CFCC code added so that a travel time could be calculated for each street. Third, the US Census Bureau had flagged a few roads as unknown. These roads were determined and the appropriate CFCC codes were entered into the TIGER file for each of them. Most of the street data corrections were based on first-hand knowledge of the area and only a limited amount of field verification was necessary. Fourth, the TIGER street data was provided in decimal degrees. This posed two problems including overlaying the data with data used for the base map and for correctly calculating the speed limits for each road segment. Since the DOQQ's and the GPS files that were generated were in NAD83 datum and UTM Zone 14N coordinates, the TIGER data had to be converted into the appropriate format so they could be overlayed on top of the base map. The speed limit for each road segment could not be calculated using decimal degrees and therefore needed to be converted to meters before the TIGER data being converted to

Cfcc	Descriptio	Speed_limi	Display_cl	Fcc
A35	Secondary and connecting road, State and county highways, separated	50	3	A35
A36	Secondary and connecting road, State and county highways, separated, in tunnel	50	3	A36
A37	Secondary and connecting road, State and county highways, separated, underpassing	50	3	A37
A38	Secondary and connecting road, State and county highway, separated, with rail line in center	50	3	A38
A40	Local, neighborhood, and rural road, city street	25	5	A40
A41	Local, neighborhood, and rural road, city street, unseparated	25	5	A41
A42	Local, neighborhood, and rural road, city street, unseparated, in tunnel	25	5	A42
A43	Local, neighborhood, and rural road, city street, unseparated, underpassing	25	5	A43
A44	Local, neighborhood, and rural road, city street, unseparated, with rail line in center	25	5	A44
A45	Local, neighborhood, and rural road, city street, separated	35	5	A45
A46	Local, neighborhood, and rural road, city street, separated, in tunnel	35	5	A46
A47	Local, neighborhood, and rural road, city street, separated, underpassing	35	5	A47

Figure 3. ArcView Speed Limit table excerpt.

projected data. If this were done after the conversion to projected data, the meter lengths would have been invalid. Lastly, it was necessary to edit ArcView's speed limit codes (Figure 3) so that they would coincide with the correct speed limits common to the main streets in Corpus Christi.

There were other considerations that had to be modeled before the GIS analysis could be undertaken. When time is used as the travel expense, many factors exist that affect the time required to travel between two points such as rush hour, school zones, one-way streets, closed streets, and construction. At the beginning of this project, analysis for only a certain time period was planned because of the difficulty of modeling so many factors at once. However, the Network Analyst extension made it easier to include additional factors when using time as the travel expense. It was necessary to model South Padre Island Drive (SPID) since travel could only occur one way in the east and west bound lanes. It was also necessary to include overpasses and left turns in the model because entry to and exit from SPID can only be accomplished at certain points. For the purposes of this project, only peak traffic on SPID, between 7:00 am and 8:00 am on the West bound lane and 4:30 pm to 6:00 pm on the eastbound lane was modeled. Peak traffic does affect many of the feeder roads, but it was not critical on the roads that were traveled for the route analysis. The last factor that was necessary to model was the school zones. Depending on the time of day, all roads leading to point B would travel through at least one school zone. Changing the road segments in the TIGER street data to the actual school zone road segments that were collected using the GPS proved to be very challenging.

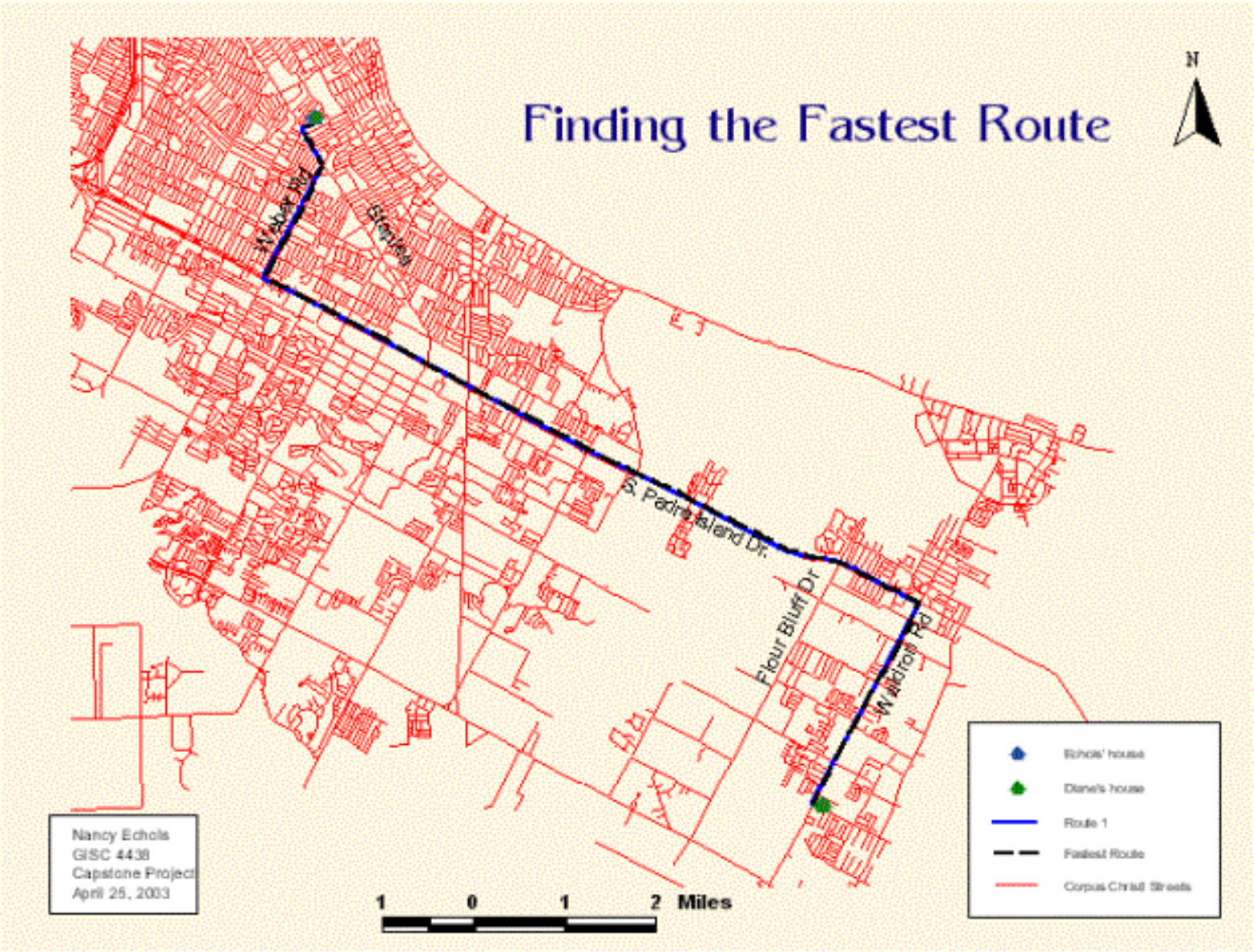

Figure 4. GIS selected fastest route compared to Route 1.

all the necessary factors were included in the street data, it was time to use the analytical abilities of the GIS to determine the fastest route from Point A to Point B. This process was accomplished in a matter of minutes. The route chosen by the GIS was ultimately the same as the pre-determined Route 1, which is normally driven. When a comparison was made between the number of minutes ArcView determined it would take to drive Route 1 and the time actually required to drive Route 1, the times were off by less than two minutes (Figure 4). Because the street information was already developed, the shortest route between Point A and Point B was also determined (Figure 5). The shortest route was remarkably different from

ArcView's fastest route and the two pre-determined routes. When the mileage was compared between ArcView's shortest route and the two pre-determined routes, the ArcView route was 2/10 of a mile shorter. While longer, the fastest route took advantage of highways and major streets that had faster speed limits. The shortest route used more feeder, secondary, and residential routes, which involved more traffic lights, stop signs, and traffic. The shortest route

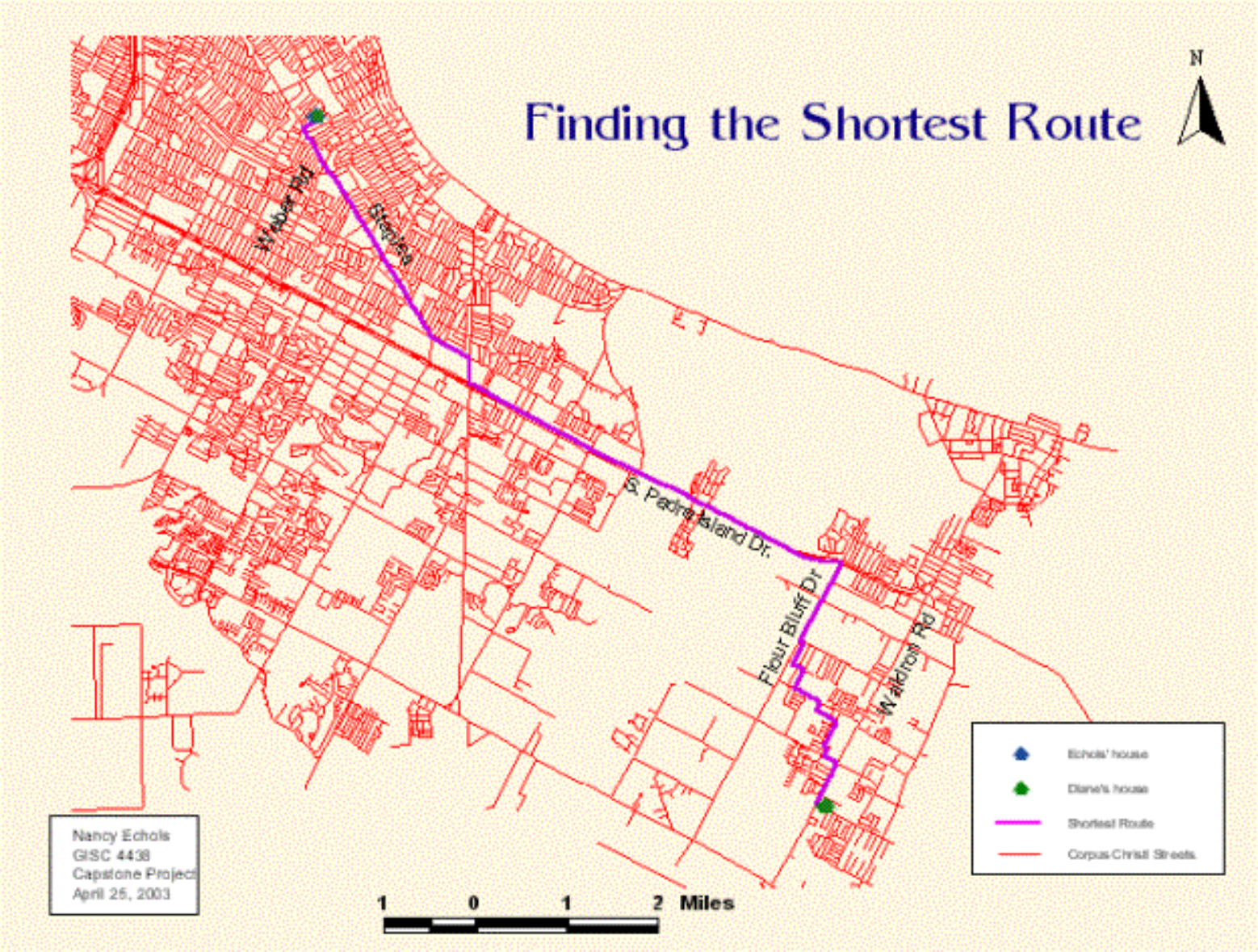

Figure 5. GIS selected shortest route.

was driven and compared to the fastest route in order to determine the time difference. The shortest route required an additional six minutes to drive. After observing the road selection difference between the fastest and shortest route, it is easy to understand why some routes

are selected when using a mapping program off the Internet to locate directions and a travel route. The algorithms that select the route are based on the shortest distance and not necessarily the fastest route. Final maps are presented in Appendix A.

The accuracy of the TIGER street data was suspect. Multiple errors were found and included streets that were present in the TIGER data but were not real roads, actual streets were not represented by the TIGER data, incorrect speed limits for CFFC codes, and CFFC codes that were mislabeled or missing. Ninety percent of this street information was corrected in the areas analyzed for this project. If the street information were to be used for other network analysis problems, further data correction would have to be conducted.

CONCLUSION:

Network analysis is a widely used application of GIS and is used by emergency services, utility companies, regional transportation authorities, railway companies, and city services to name a few. This type of analysis can be used to find not only the shortest and fastest routes but also modeling hydrologic flow, traffic flow, delivery routes, service areas, directions, and the closest facility. Roads are not the only network that can benefit from GIS analysis but also pipelines, sewer lines, and rivers. It was necessary for this project to conduct a limited amount of groundtruthing for the street data, but if the network analysis was used for emergency services dispatch it would be critical that all TIGER street data be current and correct. This project provided two different routes, a fast route, which happened to be the same as pre-determined Route 1 and a short route, which happened to be different than either of the two pre-determined routes. Therefore, it is important to remember that the shortest route is not always the fastest route since travel times are generally faster on major highways compared to residential streets.

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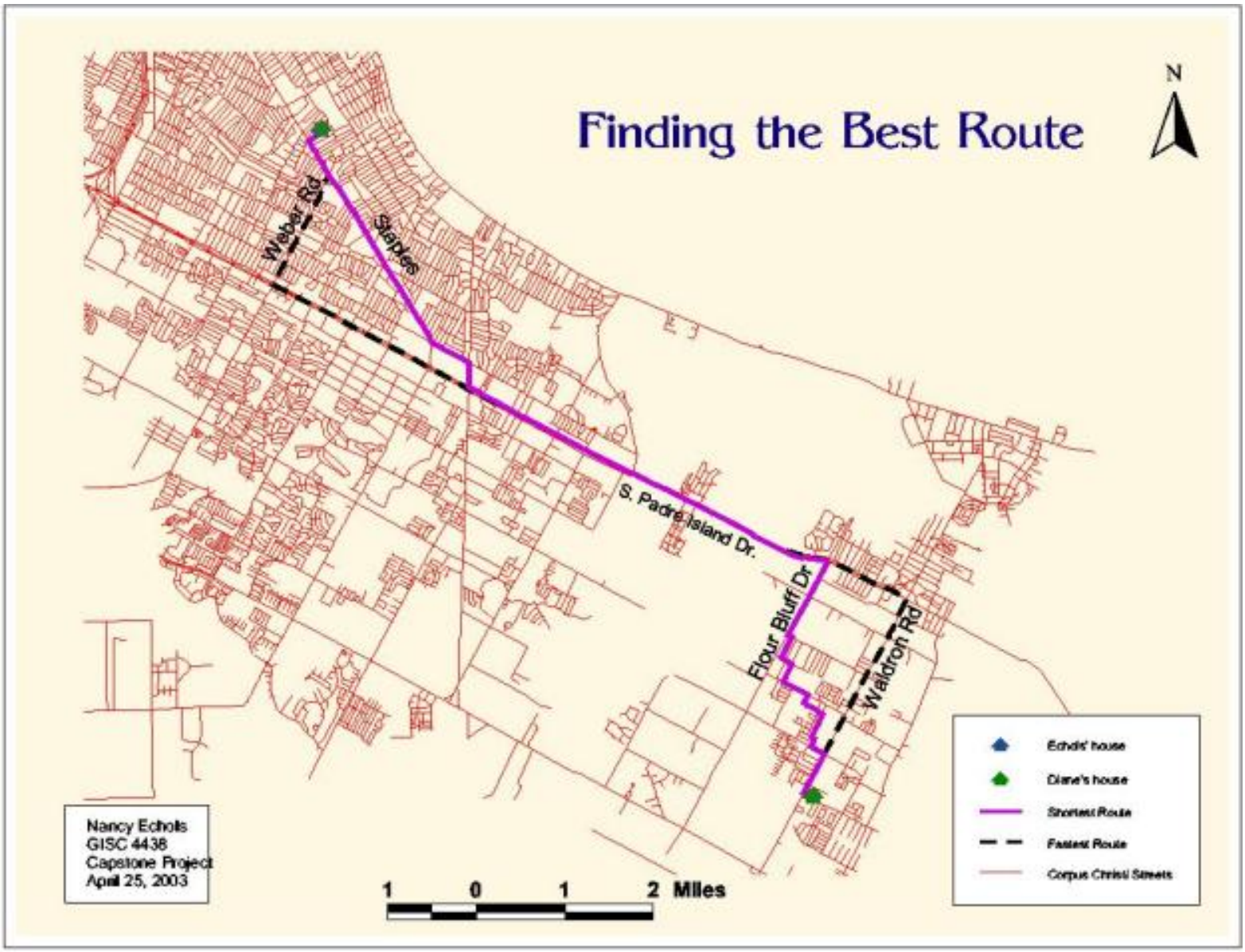
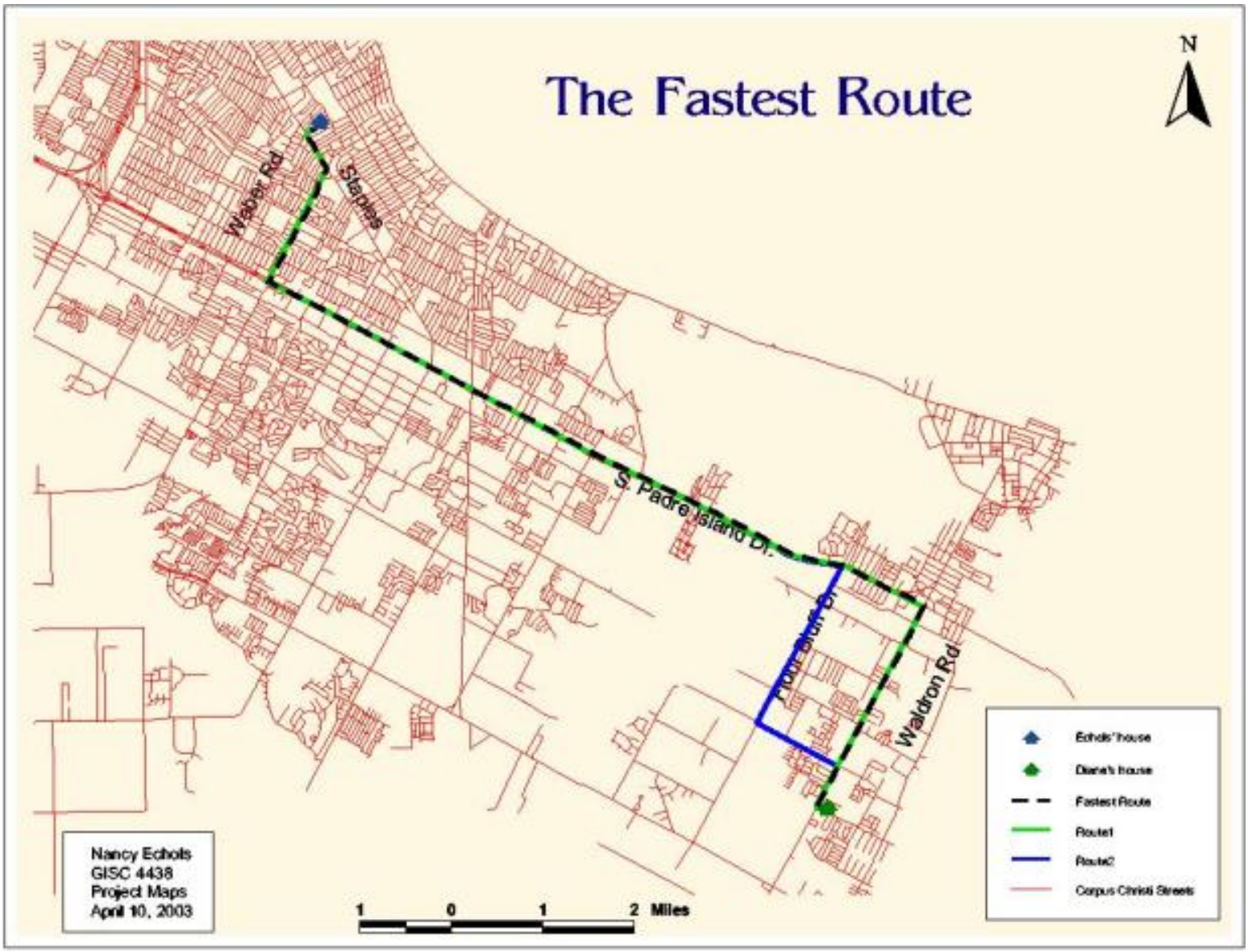
APPENDIX A:


Finding the Best Route
N
Weber Rd.
Staples
S. Padre Island Dr.
Flour Bluff Dr.
Waldron Rd.
Echols' house
Diane's house
Shortest Route
Fastest Route
Corpus Christi Streets
Nancy Echols
GISC 4438
Capstone Project
April 25, 2003
1 0 1 2 Miles


The Fastest Route
N
Weber Rd
Staples
S. Padre Island Dr.
Waldron Rd
Echols' house
Diane's house
Fastest Route
Route1
Route2
Corpus Christi Streets
Nancy Echols
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Project Maps
April 10, 2003
1 0 1 2 Miles