2001

An internet map server based transit trip and rideshare information program

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AN INTERNET MAP SERVER BASED TRANSIT TRIP AND RIDESHARE INFORMATION PROGRAM

A Thesis

Presented to

The Faculty of the Department of Geography

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

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May 2001

UMI Number: 1403975

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ABSTRACT

AN INTERNET MAP SERVER BASED TRANSIT TRIP AND RIDESHARE INFORMATION PROGRAM

by Antony Jayaprakash

The rapid growth of the Internet over the last few years has opened new possibilities for communicating with and generating customized information for a large number of users. This thesis addresses the feasibility of using the latest developments in Internet GIS technology to balance the conflicting needs of mobility and clean air around San Jose State University. A prototype for an interactive web-based transit trip planning and rideshare match list application is developed to study the development and implementation issues. The application will provide users with a customized transit trip plan and rideshare match list in the form of interactive maps and in text format. While this study brings to focus the cumbersome data preparation and integration issues, the benefits reaped from such an application outweigh the investment of time and money.

ACKNOWLEDGEMENTS

Numerous people were directly and indirectly involved in the completion of this work. First, I have had the pleasure of having Dr. Richard Taketa as my thesis advisor. His encouragement and suggestions have been greatly appreciated throughout the process. I must also thank other members of my committee, Dr. Earl G. Bossard and Mr. Eyedin Zonobi for their helpful comments. The input from all the members of the committee has greatly improved the quality of the completed thesis. My thanks are due to the entire faculty of the Geography Department and friends at San Jose State University for their suggestions and support during the entire project period.

I take this opportunity to thank my parents for their continuous support and encouragement throughout this work.

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CHAPTER 1
INTRODUCTION

The United States has the largest transportation system in the world. It serves two hundred and sixty million people and six million business establishments spread over the fourth largest country in the world (BTS 1997). Mobility is a growing issue in many communities. Roadways are becoming increasingly crowded with single occupant vehicles. Rising traffic congestion and air pollution have caused many organizations to seek solutions, such as encouraging solo drivers to share their vehicles with passengers who might otherwise be solo drivers themselves. Many city and county agencies have found that with the right approach and tools, the conflicting needs of people to move and breathe clean air can be met. A trip reduction program consists of a variety of actions for encouraging people to reduce the frequency and the distance of solo commuting. Transportation alternatives include riding transit (bus, light rail and heavy rail), carpooling, vanpooling, bicycling, walking or telecommuting. Tools like Geographic Information Systems (GIS) and the Internet are becoming more and more familiar to the nation's policy makers, planners, analysts and researchers as effective ways to manage traffic congestion, traffic safety and air quality.

Background

Passenger travel nearly doubled in the United States between 1970 and 1995, growing by an average of 2.7 percent a year. Passenger-miles per person increased during this time from 11,400 miles to 17,200 miles. In terms of absolute-miles traveled, the rise in automobile use overshadowed all other modes, growing by over one trillion passenger-miles during this period. Passenger-miles in light duty trucks, including pickups, sport utility vehicles, and mini-vans grew nearly fivefold (BTS 1997).

The cause for this extraordinary growth in passenger travel cannot be explained simply by the growth in the U.S. population, which rose by only 28 percent during the 1970 to 1995 period, as travel soared by 95 percent. Rather, changes in the labor force, income, the makeup of metropolitan areas, and other factors increased travel. Table 1 shows the percentage change in the passenger-miles traveled and the factors that affected travel demand between the years 1970 and 1995 (BTS 1997).

Table1. Changes in Passenger-Miles Traveled between 1970-1995

Factors	**Percentage increase 1970–95**
U.S. population	29.0
Metropolitan population	48.9
Disposable personal income	56.0
Number of households	56.1
Number of workers	58.8
Number of Automobiles and light trucks	86.1
Passenger- miles traveled	95.3

The nationwide personal transportation survey found that in 1990 employed persons with a drivers license drove an average of 15,280 miles compared with 8,048 miles for those who were unemployed. From 1970 to 1995, the number of households increased by 56 percent, nearly twice as much as the increase in population would suggest. The reason for this increase was due to the decrease in household size from 3.14

people in 1970 to 2.65 in 1995. More households translate into more trips for shopping, recreation, and taking care of children's needs. Increases in the number of motor vehicles also contributed to the growth in passenger-miles. The number of automobiles and light trucks grew from 107 million in 1970 to 191 million in 1994. This increase is partly related to the income growth. Disposable personal income per capita rose from $9,900 in 1970 to $14,700 in 1994 (in constant 1987 dollars). When people have more money to spend, they spend more on transportation, particularly on personal vehicles and long-distance travel.

San Francisco Bay Area

Congestion on San Francisco Bay Area freeways increased by 24 percent since 1996 (HICOMP 1998). Congestion is defined as a condition where the average speed drops below 35 mph for 15 minutes or more on a typical weekday. On a typical weekday in 1998, commuters spent an estimated 112,000 vehicle-hours in congestion, costing motorists about $1,249,000 per day (HICOMP 1998). All counties in the region experienced an increase in congestion, with the greatest increases occurring in Alameda and Santa Clara Counties. Congestion regularly occurs at 145 different freeway locations each day, affecting 327 directional miles of freeway. A one-mile length of freeway has two directional miles, irrespective of the number of lanes.

In spite of the completion of major highway improvements, regional freeway congestion has continued to grow. Overall daily delays in the Bay Area are almost twice the 58,600 vehicle-hours of delay per day recorded ten years ago, when the 1988 HICOMP report was released. At that time, the daily cost of delay was estimated to be $548,000 (HICOMP 1998). One of the more apparent effects of increased congestion is the expanded duration of commute periods. In many locations, peak periods now last up to five hours.

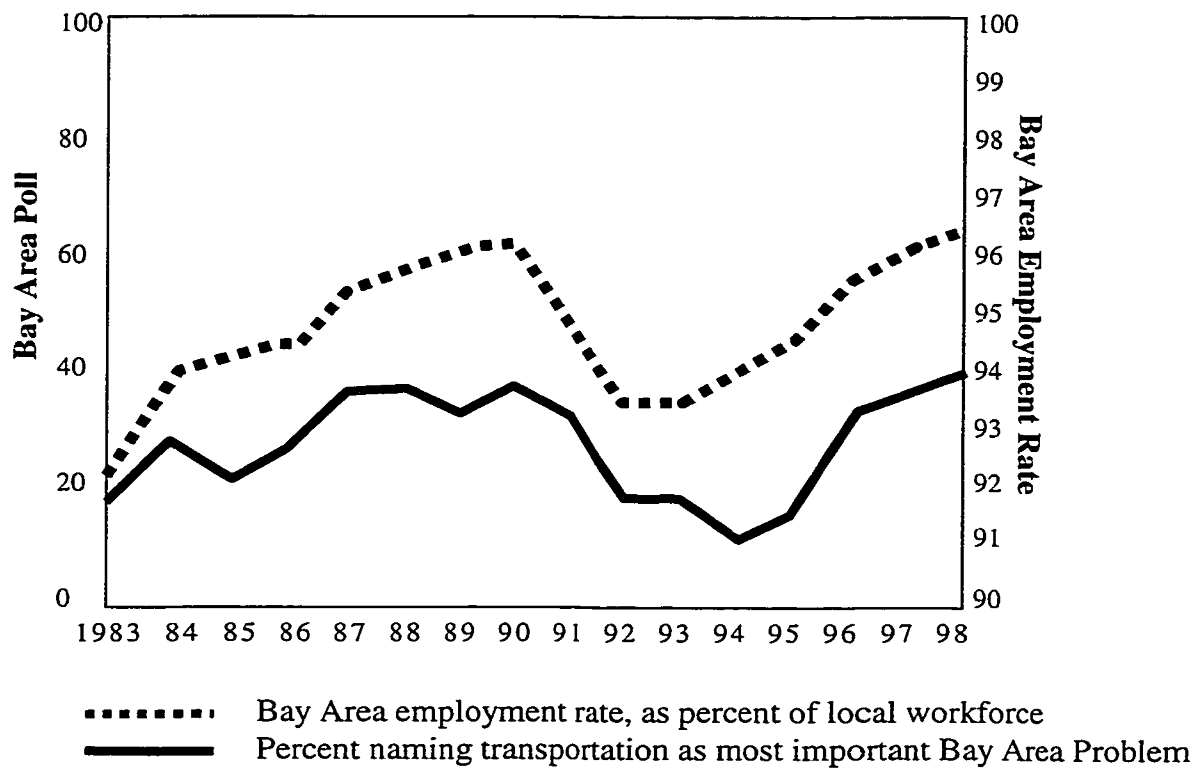
In 1995, the United States Environmental Protection Agency (EPA) named the San Francisco Bay Area as the largest metropolitan area in the nation to meet the Federal Clean Air Act's health standard for smog-forming ozone. Less than four years later in July 1998 the EPA declared the Bay Area out of compliance with federal clean air ozone standards. This will limit the region's access to federal Congestion Mitigation and Air Quality Improvement Program (CMAQ) funds, which are tied to pollution classifications.

Santa Clara County

Congestion in Santa Clara County during 1998 increased by about 8,800 vehicle-hours of delay compared to the year 1996, representing an increase of about 43 percent in the two-year period. Most of this increase occurred during the evening commute, with southbound Route 101 between Great America Parkway (Santa Clara) and Tully Road (San Jose), and northbound Route 101 from Route 237 (Sunnyvale) to University Avenue (Palo Alto) experiencing the longest delays. Several locations on Route 87 and Route 680 also experienced large increases in delay during the evening peak, as did southbound Route 280 from Page Mill Road to Magdalena (HICOMP 1998).

In the latest Bay Area Poll, released by the California Employment Development Department 1998, a record 40 percent of respondents identified transportation as the most important problem of the region.

Figure 1. Transportation Frustration Tracks Economy



The past 16 years' survey results indicate that there is a close correlation between this opinion and the Bay Area economy, as measured by the percentage of workers employed. As the economy grows, so do the problems and dissatisfaction with transportation. Figure 1 shows the relation between the frustration regarding transportation and the growing economy as reported by the Bay Area Poll, California Employment Development Department 1998.

Building more roads will not solve all the problems associated with the ever-increasing car ownership. Means have to be found to manage the existing road network better and promote alternative means of transport. On any given weekday, about 350,000 students arrive at Santa Clara County K-12 schools, colleges and universities. Although these commuters represent a substantial number of single occupant vehicle trips, the schools have historically been overlooked by the transportation demand management initiatives and are underrepresented compared to the large number of employers in Santa Clara County.

San Jose State University

San Jose State University (SJSU) is the oldest institution of public higher education in the state of California. SJSU is located within the downtown corridor of the City of San Jose. During the Fall semester of 1998 SJSU had an enrolled student population of 26,628 and staff/faculty of 1,897 members, as well as an Open University program that serves over 2,000 professionals in the county. SJSU is one of the most visited sites in downtown San Jose. In addition, this campus is considered a commuter school, with the majority of its trips starting not in the downtown corridor but throughout the Bay Region. The SJSU area experiences some of the worst traffic congestion in Santa Clara County. SJSU attracts over 8,000 cars each day to the campus. The ability of Santa Clara County's street, freeway, and public transportation systems to accommodate travel in the face of continuing population growth is a concern of many Santa Clara residents.

Another issue is the effectiveness of proposed transportation facilities in attracting new users and reducing congestion.

The Associated Students (AS) of SJSU through its Transportation Solutions Program (TSP) encourages students to use alternative modes of transportation and reduce the number of single occupant vehicles to the campus. Public transportation and ridesharing are popular alternatives among SJSU students, as more than eighteen bus lines and a light rail connect SJSU with the much of Santa Clara county and also due to the limited parking space in the campus.

This study focuses on the design, development and implementation of an interactive web-based transit trip planning and rideshare tool. The latest developments in web-based GIS technology are used to develop the application. The study is divided into two sections: first, the development of the web-based application and second, exploring the constraints and issues involved in developing and implementing the application. The application helps students plan their trip based on an origin and destination by providing information such as the bus line to take, the nearest bus stops and the schedule. The rideshare module helps students find rideshare partners. The issues relating to data preparation, database design and implementation details are also discussed.

CHAPTER 2

TRANSIT AND RIDESHARE INFORMATION PROGRAM (TRIP)

Interactions between a city and its universities are unique. Trip generation rates are higher and bicycle use is very high (BTS 1997). With the traffic situation around San Jose, limited parking in the campus, alternate modes of transportation like public transport and ridesharing are the best options to reach the campus. Table 2 details the distribution of parking facilities at SJSU.

Table 2. Parking Facilities at SJSU

Space Designation	Number of spaces
General/Students	5,704
Employees	1,080
Repair Permits	69
Disabled	177
Special Purpose	465

The concentration of classes during particular hours of the day also increases the demand for the limited parking spaces. The geographic distribution of the students of SJSU indicates that transit would be a good commute mode to reach the campus. The addresses of the SJSU students enrolled during the fall semester of year 2000 were geocoded and then overlaid on top of the transit line data. The aggregated results indicate that a significant 31 percent of the students are within one-quarter mile of at least one of the nineteen transit lines that directly connect SJSU without any transfer to another bus.

Present Process

The Transportation Solutions Program of Associated Students has been encouraging students to take alternate modes of transport such as transit, rideshare, and bike. The Transit Access Program (TAP) provides a transit pass to every registered student of SJSU. This pass entitles the students to free unlimited rides on all buses and light rails operated by Valley Transportation Authority (VTA). The SJSU parking garages have guaranteed parking spaces for students who share their ride. The TSP center assists students with personalized trip plans, transit schedules route maps, and rideshare match lists. TSP also manages the bike enclosures. The center has been providing useful information but the process could be more efficient.

The process of locating the student address on the route maps and finding the nearest bus service is a cumbersome process and the problem tends to be perpetuated when a transfer point (i.e., more than one bus) is involved. One of the problems includes the difficulty in finding the origin, destination or other desired locations on the available route maps. The bus route maps usually include only the portion of the region's road network that pertains to the particular route. However, accurately pinpointing one's location in relation to the closest bus stop may require a complete road map of the region along with the route map. Another problem is the general difficulty in determining a suitable route using the information available. The same problem persists in making rideshare matches; identifying the group of people who live in the same vicinity and keeping track of these rideshare groups is a cumbersome process. The student assistants at the TSP center help the students with this task using various resources such as the VTA system map and the Thomas guide road maps.

SJSU is an example of a large, closed environment where potential commuters have multiple, highly variable schedules and a financial incentive to arrive at the campus without a car. Additionally, the university community of students and faculty has a high level of technological sophistication, where most potential users are computer literate and have access to multiple communications technologies. This access is very critical in the implementation and success of advanced trip planning and ride sharing technologies (Ayland 1991). This combination of variable schedules, computer literacy, and access to multiple communications media makes this population a reasonable representation of future work environments for employees of large agencies and an ideal test-bed for introducing alternate commute choices. The capability of Geographic Information Systems in creating, storing, and analyzing spatial information coupled with the reach of the World Wide Web (WWW) could be an ideal solution for an interactive web based GIS application.

Geographic Information Systems

A commonly accepted definition of GIS is a system of hardware, software, data, resource people, organization and institutional arrangement for collecting, storing, analyzing and disseminating information about areas of earth (Dueker and Kjerene 1989). According to Berry (1993), a Geographic Information System is designed to accept large volumes of spatial data stemming from a variety of sources. Further, due to its capability of handling both spatial and attribute data, GIS has become an invaluable tool in the decision making process. GIS technology involves as many definitions as uses (Antenucci 1991). As a technology, GIS has evolved through three broad application domains. The first is the use of GIS as an information database, a means of coordinating and accessing geographic data. The second is the use of GIS as an analytical tool, a means of specifying logical and mathematical relationships among map layers, i.e., modeling to yield new derivative maps. The third is the use of GIS as a decision support system, a means for deciding how to act upon the results of the analysis. With the development of GIS, we now have the opportunity for a more explicitly reasoned process of land use evaluation. GIS is capable of managing large volumes of both spatial and non-spatial data while providing interactive tools for visualizing and analyzing spatial relationships within these data.

GIS and Transportation

In recent years, GIS have become widely available to public transit agencies. These sophisticated computer information systems once available only on large mainframe computers have gradually migrated to workstations and personal computers. A GIS can store, manage, analyze, and display a wide range of geographic, demographic, and facilities data in a variety of formats. Various transit agencies have begun to use GIS for numerous services planning tasks as well as the basis for a more general corporate database. These systems can provide both departments and riders with information about the agency's services and facilities.

Geographic Information Systems provide a promising tool to upgrade both the data availability and analysis capabilities of the typical service and operations of the planning staff. These tools are likely to become increasingly available and affordable. Because of the spatial nature of most transportation data, professionals found GIS to be a powerful tool to construct and analyze transportation networks, to conduct impact assessment of transportation facilities, and to integrate transportation and land use planning. GIS gives engineers the data-based means to encourage people to reduce their dependence on new roads, to stop driving alone and ride in carpools, use public transit, ride bicycles, stagger work shifts. GIS can help plan their trip, match car-poolers by where they live or work, and even by whether they prefer to ride or drive.

Internet, GIS and Transportation

The Internet has greatly improved the accessibility and transmission of all types of information, including transportation information. The Internet and GIS have changed the ways transportation professionals access, share, disseminate and analyze data and information. Data providers, including government agencies and private organizations, are discovering the convenience of publishing and disseminating transportation information on the World Wide Web and many have set up their own Web sites.

Internet GIS is a new technology that is used to handle spatial data on the Internet. It is a network-centric GIS tool, which uses the Internet as a means to access and transmit data, and analysis tools to enhance the visualization and integration of spatial data. It has new features that allow transportation agencies to publish spatial data on the network for public access. This allows transportation professionals to easily share data and to conduct transportation analysis across a network as well as at an individual site.

Features of Internet GIS

Internet GIS has features that have promising transportation applications through the ubiquitous accessibility possible over the Internet. Users do not have to buy expensive GIS software in order to access GIS data and analysis functions over the Internet. This makes it easier for transportation agencies to disseminate transportation information to the public. The user-friendly interface of Internet GIS can also facilitate data sharing within and between transportation agencies.

The second feature of Internet GIS is its ability to provide interaction between the users and the spatial data. Internet GIS offers interactive maps rather than static map images on the Web. Users can work with the maps interactively by performing conventional GIS functions such as zoom, pan, identify and query. The maps are alive on the Internet.

The third feature of Internet GIS is that it can incorporate up-to-date, real-time information. This is important for the applications in intelligent transportation systems. Several applications have been developed that display real time traffic information, transit information and trip planning by linking Internet GIS with automatic vehicle locators.

Internet GIS provides a perfect tool to access, disseminate, and visualize transportation data. Any information that can be displayed on a map such as highway and transit traffic, construction conditions, and weather information can be transferred using Internet GIS. It also offers the potential for data sharing and transportation analysis over the Internet. This thesis explores the feasibility of implementing an Internet based GIS application for transit trip planning and rideshare match list for the students of SJSU.

Transit and Rideshare Information Program

The intention of the present work is to provide customized information about transit and rideshare opportunities. Traditional systems provide a trip plan or match list through paper mail, a process that may take more than a day. For these reasons, the need for an interactive rideshare matching and trip-planning application is more demanding than those for a traditional manual process.

The core focus of this application is to create a user-friendly system that allows for maximum accessibility to the students of SJSU. The Transit and Rideshare

Information Program is a MapObjects Internet Map Server (MOIMS) application for the students of SJSU. TRIP is designed to help reduce the number of single occupant vehicles arriving at or leaving the campus and ease the congestion around SJSU by providing interactive trip planning and rideshare tools on the Internet. The Internet not only increases the accessibility to information, but can also provide an interactive and user-friendly interface through the World Wide Web. The spatial analysis capabilities of GIS and the reach of the Internet make it an ideal combination. The application will provide information about rideshare matches and transit trip plan pertaining to the most efficient route for a given origin and destination, the nearest bus stop, transfer location, and the schedule.

CHAPTER 3
IMPLEMENTATION

The Transit and Rideshare Information Program is designed to be a complete transit trip planning and rideshare matching system. It is capable of providing information for those with traditional needs as well as for those with variable schedules and occasional needs. TRIP is designed to be accessible through the World Wide Web. This design decision was driven by two features of the WWW, the popularity of the WWW along with the wide availability of free browser software and its availability twenty four hours a day, seven days a week. These two features ensure that TRIP can be delivered to a larger audience at the individual user's discretion and convenience. These features were also deemed necessary to entice interest in sufficient number of users to use the system. The application contains two components: the user interface and the map server application. The user interface consists of a form for filling out the information about the student and the trip. The map server application locates the origin and destination on the map, finds the best bus route or carpool match list and generates personalized web pages depending on the user preferences.

The System

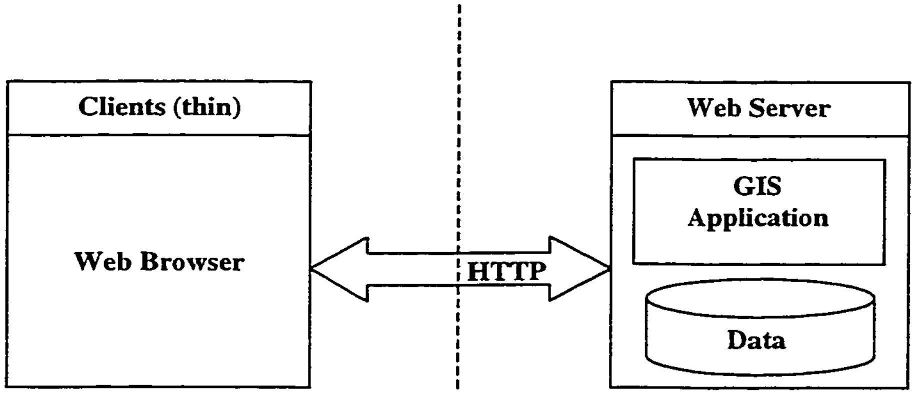
The present application would be part of a comprehensive transportation solutions program website of Associated Students, SJSU. A registered student of SJSU who wishes to have a trip planned, or would like to rideshare has access to the system by providing his SJSU student identification number. A student identification number is a unique number assigned to every registered student of SJSU. Once the authenticity of the student identification number is verified, the student is provided with an online form that collects information about the trip.

The user is directed to a corresponding map service, depending on the user's interest for a trip plan or rideshare. For a trip plan, the location of origin and destination is verified and a trip plan is generated. For ridesharing, a match list is generated after verifying the location of origin.

System Architecture

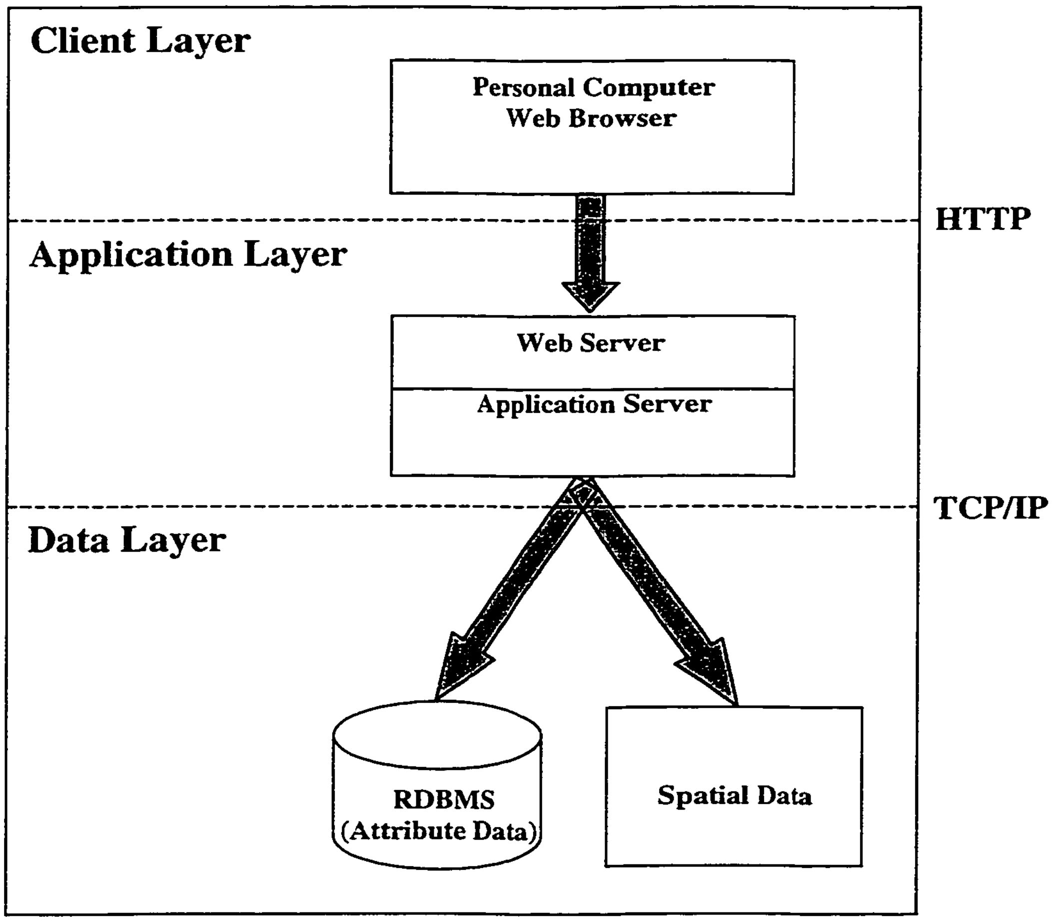
The architecture adopted for this development is the server-side architecture with a thin client (fig. 2). In server-side architecture, the user sends a request to a server, and the server processes the request. The results are sent back as a Hyper Text Markup Language (HTML) page via standard Hyper Text Transfer Protocol (HTTP).

Figure 2. A Server-Side Architecture



A generic web browser can view this HTML page. In server-side Internet GIS applications, all the complex and proprietary software, in addition to the spatial and tabular data, remain on the server. This architecture has several advantages because the application and data are centralized on the server. These advantages include simplified development, deployment, and maintenance. The system is designed with three distinct components: a server application, a client interface, and a data repository. It conforms to multi-tier architecture typical of server-side Internet applications (fig. 3).

Figure 3. Multi-Tier Server Side Architecture



The client layer consists of a personal computer running a Web browser. This layer provides the user interface, operates by generating requests to the application server via HTTP, and displays the resulting HTML file in a Web browser. The middle layer is itself a layered system consisting of a Web server layered on an application server. The Web server receives requests from the client, which is processed by the application server's Web administration module, then passed to the application server. The application server makes requests to the data layer via Transmission Control Protocol and Internet Protocol (TCP/IP) and Open Database Connectivity (ODBC). The data layer is a data repository consisting of a Structured Query Language (SQL) compliant database, and one or more directories of flat files in Environmental Systems Research Institute (ESRI) shapefile format.

Software and Tools

Table 3 lists the software and tools used for the application development and deployment.

Table 3. Software and Tools Used

Software and Tools	Function
Windows NT server	Web server operating system
Visual Basic Version 6.0	Application development
ESRI MapObjects 2.0	Application development
Microsoft Access 2000	Database
Microsoft Internet Information Server	Web server

Table 3 - *Continued*

Software and Tools	**Function**
MapObjects Internet Map Server	Map/Application server
Windows 95/98/NT clients	Client operating system
Internet Explorer or Netscape Navigator	Client browser
ArcView, Version 3.2	Data Creation
MS Visual Interdev Version 6.0	Integrated development environment
Active Server Pages (ASP)	Server side scripting
JavaScript	Client side scripting
Hyper Text Markup Language (HTML)	Web page authoring

MapObjects is a collection of embeddable mapping and GIS components developed by Environmental Systems Research Institute. MapObjects consists of an ActiveX control, a collection of more than 45 programmable ActiveX automation objects that let application developers add mapping and GIS capabilities to applications. MapObjects can be used with a variety of industry-standard programming environments such as Visual Basic, PowerBuilder, Visual C++, and others. MapObjects plugs directly into these environments, allowing rapid application development. MapObjects Internet Map Server is a collection of components that manage Web client requests, dispatch and broker requests to Web server mapping applications, and deliver maps and data via the Internet.

Database development

The first step in the development of a GIS project is to identify the data influencing the problem. The data is then created or compiled depending on the analysis. TRIP involves both spatial and non-spatial data.

Spatial Data

The geographic data is used for analysis and to display customized maps. Because ESRI's MapObjects and MapObjects IMS are the primary development software used, the file format for geographic data follow the ESRI shape file format. The geographic data include the street network of California, individual bus routes, bus stops and a route network of VTA transit routes.

California Street Network. The California street network base map provides the core geographic data for the application. It is used to create individual bus routes, display street maps to users and provide geocoding capabilities. The street network was extracted from GDT's DynaMap 2000. Interactive street maps with GIS functions such as zoom, pan, query, and identify are especially useful for Internet display. Users can zoom into or out of a specific area, locate a specific address and identify particular road links. This electronic map on the Internet is more convenient to use than traditional paper maps. The distribution of Internet maps is also much broader than the paper maps generated by transportation departments. Anyone with a web browser can get immediate access to a road map of any portion of a state they are interested in.

Individual Routes and Route Network. Like the street network, individual route information allows specific routes to be displayed as needed by the analysis results. Individual routes are also used to create the entire route network and allow for easy maintenance of the network if one route of the network requires alteration. Digitizing bus route over the road network and saving it independently created shape files for the individual routes. The individual routes were then merged together into one shape file to create the route network. The route network is used to identify the transfer points and to create bus stop maps, which are mostly the intersection of the streets and the travel path of bus routes.

Bus Stops. The bus stop map is used to identify the location of the closest bus stops to the user's specified origin and destination. In addition, these points help the users with the location of bus stops where they would start or end their transit trip. The bus stops data were created by digitizing the stops on the street network. Each street intersection that has a bus stop is given a unique identifier. This unique identifier helps in locating the bus stops and aggregating the transit lines served at a particular bus stop.

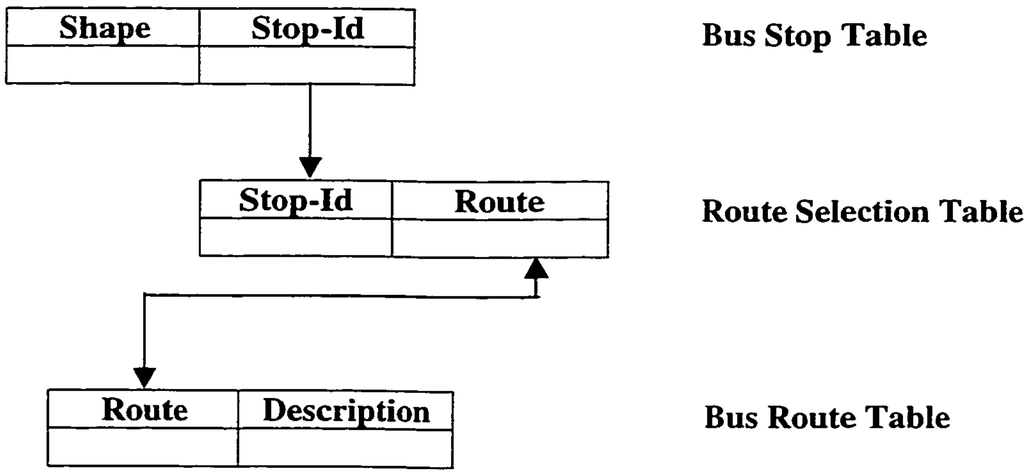
SJSU Student Data. The geocoded student information forms the base data for generating rideshare match lists. The spatial distribution of the students' data is created by geocoding their addresses over the street network. Geocoding is the mechanism that uses addresses to identify locations on a map. Even though an address is a text string containing information of house number, street name, direction, and zip code, it specifies a location in the same way that a geographic coordinate does. The process of address geocoding calculates the geographic coordinate for the address, which can be used to display the location on a map based on the assigned coordinates. The process involves associating addresses stored in tabular data files to a street network (i.e., data source) and calculating the coordinates for the addresses from this data source. The process of geocoding enables spatial analysis to be performed on the student data. The geocoded information is saved as an ESRI shape file format. This shape file forms the base data for generating rideshare match lists.

Attribute Data

VTA Schedule Database. One of the important elements of this application is the schedule database, which contains information for the entire bus schedule, data of time points (which are the bus stops provided in the schedule booklet), and descriptions of routes and time points. This database was created in Microsoft Access and is used for finding the shortest bus route and to provide schedule information to the students. This database is a relational database of multiple tables rather than a single flat table. The tables are related to each other through the information they contain. The relationship is established by the relational database concept of a primary key and a foreign key. These keys link the tables together and are used to search for information throughout the database.

The database contains three tables. They are the route selection table, the bus route table, and the bus stop table. The route selection table contains the entire schedule for each trip of each route. The bus route table includes the information related to routes such as route names, descriptions and their availability during the week. The bus stop table contains data related to bus stops such as stop-ids, descriptions and transfer possibilities. The links between the database tables is shown in figure 4.

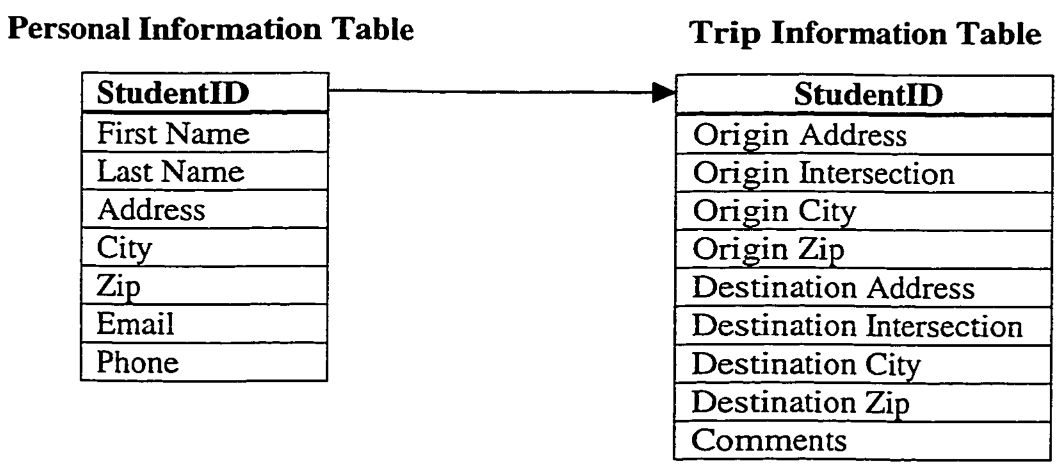
Figure 4. Relationship between Tables for Trip Plan



As shown in figure 4, there are two relationships among the tables, one between the route selection table and the bus route table, the other between the route selection table and the bus stop table. The identifier establishing the relationship between the bus route and the route selection table is "route", which is the route name, while "stop-id" is the identifier that establishes the link between the transfer table and the bus stop table. Because of these relationships, detailed route and stop information can be derived through the transfer table. Even if the route selection table does not physically contain detailed information of routes and stops, information in the bus stop table and the bus route table can be located and used by following the links between the tables.

Student Trip Information. The personal and trip information collected from the students is stored in a database created in Microsoft Access 2000. The database consists of two tables, the personal information table and trip information table. The personal information table as the name suggests, holds the personal information of a student such as street address, email and trip preferences. The information about the trip, such as origin, destination, and commute preferences is stored in the trip information table. The student-id field establishes the relation between the two tables.

Figure 5. Relationship between Database Tables

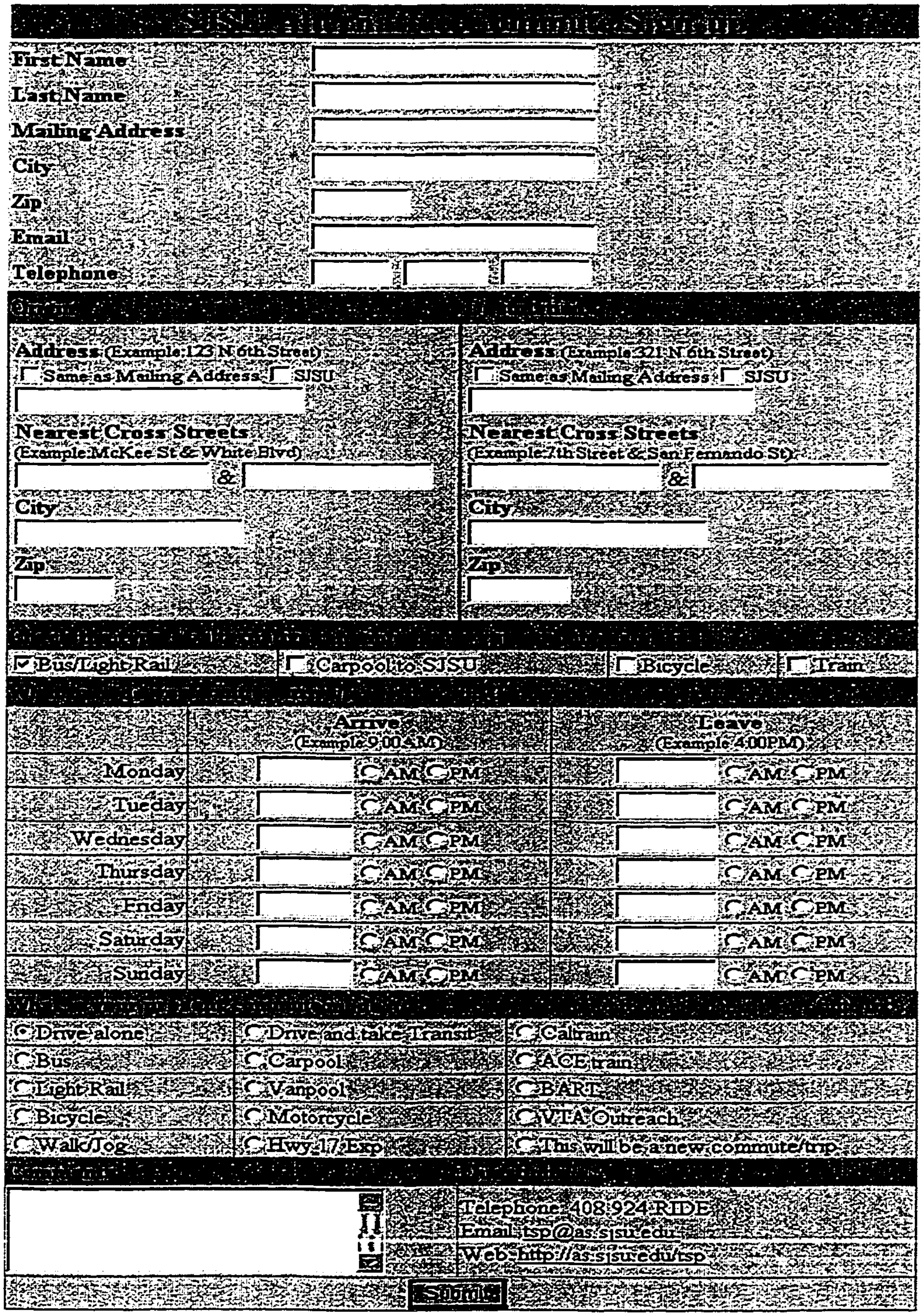


User Interface

Providing a web interface to an application has numerous advantages: the use of interactive capabilities, the capability to collect information remotely twenty-four hours a day seven days a week, use of multimedia, and availability to a large group of users. TRIP is set up as an HTML form to collect the required information from the user. The opening page of TRIP requests the student identification number. This helps in the authentication of the user. Accessibility to TRIP is presently restricted to the students of SJSU, and the authentication process enforces this restriction.

The student provides personal information such as name, mailing address, email, origin, destination and commute preferences. The online form is shown in figure 6. The email address is important because TRIP is able to automatically generate and send email messages to users. All the data validations are done using JavaScript. This ensures that users enter valid data such as numbers for telephone numbers and only alphabetic characters for names. Entering the street address or the nearest street intersection can provide the information for the origin and destination. After the user submits the information, the origin and destination are located and a map of the origin and destination is generated. The user confirms the location of the origin and destination and in case of discrepancies can make corrections by pointing and clicking the location on the map. After all data validations, the database is populated with the corresponding information.

Figure 6. On-Line Commute Sign-Up Form



Analysis

After the location of the origin and destinations has been confirmed, the next step depends upon the user request for a trip plan, rideshare information or both. The result consists of both a graphical format in the form of customized maps and a textual format in the form of directions and contact information for rideshare. The trip plan and the match lists are generated by a MapObjects IMS application executed in the web server.

Transit Trip Plan

The crucial part of the trip plan generation is identifying the transit route based on the origin and destination. The trip plan generation process with and without transfer is explained in figure 7 and figure 8 respectively. First, the bus stops nearest to the origin and destination are located and designated as the starting and ending point of the trip. A list of transit routes served at the origin and the destination is generated. The list of routes served at the origin and destination is compared to identify any common routes served. If there is a common route identified, then that route is designated as the ideal bus route. If there are no common routes, then the trip requires more than one transit line with a transfer point. To find the linking bus and the transfer location for each bus served at the origin, the list of stops is created and for each stop in this list the buses served at that stop is generated. This list is compared with all the routes served at the destination; if a match is achieved, then this gives the transfer bus and the location for transfer. The map shows the origin, destination, and the bus route. The itinerary provides information on the bus to take, where the user has to go to board the bus, and a hyperlink to the schedule. A sample trip plan is shown in figure 9.

Figure 7. Transit Trip Plan Generation Process (without transfer)

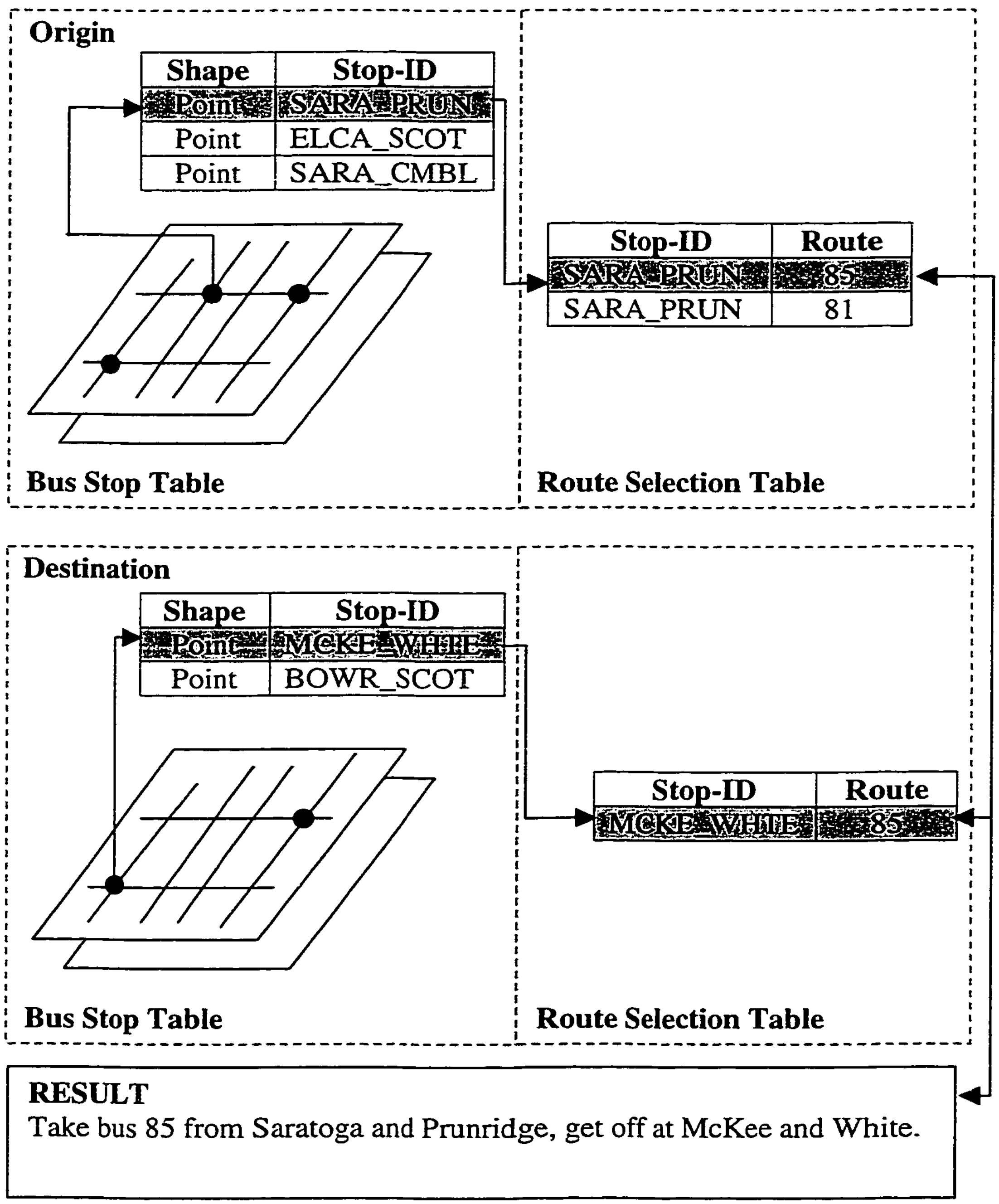
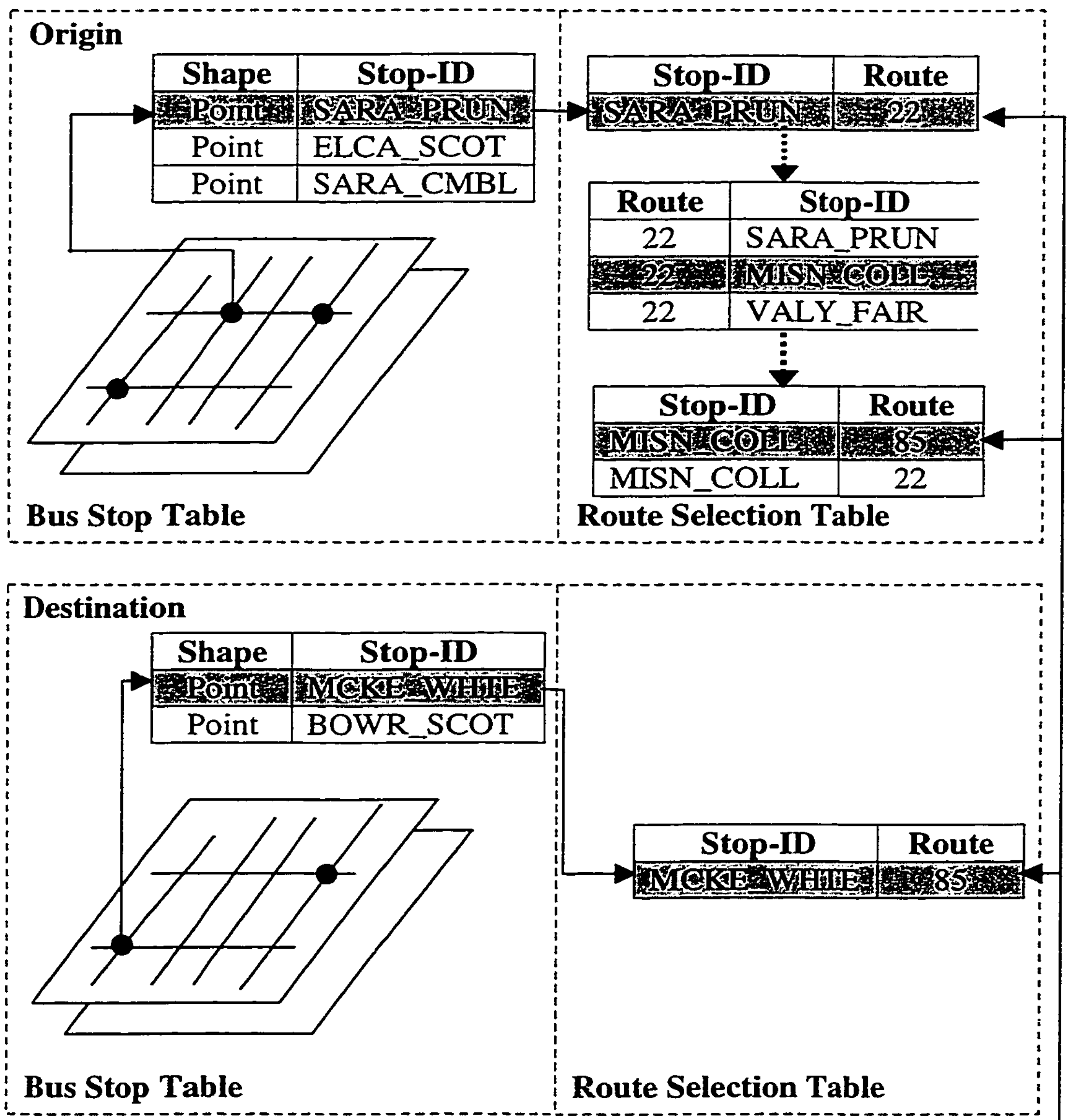
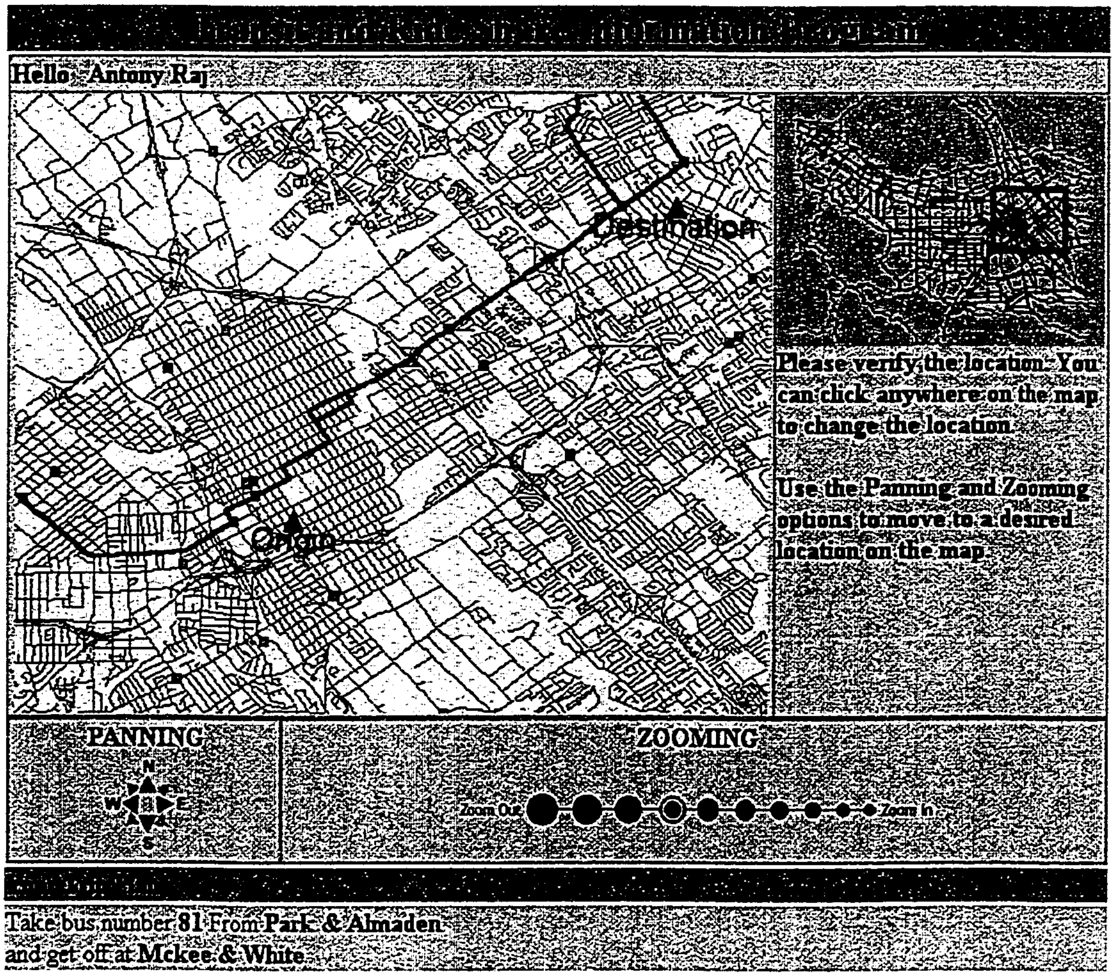


Figure 8. Transit Trip Plan Generation Process (with transfer)



RESULT
Take bus 22 from Saratoga and Prunridge, get off at Mission College, take bus 85, and get off at McKee and White.

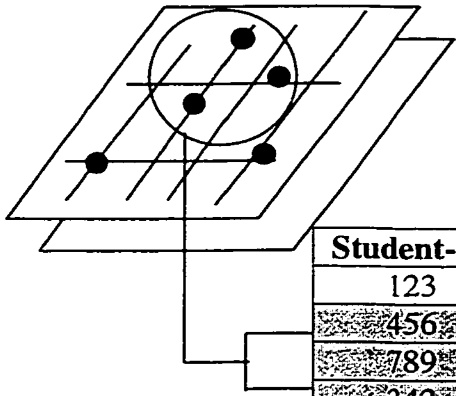
Figure 9. A Sample Trip Plan



Rideshare Match List

Once location information is collected, the matching is done using a MapObjects IMS application and a database. The process of rideshare match list generation is explained in figure 10.

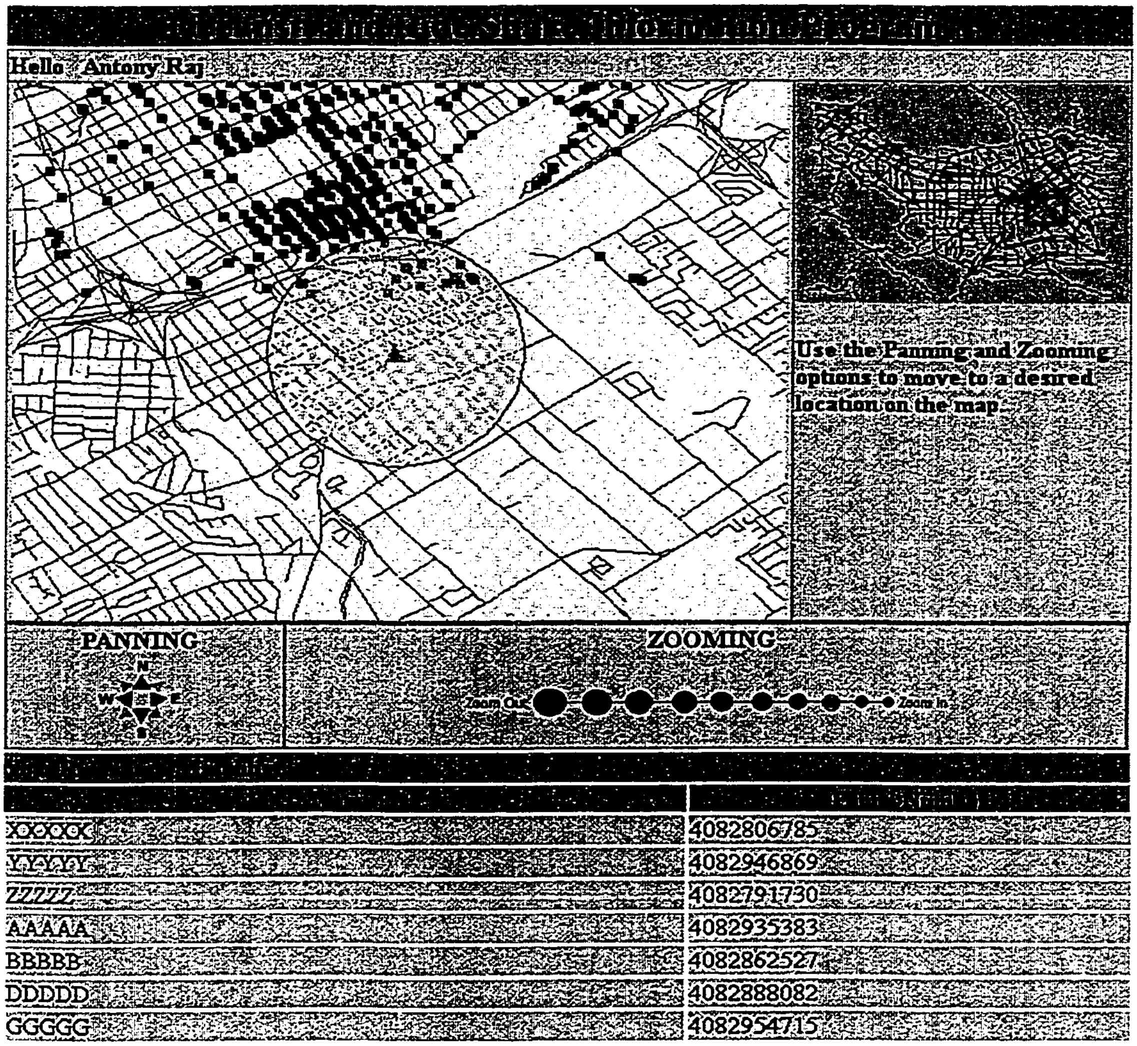
Figure 10. Rideshare Match List Generation Process



Student-ID	Name	Address
123	XYZ	1326 NORTH SAN PEDRO ST
456	ABC	529 SOUTH 10TH ST #7
789	PQR	869 VILLA AVENUE
342	LMN	1302 THE ALAMEDA #305
759	IJK	493 E SAN FERNANDO ST #1

The default geographical matching range is half a mile. Once a set of matching trips has been identified, the names, telephone numbers, and email addresses of users are displayed on the screen. Riders who have a matching trip schedule can contact each other. TRIP provides a match list with telephone numbers and email addresses. However, in addition to a simple match list, an automated email option is integrated into TRIP. This option allows a user who has found matches to have pre-formatted email automatically sent to one or more of the other users. This message contains the sender's contact information and trip details. This email contact methodology, used to augment the more traditional match list, is unique to the TRIP program. A sample match list generated is shown in figure 11.

Figure 11. A Sample Rideshare Match List



CHAPTER 4
PROJECT EVALUATION

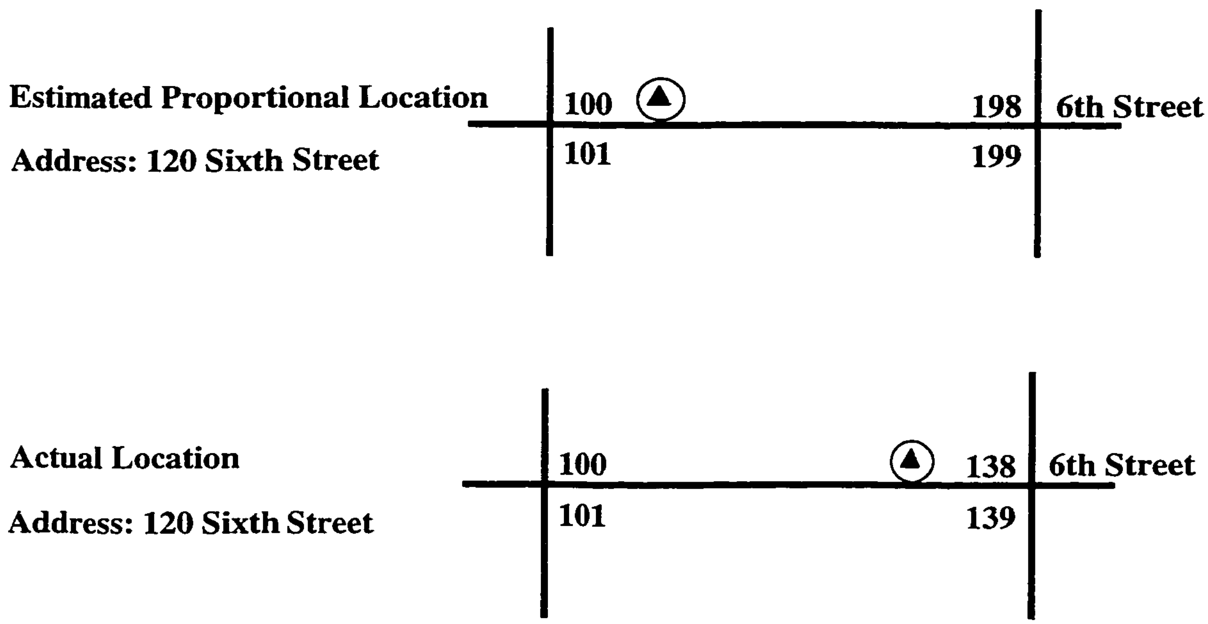
The primary focus of this web based transit and rideshare information program is to provide an ideal tool for generating customized trip plans and rideshare match lists. However, as with any software project, the implementation of such an automated process involves overcoming technical and practical issues in this unique university environment. The section below addresses the feasibility issues of developing and implementing the TRIP application at SJSU.

Data

Street Network

One of the important data elements of this project is the street map network. The base street network would be the main data source from which other data and maps are derived. The accuracy of this map and the information it offers is therefore vital for the success of the application. The primary problem faced with the base network is the outdated street network for the area. Although DynaMap 2000 is updated regularly, the network still has unnamed and missing street segments. In addition to missing streets, the geocoding of addresses on the street network also creates problems. First, the street network cannot locate some of the addresses and secondly, the address ranges and block information does not allow accurate address matching. Address ranges for developing street segments range from zero to 99 (e.g., 101-199, 201-299, 301-399), assuming that there are up to 99 addresses per block. Realistically, this is rarely the case and blocks may actually only have 20 to 30 lots with address ranges from zero to 30. Therefore, during address matching, the result of matching tends to be skewed to one end of the block as shown in figure 12. Due to the geographic scope and time constraints of the project, adding the missing street segments or correcting all of the errors in the geocoding information of the base map is not possible.

Figure 12. The Address Range Problem of Street Network



Transit Route Network

The data created or derived is only as good as its base data. The street network is the base data from which the individual transit lines were digitized. The line segments in the DynaMap does not exactly portray the existing street network. In some cases, it was difficult to recognize which street or intersection a street segment on the map was representing. Other cases also arose where bus routes travel through parking lots that are not represented on the base network map. In these cases, a segment was digitized to represent approximately, where the route would travel.

Bus Stops

The VTA schedule shows time points on the routes at a sparse numbers of stops or at the primary transfer points. Data and schedule information was not available for the stops that where between those provided in the schedule book as time points. To alleviate this problem, digitizing of all stops is required, but for this phase of the project, the decision was made to include only the time points shown on the VTA schedule. Yet, although the stops were recognized, their descriptions needed to be entered. Users need an explanation or intersection name to locate a bus stop, because providing them with a number would create confusion. Thus, intersection names were manually entered for respective bus stops to complete the bus stop map and database. This is a cumbersome process and strict quality has to be maintained as the trip-planning algorithm depends on these time points.

User Interface

The core focus of this application is to create a user-friendly system that allows for maximum accessibility to the students of SJSU. The users of this system vary from novice computer users to power users. The user interface has to be simple enough for the novice users and at the same time sophisticated enough to accommodate the power users. The users primarily interact with the system when they provide their personal and trip details. The correctness of the origin and destination information provided by the user is very important for generating the trip plan and rideshare match list. This becomes more important due to the inconsistencies in the base street network. To overcome these difficulties, the user is given the choice to enter the origin or destination in the form of street address, street intersections, or pointing and clicking on the street map itself. Furthermore, due to the inconsistencies in the street network after locating the origin and destination, the user is requested to confirm the locations. All the information from the user is collected through the sign up form. To ensure valid information, JavaScript has been used to validate all the data, and appropriate informative error messages are generated to educate the user to enter the correct data.

Technical and Security Concerns

The implementation of a sophisticated program like TRIP requires a dedicated web server set up, with adequate back up and security policies. The TRIP program is designed to be accessible only to the students of SJSU. This requires the authentication of the user. Access to the registered student database of SJSU has to be established to force this authentication. Since this data is considered sensitive, adequate security measures in terms of protecting the data from misuse has to be built into the system. Moreover, since the application requires personal information, adequate software security has to be provided to protect the data and gain the confidence of the users to share that information. The security of the web-site has not been considered for the present work.

CHAPTER 5
CONCLUSION

The success of any modern technology depends upon its ability to help find solutions to problems people face in everyday life. With the latest developments in Internet GIS technology, it is possible to develop an application which helps transit trip planning and rideshare matches and in turn helps balance the conflicting needs of mobility and clean air. The successful development of the prototype of TRIP demonstrates this. Extensive data preparation, software and hardware set up is required for the successful implementation of TRIP. However, the benefits reaped from an application like TRIP outweighs the investment of time and money.

The present prototype of TRIP is capable of creating personalized trip plans and rideshare match lists, given an origin and destination. The application has been developed within a relatively short period of three months, most of which was spent overcoming the problems in data creation. The short development period and low maintenance helps in reducing the operating cost of a service center with dedicated staff. One of the important advantages of using a Web-based application like the transit and rideshare information program is the availability to the user. Direct user access twenty-four hours a day is a feature of TRIP not found in most traditional trip planning and rideshare services. Analyzing the information about the users, their location, time of access can provide new insights about the clientele. This information can be used to improve the present service and target audience with specific requirements. The software and tools for the application were chosen keeping in mind easy development, maintainability, and the capability to add functionalities later. The modules have been developed so that they can function independently of one another, which help in easy maintenance and continuous availability of the system. The move from the prototype to implementation involves creating and adding the data with no change to the application itself. The implementation of TRIP would provide new ways for commuters to access information from the comfort of their home.

Like most application development projects, there was more than one solution to the problem, but the best solution depends on the circumstances, and the software requirements. Developing GIS applications for the Internet is a situation where the best solution depends on the application requirements. Careful analysis and understanding of the requirements can greatly simplify the development process in an Internet GIS application. An understanding of the application requirements will allow the developer to make the right architectural choice for the application.

Future Development

Although the technical feasibility of developing an application like TRIP is possible, the success of the application can only be determined by monitoring the interaction of the user with the system. The web site should be monitored to find how many students access the application, and when they access the system. Collecting feedback about the user interface would help increasing the usability of the user interface.

Moreover, software projects are not one-time tasks. They evolve by implementing the changes in the technology, data and user interaction.

The data used by the application bus stops, transit routes, schedule information and the street network information has to be standardized and refined. The algorithm for generating the trip plan can be improved to accommodate preferences like fastest trip over a trip with no transfer. The rideshare match list algorithm can be enhanced so that the schedule information is included so those matches are done on not only the spatial proximity but also their schedules.

The successful development and implementation of the TRIP prototype makes it clear that with careful database design and identifying the right technology, it is possible to find a solution to a day-to-day problem like transportation demand management.

CHAPTER 6

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