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AN INVESTIGATION OF WEB-BASED TECHNOLOGIES FOR THE PENINSULA TRANSPORTATION DISTRICT COMMISSION

by
Brian M. Revels
Graduate Student
and
Brian L. Smith
Assistant Professor of Civil Engineering

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16. Abstract

With the dawn of a new millennium, it is evident that the modern business climate is encompassed in an information technology revolution. Companies feel the pressure to utilize technological innovations for economic advantage. A danger with this practice is to simply utilize technology due to its mere existence and not because it solves a defined problem.

In the field of transportation, public transportation agencies seek to apply Intelligent Transportation Systems (ITS) technology to improve transit system operations. Recent US Federal legislation, specifically the Transportation Equity Act for the 21st Century (TEA-21), has enabled many transportation improvement programs throughout the United States. Although monetary funds are available, a difficult task is identification of the necessary initiatives to improve operational efficiency. To improve existing conditions, it is imperative to identify the needs of the transit provider and remedy these problems through the assimilation of ITS and information technology.

The objective of this project was to construct an interactive trip planner program that delivers accurate transit information through a highly visible medium in a timely manner. The design framework was completed by applying a goal-centered, systems engineering design approach. This research is relevant to the transportation industry by addressing the following objectives:

- Utilize a formal, structured design process to improve ITS implementation by encompassing all system design procedures from an initial functional requirements document to completion of a finished product.
- Integrate multiple technologies such as the Internet, geographic information systems (GIS), object-oriented programming, data retrieval and storage, and map display programs.
- Explore the communication capabilities of public transportation agencies to improve information transfer between transit agency and user.

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ABSTRACT

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With the dawn of a new millennium, it is evident that the modern business climate is encompassed in an information technology revolution. Companies feel the pressure to utilize technological innovations for economic advantage. A danger with this practice is to simply utilize technology due to its mere existence and not because it solves a defined problem.

In the field of transportation, public transportation agencies seek to apply Intelligent Transportation Systems (ITS) technology to improve transit system operations. ITS includes a broad range of information technology that seek to improve the existing transportation network by improving safety, reducing traffic congestion, enhancing mobility and intermodal travel options, preserving the environment, conserving energy, and promoting economic development.[1] Recent US Federal legislation, specifically the Transportation Equity Act for the 21st Century (TEA-21), has enabled many transportation improvement programs throughout the United States. Although funds are available, a difficult task is identification of the necessary initiatives to increase operational efficiency. To improve existing conditions, it is imperative to identify the needs of the transit provider and remedy these problems through the assimilation of ITS and information technology.

Internet Usage

One goal of transit agencies is to enhance rider services. Unfortunately, a major barrier to transit use results from inefficient user information systems. In order to maintain market share and expand ridership, transit agencies are eager to take advantage of opportunities offered by new and emerging technologies. One such method is using the power of the Internet in improving communications with existing and potential customers. Unfortunately, experience has proven that the Internet is not a panacea. As with other communication mediums, such as signing, printed material, television, radio, and telephone, the Internet possesses both strengths and weaknesses.

On the positive side, the Internet has the potential to automate information dissemination, is an interactive instrument, offers the ability to update information quickly and at a low cost, can provide easy to follow graphics, and reaches a global market. In contrast, the Internet is currently limited to individuals with the means to purchase a computer and modem access. Also, the ability to update information quickly places pressure on a provider to constantly maintain a website. Failure to do so often results in a negative public image.

In the modern business public climate, there is a rush to have a presence on the World Wide Web. Over the last few years, Internet growth has increased tremendously both in the United States and worldwide. For example, by the end of 1998, there were an estimated 76,856,000 US and 147,800,000 worldwide Internet users.[2] Although growth statistics vary significantly from one source to the next, Figures 1 and 2 show an estimation of Internet host and World Wide Web growth during the 1990's. An Internet host refers to a computer with a registered IP address. The WWW diagram displays the estimated number of websites for each time period. It is evident from the graphs that both the Internet and the WWW are growing at exponential rates. This degree of growth is expected to continue to occur until the limits of worldwide exposure are eventually reached.

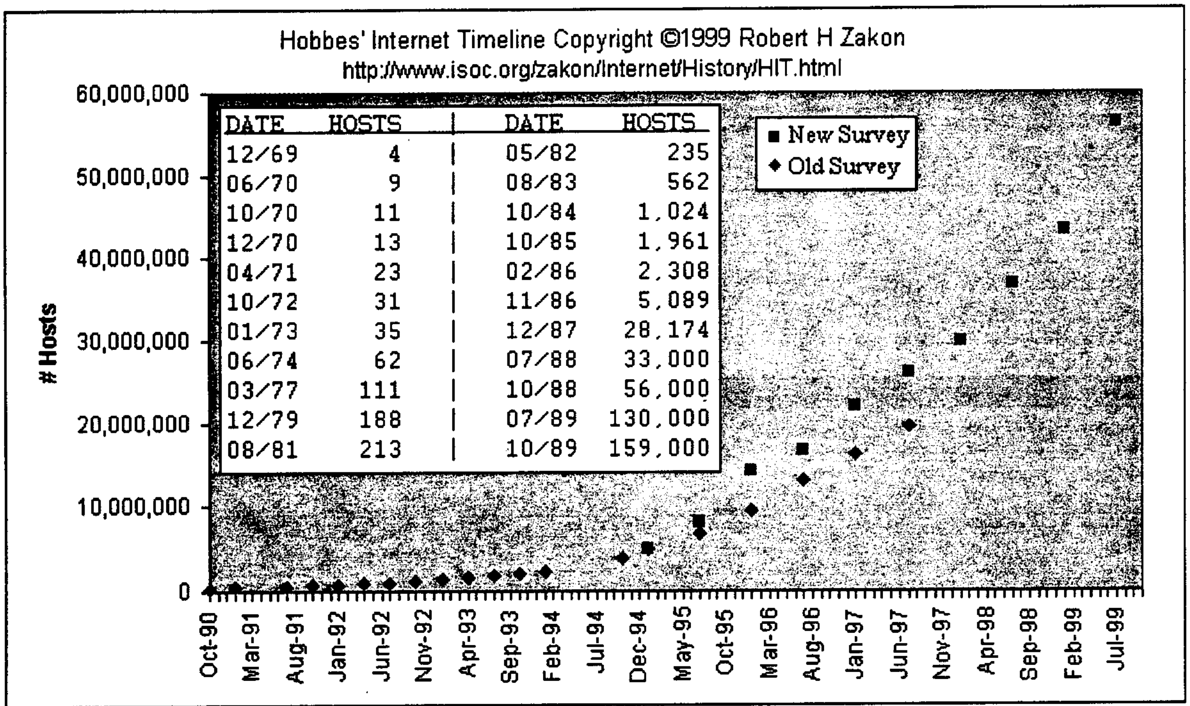

FIGURE 1: INTERNET HOST GROWTH FROM 1990 TO 1999

Source: Hobbes' Internet Timeline, Version 5.0 [http://www.isoc.org/zakon/Internet/History/HIT.html]

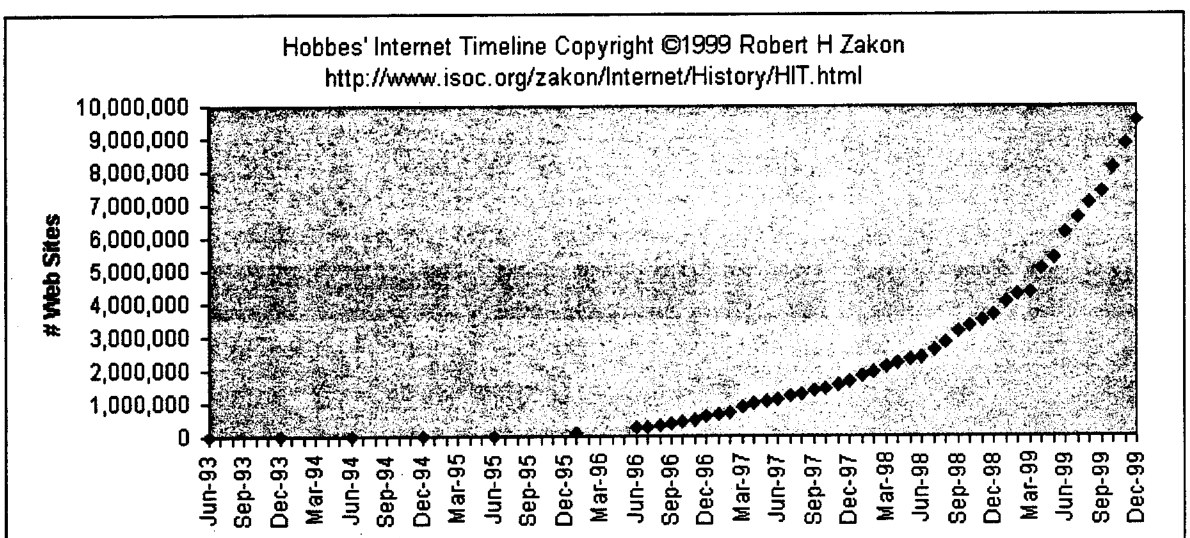

FIGURE 2: WORLD WIDE WEB GROWTH FROM 1993 TO 1999

Source: Hobbes' Internet Timeline, Version 5.0 [http://www.isoc.org/zakon/Internet/History/HIT.html]

Transit Industry Web Usage

Many transit companies with websites feel that the benefits outweigh the drawbacks. This may be true in most cases; however, before creating a website, it is vital to determine the goals and objectives of a specific public transportation provider for three reasons. In the *immediate term*, a primary concern is costs that stem from initial page design and layout, server space rental, and site maintenance. In the *intermediate term*, the reputation of the organization is at stake, affecting public relations. There is also a *long term* reason for critically assessing a company's future investment opportunities in light of future Internet capabilities. It may be possible to use the Internet in ways more beneficial to transit organizations than simply utilizing ITS technology for technology's sake. Transit companies should therefore identify specific Internet strengths that improve operational problems for their company and seek to implement these capabilities while minimizing development and maintenance costs.

Many public transportation professionals have been pessimistic when discussing the advantages of using Internet technology to distribute transit information. Some critics claim that it is too expensive and not worth the initial capital investment. Also, there exists the chance that the online information may never be used. All of these points are valid; however, it is important to remember that transit information must be distributed by some communications medium. Historically, this medium has been the use of printed paper schedules. Therefore, before dismissing the utilization of Internet-based transit information, transit agencies should perform a cost versus benefits analysis of reprinting paper schedules compared to changing transit schedules located on a company website.

Perhaps, the most feasible solution is using a combination of multiple communications media that provides flexibility and exposure to various socioeconomic groups.

Project Client

This report explores the format, types, and audiences of Internet-based information which best suit a public transportation provider. Using a goal-centered, systems engineering approach, this project identifies the information technology opportunities that an interactive website offers and compares these to the communication goals of the Peninsula Transportation District Commission (**Pentran**). Pentran was a public transportation provider offering fixed route and demand responsive bus services in southeastern Virginia for the cities of Hampton and Newport News (see Figure 3). In October 1999, Pentran merged with Tidewater Regional Transit (TRT), which provided fixed route bus services on the south side of Hampton Roads in Norfolk, Virginia Beach, Chesapeake, and Portsmouth. Pentran and TRT formed Hampton Roads Transit (HRT) which now services the entire Hampton Roads region of coastal Virginia. *Note*: Because the project began prior to the formation of HRT, the study focused solely on analyzing the original Pentran bus transit system.

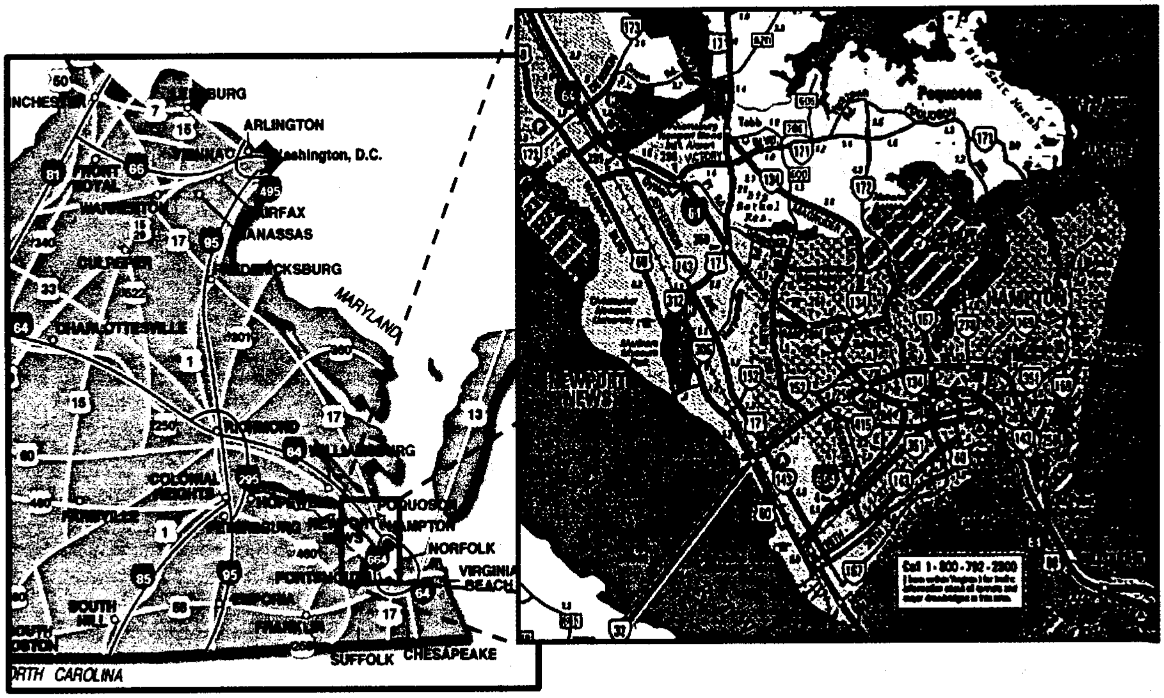

FIGURE 3: PENTRAN SERVICE AREA

Source: Virginia Department of Transportation [http://www.vdot.state.va.us/maps/maps.html]

Purpose

The research focus for this project is to investigate the capability of integrating multiple ITS and information technologies to assist in solving complex transportation issues by creating an advanced traveler information system through utilization of detailed systems design process. The project objective was to construct an interactive trip planner program for a public transportation provider that delivers accurate transit information through a highly visible medium in a timely manner. The design framework was completed by applying a goal-centered, systems engineering design approach. This research is relevant to the transportation industry by addressing the following objectives:

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Chapter 2: Systems Analysis Methodology

History & Background

The origins of systems analysis can largely be attributed to early military operations research in Britain during the years preceding World War II. Britain, recognizing that the German threat was real, concluded that they must deploy their severely limited forces in the most efficient manner in order to withstand the attack. Following WWII, systems analysis and design began to appear in industrial management, operations research, automatic control system design, and econometrics. The U.S. Air Force and AT&T were among the first organizations to recognize the benefits of utilizing a rational, objective process for development of large-scale systems. By the 1950's, systems design procedures were being used for a variety of military and commercial applications including transportation projects.[3]

Definition

According to Eisner's *Essentials of Project and Systems Engineering Management*, the "systems approach" recognizes that all elements of a system must interact harmoniously which requires a systematic and repeatable process for designing, developing, and operating the system. The general characteristics of a systems approach are defined as follows:

- Follow a systematic and repeatable process,
- Emphasize interoperability and harmonious system operations,
- Provide a cost-effective solution to the customer's problem,
- Consider logical alternatives,
- Use iterations for solution convergence and refinement,

- Satisfy all user and customer requirements, and
- Create a robust system.[4]

In addition to meeting the principles shown above, Gibson states that the systems analysis method consists of six primary phases, which occur in consecutive order:

1. Determine system goals,
2. Establish ranking criteria for alternatives,
3. Develop alternative solutions,
4. Rank alternative candidates,
5. Iterate process, and
6. Execute action plan.[5]

A critical distinction of systems analysis from other scientific methods is that it is akin to a *learning process*. Iteration of these phases affects initial assumptions and illuminates relationships not previously understood until finally converging on a stable set of conclusions. Products of these steps are continually refined, as implied by the iterative phase.

Goal-centered vs. Technology-driven Approach

Two competing methods are common when developing a systems design: *goal-centered* and *technology-centered.* The former, also known as "top down", begins with the goal – often an ideal version of future conditions – and works backward towards the current conditions, setting detailed specifications for each component as a vision of the future system becomes clear. The technology-centered approach, on the other hand, consists of a series of incremental steps for moving from the clearly understood current conditions to a loosely defined ideal. While a goal-centered systems analysis has been conducted for this particular project, the strengths and weaknesses of both approaches merit discussion.

The basic attributes of the goal-centered approach include a movement from general to specific tasks based on predefined goals and objectives. The strengths are an ability to define goals, tasks, and assumptions consistently in spite of changes in the planning environment, the state of the practice, or the state of the art. The weaknesses are possibility to lose focus if executed improperly and inability to provide detail for effective action on short-term issues.[6] The latter problem is poignant when organizations are required to demonstrate immediate results from an investment in technology or personnel.

By contrast, technology-centered or bottom-up planning is based on current conditions employing existing technology with minor extrapolations in an incremental approach. The strengths include immediate evaluation of cost effectiveness, consistency with prevalent engineering design methodology, and tangible solutions to problems that arise today and hence are the most visible. The weaknesses are a narrow focus on short-term problems, marginally decreasing improvements, and a system design that is restricted to today's technology and operating structure.[6]

For this project, a goal-centered method has been chosen for several reasons. Since the goal was not clearly defined at inception, a step-by-step approach may waste time and effort in developing tasks, which are irrelevant or incorrectly focused. With the lack of a designated endpoint for each subsystem, resources may be wasted on elaboration to an unnecessary degree. Most importantly, the goal-centered approach captures the reason for performing this particular study: "It is in the nature of systems analysis that its process continually enriches the perceptions of the problems."[6] As the Web is a medium whose state of the practice evolves rapidly, a goal-oriented approach offers a means of developing realistic solutions that retain value even as the technology changes.

The goal-centered systems engineering approach emphasizes the importance of establishing a requirements document especially when involved with software development. Requirements are important because they verify a common understanding between the client and the project developer. A detailed requirements document forms the basis for the following project characteristics: size, scope, schedule, cost, funding sources, build vs. buy decisions, and operational concerns.[7]

Application of Systems Analysis to the Goals of Transit Providers

Overall, the goal-centered systems engineering approach is relatively new to the ITS industry. Therefore, a portion of this research effort is to identify the strengths and weaknesses of employing this framework to solving transit operations problems. In addition, the research details the application of this systems engineering framework to the problem of discerning how the Web can benefit the public transportation industry. The paper outlines the goals of transit agencies, the capabilities of the Internet, and a plan that enables transit providers to move Web-based technology from a peripheral piece to an intrinsic part of a comprehensive communications package. Expanding on this concept, the study evaluates various Web-based alternatives including an investigation of existing interactive routing programs. This background information provides the basic framework for development of an interactive trip planner together with the system architecture. The report continues with a discussion of the major project difficulties and limitations, an analysis of project components, and future research opportunities. The final section emphasizes the major lessons learned, a summary of central concepts, and relevance of this project to the transportation industry.

CHAPTER 3: TRANSIT COMMUNICATION GOALS & SOLUTIONS

Preceding the system development, a literature review was conducted to identify the communication goals of transit agencies. In conjunction with interviews with the project client, Pentran (see Chapter 1), several communications goals have been identified: enhance rider services, market the service as a transportation option for non-transit users, facilitate the merger with other transit services, and reduce the confusion and abuse of route transfers. The format of this chapter involves defining each transit communications goal and then discussing solutions and opportunities using the Internet.

Enhancing Rider Services

James and Siddiqi point out that in order to increase the public's use of transit services one needs to increase the attractiveness of the service.[8] One way to accomplish this is to reduce the uncertainty resulting from the fact that passengers do not have direct control over the vehicle. This uncertainty may be addressed by three related points: increasing the reliability of the transit information, informing schedule changes, and giving users information specific to their travel needs.

Increase reliability

Transit riders indicate that the time spent waiting for transit service is more aggravating than the combined time spent riding the service and walking to and from the stop.[9] In fact, in travel time studies, some analysts double the time spent waiting before adding it to the time spent in motion when calculating the rider's opinion of service. The primary factor contributing to this problem is the rider's perception of reliability. Ideally, vehicles arrive and depart at the expected times and locations; however, incidents and traffic conditions affect the performance of the service. This, in turn, decreases rider satisfaction, which directly relates to system reliability.

One method to increase the reliability of a transit system is to convey incident information to the passengers. With a website, several types of information could be communicated such as immediate changes (e.g. delays from accidents or other incidents), site-specific details (e.g. bus *x* will be 5 minutes late or stop *y* is 100 feet away due to inclement weather), and long-term impacts (e.g. rerouting due to street repairs and other roadway construction). For example, the MARTA (Metropolitan Atlanta Rapid Transit Authority) webpage, http://www.itsmarta.com, contains a feature called "Renovation updates". This sub-page provides information on route changes, holiday schedules, and service changes during upcoming street repairs. In short, customers have many reasons to doubt whether a schedule is accurate in the first place. A website that provides updated information may help alleviate some problems related to system reliability.

Announce changes in schedule information

One reoccurring transit operations dilemma involves permanent changes to route and schedule information. Paper schedules have been used extensively by transit organizations to market and explain their services. Unfortunately, the reproduction of paper schedules incurs high publishing and distribution costs. Subsequently, many transit companies will only make annual schedule changes to minimize these costs.

In addition to paper schedules, bus transit companies utilize the bus stop sign as a simple yet informative communications medium. While the sign lets passengers know the location of the stop, it can also reveal other types of information such as route numbers, hours of operation, customer service numbers, and schedules showing nearby stops and times. Similar to paper schedules, the major weakness of bus stop signs is that the information is difficult to revise, update, and maintain after initial installation. One study estimates that most signs are changed every seven to ten years.[10]

In contrast, the Web allows information contained on a website to be updated frequently. Schedule changes simply involve updating the table or file with the new stop times. Therefore, one can envision the following applications that would complement the information conveyed by static signs and paper schedules:

- protracted service changes (e.g. peak tourist month)
- schedule changes caused by incidents (accidents, weather, and special events)
- route changes due to road construction and other infrastructure renovations
- changes in fare or transfer policies

Naturally, changes in schedule information can be viewed as a subset of techniques that increase the reliability of transit information. However, there is a slight difference in emphasis. Reliability pertains to information from the transit service as a whole, whereas schedule information focuses on daily transit operation issues.

Deliver customized information by format and type

Bergenhoff points out that the ideal passenger information system would have "very basic features, such as easy-to-remember timetables..."[11]. Even if two bus riders want the same type of data, they may desire different formats. People who have difficulty reading a timetable may prefer to see data displayed graphically. Maps can highlight the appropriate stops, routes, street network, origins, and destinations for the user. Alternatively, some clients may prefer to see information in a short outline form, while others may prefer more details. An effective website satisfies a variety of preferences.

A site can also convey customized types of information to transit users, such as the route, stop, or type of vehicle specific to their needs. For example, a rider living in one section of town can enter the time by which a destination needs to be reached, and the website may host software that calculates and transmits the appropriate information. If certain riders need a wheelchair lift or a lighted stop, these data may be included as well.

Theoretically, one could argue that the website reduces operational costs of the transit agency, since the customized user information is provided by the site rather than a company dispatcher or customer service department. Realistically, these services might not be provided to this extent without a website. Hence, in the short and medium term, it seems more appropriate to classify customized user information as a beneficial service to clients rather than as an initiative that reduces transit costs.

Attracting New Market Segments

The systems analysis suggests two specific markets that a transit service may capitalize on through the use of improved communications capabilities: tourists and regional employers. The former involves using the Web as a marketing device, reaching directly out to potential riders. The latter entails using the Web to form a strategic alliance with business management that could influence employees to become transit patrons.

Tourism

Tourism represents a notable transit ridership source. This market segment needs additional information that is not necessary for regular passengers. The lessons learned from designing passenger information maps at airport terminals are applicable to tourists using transit. One finding is that new users may need help aligning themselves with the map's orientation.[12] The ability to display landmarks (such as airports, malls, schools, or parks) helps tourists determine their current location, desired destination, and path between the two locations.

Regional employers

A second market that transit agencies may wish to pursue is a regional employer. Many of these employers may be unaware of the 1996 law allowing employers to provide tax-free benefits to transit patrons. The process works by an employer purchasing vouchers from a transit authority. The cost of the vouchers is reimbursed through employer tax deductions.[13] TRAFFIX, a transportation alternatives program in Hampton, Virginia, refers to this plan as "Commuter Check". Commuter Check is an incentive program for employers to give their employees assistance with commuter transportation costs and promote public transit.

Difficulties with increasing transit ridership

The literature suggests that caution should be used if expecting the conveyance of information to increase ridership. For example, transit services in Richmond, Virginia found that providing additional transit information to the public did not increase ridership. This was mainly due to the fact that most automobile owners are not likely to switch to using public transportation even with better information disseminated by transit services.[14] Excluding large, dense metropolitan areas such as New York City and Washington, DC, private transportation (i.e. driving a car, van, truck, or motorcycle) for commuter trips dramatically exceeds transit ridership. According to a December 1999 Bureau of Transportation Statistics report (*Pocket Guide to Transportation, BTS99-06R*), the split between public and private transportation usage is approximately 4.4 to 95.6%, respectively. The percentages were based on total passenger-miles for the United States from 1997 data. The primary benefits of private transportation include door-to-door service, high flexibility and reliability, personal control of the vehicle, and faster travel speeds than public transportation.

Another concern is that many current transit riders may not have access to the Internet in its present form. Transit ridership in the United States is largely composed of lower income groups. Unfortunately, most low-income families do not currently own a personal computer, which limits Internet access. Public kiosks are available but are mostly limited to larger transit organizations and in areas with a high proportion of tourist ridership. However, given the tremendous growth of the Internet, Web access may become as common as the television in the next five years. The electronics industry has experimented and introduced some combined television and computer units into one hybrid entertainment system.

Facilitating Transfers to Other Transportation Modes

A significant benefit of a website is that it allows links to related sites. This feature can be used to enable links to other transportation service providers and vice-versa. Thus, the exposure of a transit agency website increases as more people are able to find the site from different listings. This capability is especially useful in areas with multiple transportation services.

While the use of these links has become common, there are other features of the Web, which promote the integration of data from two different sources. For this research project, the bus company, Pentran, may find it beneficial to have a direct link to other webpages that display real-time traffic information for the highways and major arterials in the Hampton Roads region. A similar type of link exists from the Washington Metropolitan Area Transit Authority webpage, http://www.wmata.com. From the WMATA website, individuals can link to a variety of regional transportation information including the Washington, DC SmarTraveler website.

Reducing Transfer Confusion and Abuse

For transit passengers, there may exist a genuine confusion about fare structure and transfer policies. This confusion can be addressed by an innovative website design. One remedy is to create an application that allows a potential passenger to click on an origin and then be given a color-coded map showing destinations within a particular price range.

A second problem is the intentional abuse of the transfer policy to avoid paying a fare. This may occur when a ticket is given from one rider to another. This type of system abuse cannot be directly addressed by having a website. However, in a separate effort, the transit industry may want to consider using an advanced transfer handling system, a technology that uses recorded route information to ensure a passenger is not reversing direction or stopping over at a particular stop.[15] Then, public transportation organizations may use the Web to market this information to travelers in order to reduce instances of attempted transfer abuse. This is a prime example of the Web working in tandem with other ITS-enhanced transit operation initiatives.

Interdependency of Goals

In review, the transit communication goals were identified and discussed following a detailed literature investigation. Enhancing rider services were found to be the most relevant goal pertaining to this research. Clearly, there are overlaps between rider service enhancement and other communications objectives. For example, a site that gives users customized information for how they may get from point A to point B including stop location, schedule, and fare may actually impress potential advertisers as well as clarify the transfer confusion. The value of distinguishing these goals is to help a transit company to decide where to allocate future resource investment. In reality, a transit organization is limited by budget constraints. Therefore, it is recommended to identify which specific goals are most important for a particular transit company on an individual, case-by-case basis.

Chapter 4: Internet Advantages and Disadvantages

Following the research and identification of the transit communication goals, the research team sought to analyze the advantages and disadvantages of Web-based information transfer. The strengths and weaknesses were identified based on researching multiple publications on the Internet and its inherent characteristics. This process will assist how the Internet can specifically benefit the public transportation industry. Negative Internet characteristics were also determined so Web developers can avoid situations that are detrimental to the transit organization.

Strengths

The Web is a fundamental component of the world's modern communication network. It has many positive attributes such as global information distribution; accessibility to a growing market; interactivity; ability to revise, change, and update information at low cost; capability to include user-friendly graphics; and high visibility and exposure. Each Internet advantage is detailed in the following sections.

Global information distribution

Global information distribution is an important characteristic of the World Wide Web due to the shear size of the communication medium. Geography does not limit the feasibility of distributing information to customers on a worldwide scale. A practical example is the tourist market segment alluded to previously: travelers can plan their itinerary for a vacation before leaving home. With the Web, transit information that helps with trip itineraries is readily available to multiple interest groups in other states or countries.

Market accessibility

The Internet is growing at an unprecedented rate confirming that it is virtually essential for a modern business to join to maintain market share against competitors. When compared to television, radio, and printed materials, the current exposure of the Web is significantly larger and continuing to increase. For example, current sources show that Internet traffic is growing by 20 percent every month.[16] Also, it is estimated that by the year 2001 approximately 174.5 million people will have access to the Web.[17] Although Internet growth estimations vary by source, all analysts agree that the size of the Internet will continue to increase. The main argument is the intensity of this growth and accuracy in the measurement criteria. As more people become exposed, companies will have larger markets from which to advertise and seek new customers. This large market accessibility can be used to one's advantage if a company can build trust at an early stage and maintain this relationship. There is a potential for huge market penetration if the appropriate resources are allocated for successful website design and development, especially as the reach of the Web becomes as common as the exposure of the current personal computer.

Interactivity

Interactivity is the ability for the viewer to learn information from the website. Unlike brochures or pamphlets, a website allows a user to question, decide, and learn through participation. This form of communication is more successful than contemporary methods because the user has direct control over the exposure to the material. The following quote summarizes this issue: "Your website isn't something people read, it's something they do. Visiting your site is an activity. The tools for building a website allow it to interact with the viewer. Make use of these tools."[18]

Flexibility

A website possesses remarkable flexibility. This characteristic allows revisions and updates at a fraction of the time and cost of re-printing material. Unlike hand-written surveys, websites can use direct customer responses to revise the site. This feedback can be easily constructed using suggestion boxes and surveys. Many consumers find it beneficial to complete the surveys knowing that their opinions could make positive changes. These Web polls are cost effective ways to determine customer interests. An important concept for website developers to remember is that a productive website is not one that is initially developed perfect and allowed to sit idle but rather is revised and corrected at frequent intervals.

User-friendly graphics

An additional website strength lies in its ability to include user-friendly graphics. Many people have a much easier time understanding information if it is displayed with a map, diagram, or picture. If it is designed in a user-friendly manner, then the customer has the control over what information is shown rather than a simple static table displaying set information. It is often easier to provide detailed, color graphics via the Web than through a printed medium, such as newspapers or magazines.

Visibility

A successful website must somehow attract attention to distinguish itself from the competition. 24-hour visibility is both a website strength and weakness. Worldwide, people can view and receive information about a company without the limitations of a customer service staff. This information is always available to customers assuming the communication links and computer software applications are working correctly. Possessing 24-hour visibility can also be detrimental to a company if the website has incorrect or outdated information. Therefore, it is vital to ensure that all dynamic information is correct and updated frequently.

Weaknesses

Like any communication medium, a website possesses negative characteristics. These problems vary in source but all eventually hinder the overall effectiveness of the website. Negative attributes can be used as early warning signs by website developers. The primary weaknesses discussed in this research include credibility, liability, competing information, incorrect target audience, and slow system operations.

Credibility

In the modern marketplace, credible information is critical to company reputation. Hinchliffe states that Web users must be able to carefully determine whether website information is true or false.[19] Although this argument may have originally pertained to posting scientific data, this can easily extend to websites for mass transit agencies. Once information is posted on a site, users may find it at any time and assume that it is valid. Therefore, it is essential to frequently check pages and correct errors. To facilitate this issue, a transit agency may want to provide a time stamp notifying the most recent webpage updates. Credibility also signifies the need for continual personnel involvement. A transit webpage is not a set-up and forget-it type of application.

Liability

Liability must be considered when providing traveler information in a Web-based application. It is sometimes overlooked in website development but the results of its absence can be extremely detrimental. Since most transit agencies provide some information on schedules and routing features, a posting should state that this information is for "Aid purposes only". With a properly written disclaimer the transit authority can avoid potential legal complications and customer dissatisfaction arising from the deliverance of incorrect rider information.

Competition

Competing information sources are a challenge. The advantage of the Web for transit information distribution extends to other websites meaning that information is a cheap commodity. The general public is not likely to "surf" a transit website. Therefore, designers must consider ways to make their site stand out against others, such as utilizing key words in title pages to facilitate queries by search engines. One remedy is to link transit information to other more popular websites such as tourism and general information within the geographic region.

Target audience

A fourth weakness relates to the target audience. Unless people who directly benefit from its services access the website, then its development may seem to be an unnecessary investment. Although global information distribution was described as an Internet advantage, its importance to the transit industry as a whole is restricted because potential transit ridership for a given company is limited to the local geographic region.

A private company's advertisement to use the Web includes the following passage: "An AC Nielson survey of Internet users revealed that the median household income of the group [using the Web] is $63,000..."[20], which does not suggest a favorable share of transit users. This is a direct result of transit users typically being in lower income groups. Low-income groups represent a low percentage of personal computers owners and, therefore, Internet access is currently limited. A 1998 WWW user survey conducted by the Graphics, Visualization & Usability (GVU) Center at Georgia Tech showed an average household income of $52,500. The survey sample size was approximately 10,000. Figure 4 shows the average household income for multiple demographic groups.

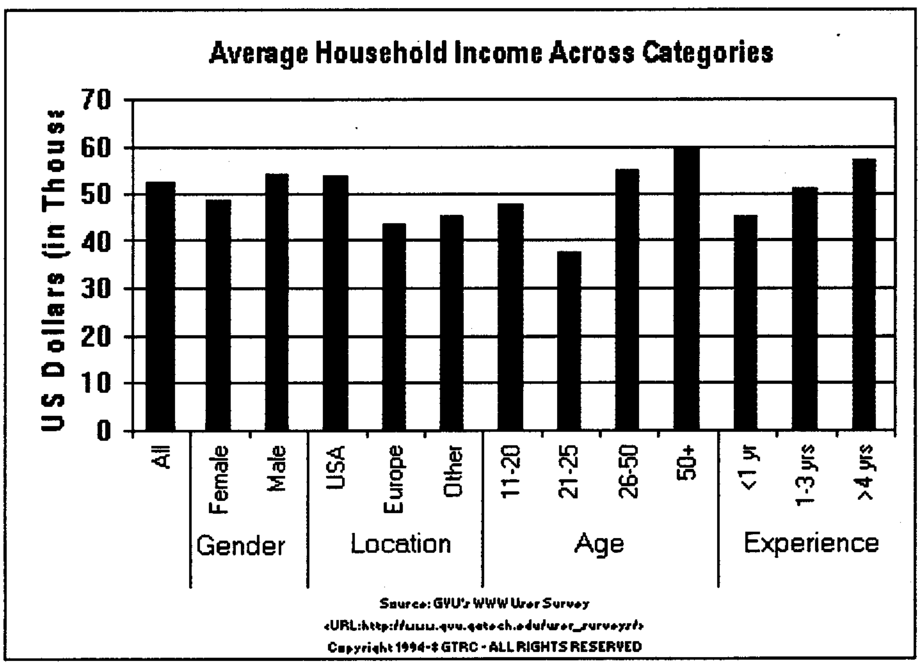

FIGURE 4: WWW USE BY INCOME

Source: GVU's 9th WWW User Survey [http://www.gvu.gatech.edu/user_surveys/survey-1998-04/]

Conversely, recent trends in the electronics industry suggest that a computer-television hybrid system may be a common, low-cost household item within the next few years. As of February 2000, the Sony Corporation has a product called the Sony WebTV Internet terminal that ranges in price from $100-200. These units integrate Internet and television programming from cable, satellite, or broadcast signals. An additional monthly fee of approximately $20-25 exists for Internet access excluding the monthly fee for regular cable or satellite services.[21]

Waiting time

Another drawback of the Web deals with the waiting time required to download the site. Detailed graphics (maps, images, and routing features) hinder the overall speed at which a site operates. This inconvenience to the customer directly relates to the reputation of the company and may deter future site visits. To avoid this problem, the system must be designed in an efficient manner to reduce the waiting time. One way to decrease the waiting time is to first transfer the written material to the viewer. While the user reads over the text, the more detailed visual graphics load in the background.

Synopsis

Clearly improvements in technology (e.g. availability of the Web via home televisions and better methods of transferring data) will alleviate some problems related to target audience and waiting time. Yet, the first three issues – credibility, liability, and competition – are challenges that remain regardless of technological advances. The next step is to analyze how the strengths of the Internet can aid the communication goals of the transit industry.

CHAPTER 5: EVALUATION OF INTERNET OPTIONS FOR TRANSIT

The examination of the Web's advantages and drawbacks in conjunction with transit agency communication goals suggests several Web-based features that could assist the public transportation community. Realistically, activation of a website will not dramatically increase ridership for existing transit dependent groups. Nonetheless, information can be provided to improve rider services for existing customers. In addition, a small portion of non-transit users may be influenced to use transit if additional incentives are provided such as employer reimbursement for transit expenses.

Static information on Transit Webpages

Every transit organization with an Internet presence has some form of displaying their route and schedule information statically. Basically, it is a digital reproduction of schedule information found in paper schedules. The benefits of static schedules include low cost and easy implementation. The information can be updated periodically with relatively minor adjustments. It has been previously emphasized that it is essential to frequently update and revise this information. It may be worthwhile to include a section from the main webpage stating recent changes to transit schedules. The main drawback is that this communications medium is not interactive with the user meaning the riders must derive how to use the system on their own.

Interactive Routing Application

An interactive routing feature, or trip planner, is an online transit information system that allows someone unfamiliar with a transit network and service area to plan a trip. It automates the procedure of finding the most efficient trip either manually or with human assistance from the public transportation provider.

The basic process of an interactive routing application is to prompt the user for an origin, destination, and a departure or arrival travel time. The user is then returned via the Web a map and customized personal itinerary. The information may include bus routes, bus stops, route transfers, departure and arrival times, fare (cost), and other information from the origin and destination to their respective bus stops.

State of the Industry

As described in the second chapter, the systems approach is an iterative process. One cannot expect a client to lucidly articulate transit communications goals without being given at least some understanding of the capabilities of expected communications technologies. In practice, analysts find it useful to initially perform the steps outlined by Gibson – define goals, technical capabilities, and an action plan – and then refine the products of these steps using new information acquired from the previous iteration. One of the necessary components of this process is a review of the current state of the practice. In this case, assessing the types of information communicated by other transit sites provides a framework from which to develop a prototype interactive trip planner.

<u>Common features of transit Internet presence</u>

Although transit webpages are unique and creative in design, it has been found that most sites contain similar types of information. In general, most include some form of static schedule information. The schedules vary from very simple time and location tables to more complex applications with visual graphics. The purpose of a static schedule is to provide, on the Internet, the same information found in written schedules. Static schedules are easy to create and maintain. Regarding maintenance, the webpage designer's only major revisions include annual or bi-annual schedule updates. A time stamp is a useful way to notify Web users of recent updates.

Ten website features were found through examining sites from a sample of nationally recognized transit authorities. Table 1 summarizes information found from six transit organization websites and their respective features. This research was conducted in early March 2000 and includes the following:

- ***Static schedule information***. All transit companies with webpages display some type of static schedule information. This generally includes timetables. This transit information is relatively simple to construct and maintain.
- ***Map display of the service region***. This map shows the routes, usually color-coded or numbered, laid over a general street network. Map attributes include airports, shopping centers, landmarks, and government buildings.
- ***Transit user instructions***. These instructions cover how to ride the transit system in a safe and efficient manner. Specific items include fare information, hours of operation, transfer procedures, how to board and exit the bus, and emergency instructions. For some transit agencies, this section was expanded to include other rules and regulations.
- ***List of special transportation services***. These services involve disabled and handicapped access to the transit system. Also, a list of important telephone numbers is provided for transit users.
- ***Frequently asked questions (FAQ's)***. This section answers common questions related to the transit authority. This component is valuable to customer service departments because the website answers simple questions allowing the customer service representatives to focus on more complex issues. In addition, website users find it rewarding to receive answers to their questions in a quick and efficient manner.

- ***Incident and construction information*** indicates service changes due to roadway construction, accidents, severe weather, and special events. This feature can be provided by either dynamic or static methods. Real time deliverance is more accurate but also more difficult to design. As a preliminary step, a transit agency could seek to post long term service disruptions on their site.
- ***Company profile and background*** describes agency history, fleet size, number of employees, service area, and safety and performance records.
- ***User feedback*** is a valuable asset to determine current rider satisfaction. Websites can provide links to suggestion boxes and online surveys to attract user feedback. This data is easy to collect and organize for statistical purposes. In addition, the cost is significantly less than hand-written, telephone, or in-person surveys.
- ***Fare information/Ticket purchasing.*** All transit organizations with websites provide fare information for riding the system. Some companies also allow for online ticket purchasing.
- ***Online Trip Planner.*** This feature is becoming more common as ITS and specifically traveler information systems are being developed for transit.

Table 1: Web Capabilities of US Transit Organizations (March 2000)

Feature	Atlanta (MARTA)	NJ Transit	Chicago (CTA)	Tri-Met (Portland)	San Diego	Washington (WMATA)
Static schedule	✓	✓	✓	✓	✓	✓
System map	✓	✓	✓	✓	✓	✓
User instructions	✓	✓	✓	✓	✓	✓
Special services	✓	✓	✓	✓	✓	✓
FAQ's	✓			✓	✓	✓
Static incident information	✓	✓	✓	✓	✓	✓
Company profile	✓	✓	✓	✓	✓	✓
User feedback	✓	✓	✓	✓	✓	✓
Fare information/ Ticket purchasing	✓	✓	✓	✓	✓	✓
Interactive Trip Planner	No	No	In progress	In Progress	Yes, In use	Yes, In use

Transit Webpage Sources:

Metropolitan Atlanta Rapid Transit Authority (MARTA): http://www.itsmarta.com/
New Jersey Transit (NJT): http://www.njtransit.state.nj.us/
Chicago Transit Authority (CTA): http://www.transitchicago.com/
Tri-County Metropolitan Transportation District of Oregon (Tri-Met): http://www.tri-met.org/
San Diego County Public Transportation: http://www.sdcommute.com/sdmts/
Washington Metropolitan Area Transit Authority: http://www.wmata.com/

Although not shown in Table 1, the investigation also included looking at smaller public transportation agencies. The smaller transit organizations had most of the features listed in the table excluding the interactive trip planner. It was, therefore, concluded that Pentran, the project client, is one of the only transit agencies of its size that is currently investigating the implementation of an interactive trip planner. The following chapter describes the details of designing the prototype trip planner.

CHAPTER 6: DEVELOPMENT OF A PROTOTYPE INTERACTIVE TRIP PLANNER

This chapter describes the major components of the planner and its development processes from initial concept to final product. All of the preceding work for this project forms the early stages of the design process to develop the foundation for the prototype interactive trip planner. The system analysis methodology presented in Chapter 2 integrates into the software design model (see Figure 5) as the precursor to the specific system design. The preliminary research effort formulated the guidelines for the **system functional requirements document** (see Appendix A). The importance of the functional requirements document is often overlooked in systems design but it is imperative for the overall success of a project. This lesson has been repeatedly emphasized in various software engineering applications. The following quote by Brooks summarizes the significance of effectively developed software systems requirements, which in turn can be extended to apply to ITS acquisitions:

Requirements

"*The hardest single part of building a software system is deciding precisely what to build. No other part of the work so cripples the resulting system if done wrong. No other part is more difficult to rectify later.*" ---
[Brooks, 1987] [22]

The primary steps for the system design of the trip planner include:

1. Functional requirements document (Appendix A)
2. Systems design with flowcharts and database descriptions (Appendix B)
3. Program development and coding
4. User interface development and Testing phase (Appendix C)
5. Client-user feedback
6. Implementation strategy

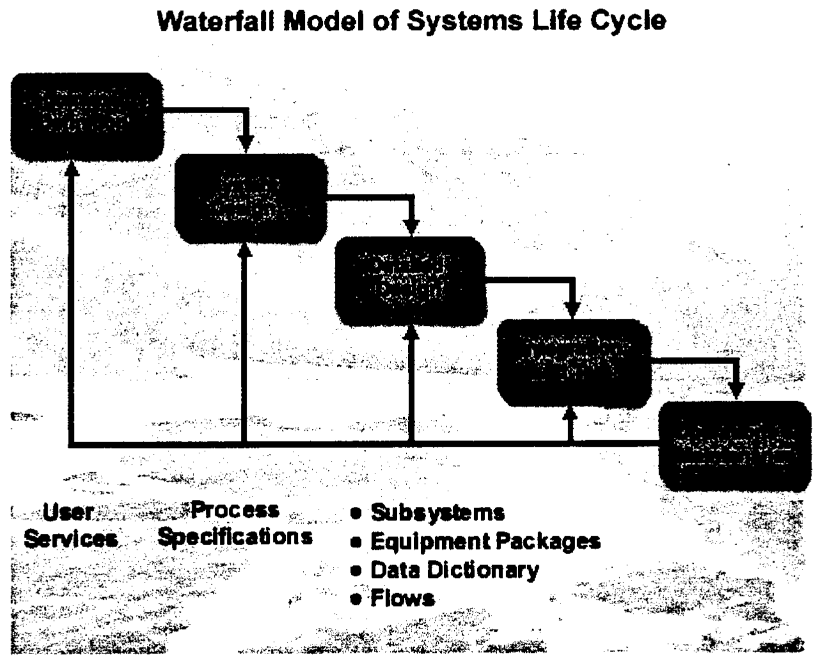

FIGURE 5: WATERFALL MODEL FOR A SYSTEMS LIFE CYCLE

The steps of the trip planner closely resemble the "waterfall model" commonly used in systems engineering. The shift was made from the original systems analysis methodology to the revised systems design due to the fact the prototype trip planner involves software development.

Trip Planner Description

An interactive routing application, or trip planner, allows unaccustomed transit riders to plan trips from origin to destination. From user location input (*Origin and Destination*), the routing program searches for bus stops using a spatial radius search. The planner finds trips based on origin and destination pairs by bus route identification utilizing an incremental transfer algorithm. The planner first attempts to search for no-transfer trips. If no zero transfer trips are found, it seeks for potential one-transfer trips. If one-transfer trips are unavailable, it looks for trips with two transfers, which is the maximum allowable number of transfers for the Pentran bus system. Transit trip times are matched as close as possible to the user-defined departure or arrival time by accessing transit system schedules. Trip ranking occurs by minimizing total travel time. The total trip time is the addition of bus travel time plus layover time during transfers. The top trip itineraries are then displayed by adding the total trip time and the estimated pedestrian walking time (20 minutes per mile) from the origin and destination to their respective bus stops. After the user selects a desired trip, the planner displays a full trip itinerary and two travel maps. Each map includes the origin or destination with their respective bus stops. Figure 6 is a rudimentary flowchart showing the steps between user input and trip calculation.

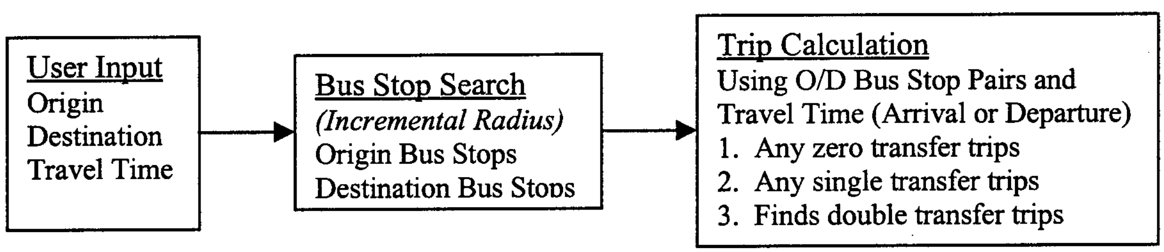

FIGURE 6: TRIP PLANNER FLOWCHART

Prototype System

The system architecture for this project involves various software and technology integration. A simplistic diagram for how the interactive trip planner program works is shown in Figure 7. The system consists of three main modules, which are controlled by the trip planner code, the central part of the system. The spatial database includes all GPS data collection (bus stops and routes), which is organized using ArcView, a GIS software package. The relational database contains the time schedules, all temporary data storage for possible trip plans, and a log of pertinent information entered by the users.

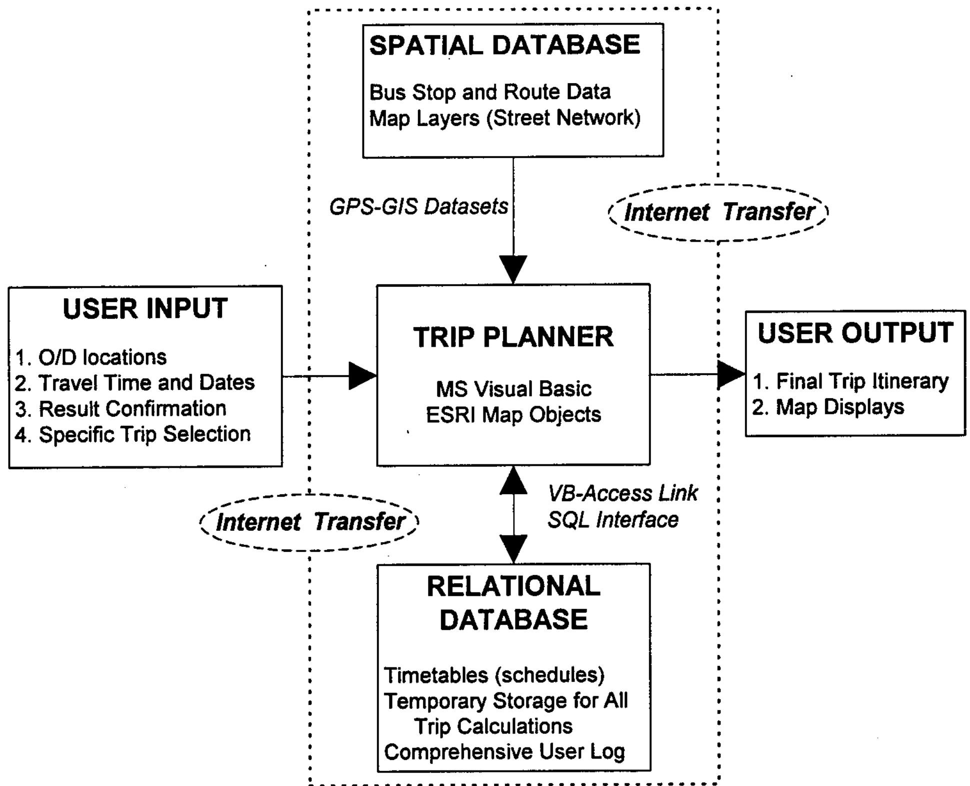

FIGURE 7: SYSTEM ARCHITECTURE

The main benefit of this project relates to the development of the trip planner using a system engineering design approach. Prior to any software development, this project engaged in a comprehensive systems analysis which transformed into the functional requirements document for the project design. The functional requirements are included in Appendix A (Functional Requirements). The public transportation industry may find it beneficial to use these design procedures as a foundation for future research and development related to traveler information systems. Using the basic system architecture and functional requirements, the research team developed a detailed, comprehensive system design for the trip planner. The system design flowcharts are included in Appendix B (System Design).

The existing trip planner program requires a variety of computer software applications. Listed below is a list of all software packages used in this project. The programs essential to running the trip planner are **bolded**. This trip planner must operate on a Windows-based (95/98/NT) platform.

SOFTWARE PACKAGE	PRODUCT DEVELOPER
Pathfinder Office, Trimble GPS receivers	Trimble Navigation
ArcView GIS Version 3.1, 1998	ESRI
Map Objects Version 2.1	**ESRI**
Map Objects IMS (Internet Map Server) Version 2.0	**ESRI**
Visual Basic Version 5.0, 1997 (Professional Edition)	**Microsoft**
Microsoft Access 97	**Microsoft**
Personal Web Server (Control Panel, Windows 95/98)	**Microsoft**
Web Browser (Internet Explorer or Netscape Navigator)	**Microsoft, Netscape**

ESRI: Environmental Systems Research Institute

The Trimble GPS receivers and Pathfinder Office were used for the data collection portion of the project. ArcView GIS organized the collected GPS data into useable shapefiles. Microsoft Access was used for the database creation. The ESRI products and MS Visual Basic were used for coding. The Personal Web Server and Web Browsers were used for Internet information transfer and display purposes, respectively.

Data Collection

Similar to most engineering projects, the first task involved data collection. Since no digital information existed for the Pentran bus system, bus stop and route data was collected using a global positioning system (GPS). GPS is a satellite-based recording device that collects location (Latitude, Longitude, and Altitude) information and other ancillary attribute data.[23] The stop and route data was collected over the course of one week during June of 1998. The Pentran bus system had 13 individual routes with approximately 60-100 stops on each route. Bus stop data was gathered in each direction (inbound and outbound) and included the following attributes:

- Geographic position (latitude, longitude and altitude),
- Route number and direction (either inbound or outbound),
- Presence of proper signage and shelters,
- Presence of curb-cuts (ADA compliance), and
- Location with respect to street (corner or mid-block).

The Pentran bus route data was compiled by driving each route in both directions and recording the proper route number. The 1999 Pentran system map is shown in Figure 8.

FIGURE 8: PENTRAN SYSTEM MAP FROM PAPER SCHEDULE

After all of the GPS data was gathered, the research group utilized a procedure called differential correction to eliminate errors that are purposely transmitted through the GPS satellites for government security purposes. This process was done by using information collected by the Virginia Institute of Marine Science (VIMS) in Gloucester

Point, Virginia. VIMS continuously gathers GPS data on a known ground position (Gloucester Point station). Simultaneously, a database stores the difference between the actual location and the location given by the GPS receivers. This value, which changes multiple times per second, can then used to correct GPS data so long as the data collection time is known and the data is collected within a few hundred miles of the ground beacon.

Following raw data collection and differential correction, the research group organized the data by creating GIS (Geographic Information System) data files. ArcView GIS shapefiles were constructed for each bus route and stop data set. Bus stops and bus routes were point and line themes, respectively. Each stop was then geo-referenced to a street network shapefile to identify a street location. For example, the bus stop on the corner of Washington Street and 45th Street was visually inspected in the ArcView program to be near the intersection of these two streets according to the street layer.

Database Creation

Another necessary component for the trip planner was a database containing the bus system timetables and a route transfer matrix. Both of these databases were created using Microsoft Access. The bus system timetables are basically identical to a paper, bus schedule. For each route, the bus stops are shown with their corresponding arrival and departure times (*see Figure 9*). The transfer table was created specifically for the trip planner application. Figure 10 shows a portion of the transfer table for Route 1. Similar transfer tables were created for each of the Pentran routes. The route transfer array provides bus stop transfer points for each route (Stop_Num) and lists the different routes that a particular bus stop transfers to (T to 2I, 2O, 3I, 3O, etc.). This database is essential when a zero transfer trip is nonexistent. The trip planner allows for one and two transfer trips. Additional databases include storage files for the multiple trip routings for a specific trip calculation and user profiles.

Microsoft Access - [route01 : Table]

1001	1002	7:45 AM	10:45 AM	1:45 PM	4:45 PM	7:45 PM	10:45 PM		8:15 AM	11:15 AM
1002	1003	7:45 AM	10:45 AM	1:45 PM	4:45 PM	7:45 PM	10:45 PM		8:15 AM	11:15 AM
1003	1004	7:45 AM	10:45 AM	1:45 PM	4:45 PM	7:45 PM	10:45 PM		8:15 AM	11:15 AM
1004	1005	7:50 AM	10:50 AM	1:50 PM	4:50 PM	7:50 PM	10:50 PM		8:20 AM	11:20 AM
1005	1006	7:50 AM	10:50 AM	1:50 PM	4:50 PM	7:50 PM	10:50 PM		8:20 AM	11:20 AM
1006	1007	7:50 AM	10:50 AM	1:50 PM	4:50 PM	7:50 PM	10:50 PM		8:20 AM	11:20 AM
1007	1008	7:55 AM	10:55 AM	1:55 PM	4:55 PM	7:55 PM	10:55 PM		8:25 AM	11:25 AM
1008	1009	7:55 AM	10:55 AM	1:55 PM	4:55 PM	7:55 PM	10:55 PM		8:25 AM	11:25 AM
1009	1010	7:55 AM	10:55 AM	1:55 PM	4:55 PM	7:55 PM	10:55 PM		8:25 AM	11:25 AM
1010	1011	7:58 AM	10:58 AM	1:58 PM	4:58 PM	7:58 PM	10:58 PM		8:28 AM	11:28 AM
1011	1012	7:58 AM	10:58 AM	1:58 PM	4:58 PM	7:58 PM	10:58 PM		8:28 AM	11:28 AM

FIGURE 9: PENTRAN ROUTE 1 TIMETABLE

Microsoft Access - [Transfers01 : Table]

1001	0	0	0	0	0	0	0	0	6073	6532	7065	7532	0	0
1007	0	0	0	0	4001	4553	0	0	0	0	0	0	0	0
1032	2061	2501	0	0	0	0	5001	5576	0	0	0	0	0	0
1049	2021	2527	3001	3549	0	0	0	0	0	0	0	0	8040	8501
1098	0	0	3050	3501	4049	4501	5040	5534	6088	6515	7081	7515	0	0
1501	0	0	3050	3501	4049	4501	5040	5534	6088	6515	7081	7515	0	0
1551	2021	2527	3001	3549	0	0	0	0	0	0	0	0	8040	8501
1570	2061	2501	0	0	0	0	5001	5576	0	0	0	0	0	0
1596	0	0	0	0	4001	4553	0	0	0	0	0	0	0	0
1599	0	0	0	0	0	0	0	0	6073	6532	7065	7532	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

FIGURE 10: PENTRAN ROUTE 1 TRANSFER TABLE

Trip Planner Coding

The trip planner was organized and built by using Microsoft Visual Basic code - Professional Edition, version 5.0. Visual Basic, an object-oriented program, was used to build the user interface, which collected and displayed all trip information. The strengths of Visual Basic include low cost to purchase ($500 and $100 for commercial and academic purposes, respectively), ability to integrate with multiple software programs including ESRI products, and a comprehensive selection of user interface tools. For this project, the programs assimilated using VB code include ESRI Map Objects, ESRI Map Objects IMS (Internet Map Server), ESRI ArcView shapefiles, HTML, and the Windows-based Personal Web Server.

Trip Calculation

The actual algorithm used to calculate trips in the Pentran Interactive Trip Planner is logical and straightforward in nature (see Appendix B). Basically, the governing rule used to calculate trips is to *find the trip that returns the overall shortest bus travel time.* The calculation is internal to the Visual Basic code. All possible trips are stored in temporary MS Access files. The trips are then sorted by total bus travel time. The top four trips are transferred to the user interface where the user selects their choice. After a choice is made, a final, detailed trip itinerary is returned with maps showing the origin and destination and the respective start and finish bus stops.

Final Product

The trip planner project is completed and is now functional as a prototype program. Rather than describing each step individually, it was decided to walk through how a typical user would use the interactive routing program to derive a trip. Briefly, the planner runs through the following user interface procedures to calculate transit trips:

- Introductory Page
- Origin and Destination Input
- Origin and Destination Confirmation
- Travel Time Input
- Trip Selection by user

- Final Trip Itinerary and Map Display
- Return Trip Calculation (Switches Origin and Destination), *if desired*

Screen shots of each interface screen are shown in Appendix C. The screen shots were taken from an actual trip calculation using Netscape Navigator. The example calculates a one-transfer trip but the planner also works correctly for zero and two transfer trips. The origin is entered using the landmark list. The user enters the destination by utilizing the regional map. The travel time is inputted as a departure for a Monday at 3:00 P.M.

The following section begins with an analysis of a major project dilemma encountered during the development stages. Next, project recommendations and improvements are established and explained for this planner and other potential investigations. The last portion of Chapter 7 describes a plan to incorporate AVL technology into the trip planner application. Basic guidelines are provided to integrate the current project with future ITS technologies.

Chapter 7: Project Analysis & Proposed Future Research

Speed/Accuracy/Aesthetics Tradeoff

One of the primary project difficulties encountered during the development of this program involves a tradeoff between three program characteristics. The three attributes are *trip calculation speed*, *performance accuracy*, and *visual aesthetics*. Trip calculation speed is the actual computer time required to compute a given trip. The main variable controlling calculation time is the number of transfers. Trip calculation time increases significantly as the number of transfers increases from zero to one to two. To verify this trend, multiple samples were taken for zero to two transfer trips. The statistics for these results are shown in Figure 11. Computer calculation times were defined as the time it takes to return a trip calculation via the web interface following the selection of trip travel time. As seen from the figure, computer calculation times increase as the number of transfers also increase. Calculation time is important for Web-based applications because most Internet users are accustomed to receiving information quickly (less than 10 seconds).

In the preliminary design, this problem was recognized but its overall hindrance to the trip planner was not identified until testing commenced. The calculation time dilemma presents a major problem for implementation. As mentioned previously, Internet users are accustomed to receiving information very quickly. Another problem deals with the fact that the current trip planner has no ability to inform the user when the processing will be completed. Prior to commercial implementation, it is recommended that some clock be added so that users have some sense of when the trip planner will return a solution. Otherwise, many Internet users will abandon the site early thinking that the program is not running or broken.

Interactive Trip Planner Computer Calculation Times (Speed Test)	Trip Transfers		
	Zero	One	Two
SAMPLE SIZE	30	28	5
MINIMUM VALUE (Sec)	8	17	41
MAXIMUM VALUE (Sec)	32	227	280
AVERAGE (Sec)	19.5	70.0	129.8
STANDARD DEVIATION (Sec)	7.7	49.9	102.0
95% C.I. [STUDENT-T DIST.] (Sec)	2.9	19.3	126.6
Note: These times are specifically for the trip calculation portion of the planner and do not account for use of introductory pages and selection of origin, destination, location confirmation, travel time, and final trip itinerary.			
A 95% Confidence Interval was calculated using a student-t distribution because there exists a small sample population for the three types of trip transfers, especially the two-transfer trip. T distributions are governed solely by one parameter, the number of degrees of freedom. The "degrees of freedom" value is equal to one minus the sample size.			

FIGURE 11: COMPUTER CALCULATIONS TIMES FOR TRIP PLANNER

Performance accuracy is the ability of the trip planner to return an accurate trip profile. Example: For a given origin and destination pair, the trip planner returns the most efficient movement using the transit system. The main tradeoff occurs between calculation speed and accuracy of performance. Both of these issues are pertinent for the overall effectiveness of this program. Therefore, during the development of this trip planner, we constructed this planner by minimizing calculation time and maximizing the accuracy of trip results.

The third component involves the visual appearance of the information being displayed. The trip planner would run slightly faster if it contained no maps or graphics.

However, when giving directional information, the public comprehends the information better when the itinerary includes a spatial reference, or map. Consequently, the decision was made to use maps for this project because its benefits outweigh the limitations. In the early stages of the project, map loading was viewed to be a major drawback for the transfer of information from the web server to a user. This problem was overestimated, as map loading is not the bottleneck when compared to calculation speed. In retrospect, more emphasis should have been placed on the internal calculation for the planner.

The primary cause of the high trip calculation speeds relates to the fact that this project resulted in the development of a **prototype** system. It is important to remember that this system was not designed for commercial purposes. The program is running off of a 1998 Micron Electronics, Inc. personal computer with the following system specifications: Intel Pentium II processor, 128 MB of RAM, and 8 GB of total hard drive capacity. The program is currently using the standard Microsoft Personal Web Server, which is included with Windows 98. In addition, the program uses MS Access as the main storage database. This application has limitations in both querying and retrieval functionality. Also, the computer currently being used is not solely dedicated to run the routing program and it is not a dedicated server. For a commercially designed application, the software and hardware computer components would be upgraded to allow for additional memory, processing capability, and web server performance.

Recommendations

<u>Software testing and evaluation</u>

To date, the interactive trip planner is complete and functional for calculating trips from the original Pentran bus transit system for Routes 1-12. However, it is important to remember that this project is a research prototype and, therefore, we caution immediate public usage. To cover any liability issues, we recommend that a statement be included to the Internet interface and for any similar projects that states that this program is in a research and testing phase.

Prototype implementation

One of the most difficult segments of this project is establishing how to set this program up so that the transit riders can utilize it. A project such as the planner requires a detailed level of testing prior to public exposure. Therefore, controlling it at the central developer allows for monitoring and corrections by individuals familiar with the system. Similar to any large-scale software development, there must exist some intermediate period where the developer teaches the client the inner workings of the program.

Bus route numbering schemes

The issue with route numbering caused some programming difficulties during the coding phase of this project. Throughout this program, the trip planner uses a bus route number to identify a particular bus route. For a pure numeric system, this process is relatively simple because the first one or two digits of each route represents the route it is on. For example, stop 4 on route 3 is coded as 3004 and stop 6 on route 11 is coded as 11006. In the Pentran system, some confusion occurred when coding route 8A. The problem was overcome by using a different numbering scheme for non-numeric routes (Example: Route 8A was coded as 88). As a result, the code for this program became specific for use only to the original Pentran system. If this project were used in the future for some variation of the original system, then a different route-numbering scheme would need to be adopted. Perhaps, one solution involves the use of look up or reference table. This would simplify problems made in coding this trip planner. This is particularly important for Pentran because with the recent merger there now exists duplicate route numbers carried over from the preceding route numbering.

Hampton Roads Transit (Pentran-TRT merger)

An evident usage limitation of this trip planner formed following the primary development stage of this project. All Geographic Positioning Systems (GPS) data were collected for all original Pentran bus routes and stops. The recent merger of Pentran with Tidewater Regional Transit (TRT) hinders the immediate implementation of this program due to certain political and operational concerns. However, the new transit organization, HRT, can expand upon the work completed for the former Pentran system and extent it to include all new bus stops and routes. The major benefit of this project is that the basic system design is applicable to multiple scenarios meaning the design is flexible to various types of transit system configurations. Flexibility is one of the major benefits of the system design approach that was employed for this project. The likelihood of a company merger was not included in the original design procedures; however, the inherent system still remains intact. The additional work for the new portion of the HRT system would consist of the following components:

1. GPS data collection for new bus stops and routes,
2. Implementation of new GPS themes into Visual Basic,
3. Some coding corrections to account for different route numbering schemes, and
4. Creation of new maps for user origin and destination selection.

Integration of ITS Technologies

With the recent growth of ITS deployment, many private companies are now providing traveler information services in large US cities. SmarTraveler, http://www.smartraveler.com/, provides traffic, transit, incident, and weather information to 12 US metropolitan areas. Traveler information systems are another field within ITS used to improve existing transportation conditions. Similar to the interactive trip planner application for transit, SmarTraveler and other traveler information services will continue to ride the wave of information technology assisting in transportation decision making for the public.

The current trip planner was not designed to incorporate real-time traffic conditions for the regional road network. Trip calculations are based solely on using the static bus schedules for the transit system. Therefore, the trip planner essentially automates the procedure of manually formulating a trip from origin to destination. A future research effort might include the addition of real-time traffic information of the local street network in calculating the bus trip travel times. The benefit of this endeavor would be that the estimated travel times would be much more accurate than the existing static method.

One method in which to incorporate real-time traffic updates with a transit trip planner involves the use of AVL (automatic vehicle location). AVL, a subgroup of ITS, are computer tracking systems that locate vehicle positions and transmit this data to a central dispatch center. For the most part, the computer tracking systems are GPS-based. The efficient use of an AVL system will improve safety, system operations, and customer service at a lower cost when compared to manual collection methods such as driver updates. A study of US transit management systems estimates the following benefits from AVL systems:

- Decreases transit travel times by 15 - 18%
- Increases service reliability in on-time performance by 12 - 23%
- Decreases incident response time up to 40%
- Predicts high cost effectiveness (45% return on investment) [24]

Like the interactive trip planner, AVL requires a detailed level of technological integration. Figure 12 depicts the location data transfer between multiple technologies. GPS is used to calculate the bus location. This data is then transmitted from the bus to the central dispatch center or transportation management center where it can then be processed and displayed to a variety of other end users. As shown in the diagram, the final communication tools may consist of telephone and the Internet. This valuable information can also be used in conjunction with the trip planner.

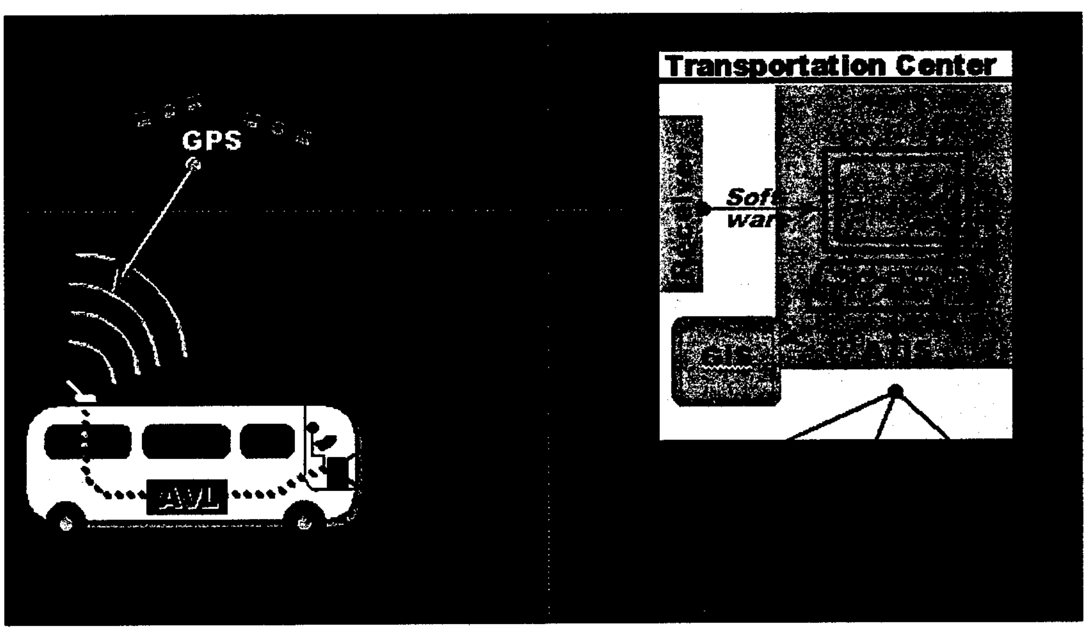

FIGURE 12: AVL TECHNOLOGY

Source: http://pcb.volpe.dot.gov/ppt/trnst_man02.ppt

After the location data is processed at the central dispatch or TMC, it can be utilized in some fleet management program that calculates approximate time arrivals to future bus stops. This information can be very useful for a bus company because the transit vehicles must interact with regular car traffic, there exists no separate right-of-way. Figure 13 is a schematic of a preliminary system architecture for this concept.

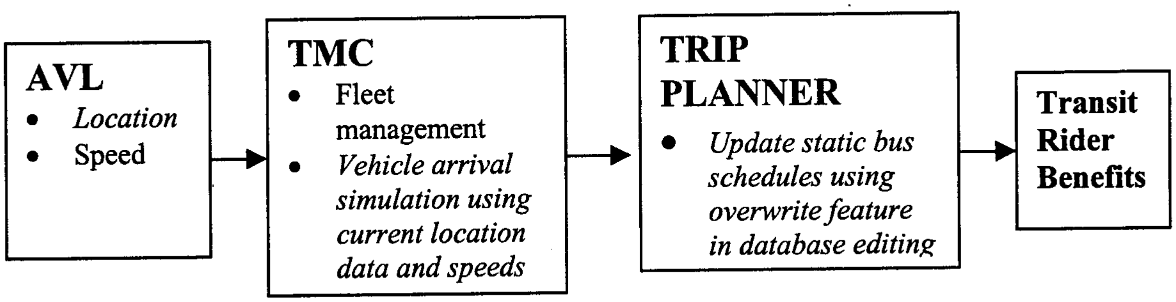

FIGURE 13: INTEGRATION OF AVL & INTERACTIVE TRIP PLANNER

The static schedule update and overwriting feature warrants further detail. AVL systems can estimate future arrival times based on individual use or the combination of distance calculations and historical observations. Distance computations simply utilize the known location of a bus and the distance to the next stop. From there, a program can use either a measured or theoretical travel speed to determine the bus stop arrival time for subsequent stop locations. A limitation with the distance-based calculation is that assumes an average, sustained speed between the current location and the next bus stop. In high traffic areas, this assumption does not hold true due to the number of traffic signals that may exist along a particular bus route and traffic congestion during peak travel periods.

To improve this decrease in arrival time accuracy, the AVL system could integrate local traffic signal information into the computation. One way to accomplish this task is to calculate an average vehicle travel delay at traffic intersections. The average travel delay could be computed for the following traffic conditions: weekday morning peak, weekday evening peak, weekday midday, weekend peak, and off-peak. Based on current traffic conditions and time of day, an estimated vehicle delay calculation can be used to further revise the estimated arrival time from the AVL system.

Historical referencing estimates arrival times based on matching the current travel conditions to previously stored similar scenarios. The travel conditions used to characterize traffic consist of volume, flow, time of day, day of week, weather, and occurrence of incidents. This method requires a detailed database storing multiple traffic parameters and some type of complex prediction algorithm.

Regardless of the format used, these time updates must be transferred from the parent program to the data files storing the bus route timetables utilizing a database overwriting scheme. For this interactive routing application, this task is conceivable by performing the following steps in sequential order:

1. Reference updated arrival times to a particular bus stop number and route.
2. Open database file containing the specific bus stop and locate specific row for the bus stop.
3. Utilize a search operation to find the particular column that corresponds to the current bus run. (Example: 1st run at 7:03 AM, 2nd run at 7:33 AM, 3rd run at 8:03 AM)
4. Overwrite static time with updated arrival and departure time.
5. Close database.

Although the assimilation of AVL with the transit trip planner requires additional research, system analysis, and funding, the potential long-term benefits warrant at least an initial investigation and feasibility study. To summarize, ITS is a large and continually expanding field. To ensure maximum efficiency, transit organizations must carefully select the proper ITS tools that are most effective to solve their current and estimated future dilemmas. With that said, the content of Chapter 8 is to summarize the research, reemphasize key concepts and lessons learned, and conclude with an explanation of how this project relates to the field of intelligent transportation systems and traditional transportation engineering.

CHAPTER 8: CONCLUSIONS

A systems analysis was applied to the problem of determining how the World Wide Web can assist a public transportation services provider meet its goals and objectives. The principal recommendation is to improve the quality of the service for riders by offering tangible transit traveler information to patrons. For this project, the concept was explored to ensure that this research was a worthwhile endeavor in terms of necessity, feasibility, adequate return on investment, and overall benefit to the field of transportation. The preliminary investigation strengthened the argument and lead to the development of the functional requirements procedures and subsequently the design of the prototype interactive trip planner.

Another finding is that the Web offers ways to improve transit performance without necessarily increasing operational expenditures. Typically, one thinks of transit performance as some physically observable characteristic, such as headways, ridership, or operating speed. The quality of the ride, which is paramount to the transit rider – including confidence in the service – is a critical factor. An additional conclusion is that the systems analysis is used to look substantially farther than industry practice. Although current problems are relevant, future challenges, especially as Web market penetration grows, may be addressed now through planning efforts.

Recommended Functional Design

The main benefit of this project relates to the development of the trip planner using a systems engineering design approach. Prior to any software development, this project engaged in a detailed functional-level project design. This framework can be used as a guide for future development of Web-based transportation information systems in the transit industry. The original functional requirements are included in Appendix A. Pentran may use the design procedures as a foundation for future research and development related to traveler information systems.

Lessons Learned

The major lesson learned from this research is the importance of using a systems engineering approach. Due to project complexity and the lack of knowing the end result, the system design, which preceded project development, ensured that the project had a guideline to follow. However, this assurance did not result without a cost. The design framework was very time consuming and required patience to complete. The design document took approximately six months to complete utilizing a research team of four graduate students working on a part-time basis.

In project design, the key element to remember is that systems design is an iterative process. Even at the completion of the prototype development, the project team identified many modifications and improvements. Another important consideration for any type of engineering project is the willingness to accept changes that correlate with alterations in the client's objectives. During the development phase, the end user might change certain goals and objectives. It is crucial to plan for these contingencies by ensuring that proper communication takes place between the project developer and the client. The project must be completed in a manner to deliver a final product that fulfills the requirements stipulated by the project contract. Finally, in most cases involving engineering project development, an inherent job task is for the consultant to help the client to identify and solve the actual problem. Fundamentally, it is actually straightforward. The client needs assistance to establish and design a remedy to a certain issue or problem. Otherwise, the client can solve the dilemma, in-house, without outside consultant support.

Project Summary

In review, the project objective is to construct an interactive trip planner that delivers accurate transit trip information through a highly visible medium in a timely and efficient manner. The initial project goals have been accomplished with success. Realistically, the outcome of trip planner was difficult to assess during the initial development stages. I feel this planner was a success in incorporating many different kinds of technology and delivered a final product that can be accessed by all individuals via the Internet. In retrospect, I feel that a more efficient development strategy would have been to utilize the training and expertise of students with computer science and programming knowledge earlier in the coding stage. I feel one of the major drawbacks of this trip planner for actual implementation involves the computer calculation time for complicated, multi-transfer trips. In future trip planner development, I would strongly recommend that the systems design focuses on this design issue. In conjunction, from this research it is evident that the database structure is fundamental for overall program success. The main speed problems are not from slow data transfer from the web server but they are instead the internal database searching that must take place to compute a trip.

As mentioned previously, a prototype design is difficult to construct correctly at the beginning and therefore, requires a detailed framework or outline prior to any attempts at coding. The project designer must also be open to changes midstream by the client and other external factors. For this project, one unforeseeable problem, which complicated the eventual implementation of the trip planner, was the merger of Pentran with TRT. Although a great amount a time was put into the preliminary project development, sometimes outside, unpredictable situations may arise that hinder the original project achievement. One solution for the merger problem would be to extend the project to include the incorporation of bus route and stop data for the new HRT bus system.

Relevance of Project to Transportation Industry

The Pentran Interactive Trip Planner incorporated modern ITS technology to assist the operational concerns of a transit organization. The intention of this ITS project was not to solve all transportation-related problems for the transit industry. Nevertheless, in review, it is evident that the success of any company is influenced by user and customer satisfaction. In my opinion, this is a major benefit of this project and other ITS applications. The information exchange between transit provider and user is crucial to improve operations for public transportation agencies. By providing users with more travel information, they have a sense a having greater input into their personal transportation decision making process. Tools that assist a transit user result in a more enjoyable traveling experience. ITS should be included as an addition to or alternative to consider in the standard transportation planning process.

Intelligent Transportation Systems are bridges that link transit provider to rider. Efficient information exchange ultimately leads to improved efficiency and better operations without the need for excessive infrastructure improvements. ITS alone cannot solve transportation problems. However, ITS does provide a variety of tools to help address surface transportation problems through an intermodal, strategic approach to transportation. Through effective integration and deployment, ITS enables a more efficient use of existing funding resources and improvements to safety, mobility, and accessibility.

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APPENDIX A (FUNCTIONAL REQUIREMENTS)

REQUIREMENT DOCUMENT FOR PENTRAN INTERACTIVE PLANNER

The purpose of this project is to develop an interactive trip planner for users of PENTRAN, public transit for the Peninsula region of Virginia. PENTRAN transit consists of 12 bus routes that cover the cities of Hampton and Newport News and a limited area of York County. The goal of this project, in conjunction with a well-developed Internet site, is to increase ridership, provide beneficial traveler information, and improve the public image of PENTRAN.

The interactive routing feature, or trip planner, will allow a user that is unfamiliar with the PENTRAN routes and/or service area to plan a trip from their origin to a specific destination. The user will enter their origin and destination by entering an address, inputting a street intersection, selecting a predetermined location (landmark), or selecting from a map of the service area. The routing program will calculate possible trips between the origin and destination by examining possible bus stops utilizing an incremental radius search of the origin and destination. These trips will then be presented to the user, for the user to select and view a particular trip. Once a trip is selected, a trip itinerary will be presented to the user with all of the necessary travel information. Also included will be a trip map that shows the desired bus stops for pickup and delivery and their relation to the origin and destination through the use of a street network.

This routing system will provide a user with tools to choose the route that best matches their personal preferences such as shortest travel time, minimum transfers, shortest walking distance, etc.

USER INPUTS

The routing feature is started from a browser by entering the specific URL. At the start of the feature, the user will be presented with the origin inputs page. From this page, the user will enter their origin location. After the origin is successfully entered, the destination inputs page is presented to the user with a similar setup. A map with both the origin and destination are returned to the user for location confirmation. Finally, the time input page is presented to the user and the individual enters either an arrival or departure time. By default, these themes will be included on the map: street network with labels, city/neighborhood labels, and landmarks.

Origin (four options of inputting origin all contained on same screen)

A. enter specific address

1. include user instructions for entering address
2. not case sensitive
3. user must enter a street number
4. allow user to re-enter address within same text box

B. enter street intersection

1. include user instructions
2. include two text boxes, one for each street
3. allow user to re-enter streets within same boxes

4. not case sensitive

C. select landmarks from pull down menu (on same input form as A)

1. use landmarks indicated on PENTRAN maps and popular stops from user data

D. click on map

1. start off with full view of service area (label Hampton and Newport News)
2. let user zoom in and out on map
3. enable/disable map layers based on map extent
4. include instructions on zooming and picking (changing tools)

Destination (four options of inputting destination all contained on same screen)

A. enter specific address

same as above

B. enter street intersection

same as above

C. select landmarks

same as above

D. click on map

same as above

Origin and Destination Confirmation

A. Display origin and destination points to user

B. User accepts or rejects sites

Times and Date (Arrival and Departure times on a separate third screen)

A. only accept arrival or departure time (radio buttons prevent user from selecting both options)

B. departure time (leaving origin)

1. select hour from pull down menu
2. select minutes (15 minute intervals) from pull down menu
3. select AM or PM
4. make current time default to next 15 minute period

D. arrival time (arriving at destination)

same as departure time

E. select day of the week from pull down menu

1. make current day default

The program uses an incremental radius search to find the closest bus stops.

VIEWED OUTPUTS

Once the program has identified potential trips, the user will select one trip for viewing from the list. The results will be displayed in a tabular and map format. This is intended to be the final page for the feature but the user will have the option to return and view another trip, schedule a return trip, or return to the beginning and plan a new trip with a new origin and destination.

Itinerary (step by step instructions)

A. estimated departure time

C. bus route number and color

D. all transfer locations and times
E. estimated arrival time

Trip Map
A. Permanent layers (always displayed)
    1. street network
    2. landmarks
    3. Origin and destination points will be labeled as such
    4. nearest bus stop to origin and destination will be labeled
        a. get address from database
B. Non-permanent layers (on/off depends on current zoom level)
    1. labels for street names
        a. which streets are labeled is defined above
C. Layers that can be turned on/off by user
    1. all bus stops for each route used during trip

SYSTEM PERFORMANCE

Internet browsers
A. compatible with Netscape and Explorer
B. have optional text pages of static schedules (to be developed by PENTRAN)

Map loading times
A. include message for user while map loads
    1. "Please wait while map loads"
B. give periodic updates while loading
    1. "Finding nearest bus stop"
    2. "Searching all available routes"
    3. "Loading is complete"
C. include messages every 15 seconds to ensure user confidence of system

Server logs (recorded as database file on server computer)
A. each time the feature is run a new log record is started
B. user profile characteristics
    1. record internet address (domain name) of user
    2. record type of browser used
    3. record time spent at site for each user
    4. previous site visited (how they found PENTRAN site)
    5. link to user comments
C. program profile characteristics
    1. record all confirmed origin and destination addresses entered
    2. record map-loading times
    3. record the number of successful schedules produced
    4. determine if a final map and itinerary was given to user
    5. record time of day and date

APPENDIX B (SYSTEM DESIGN)

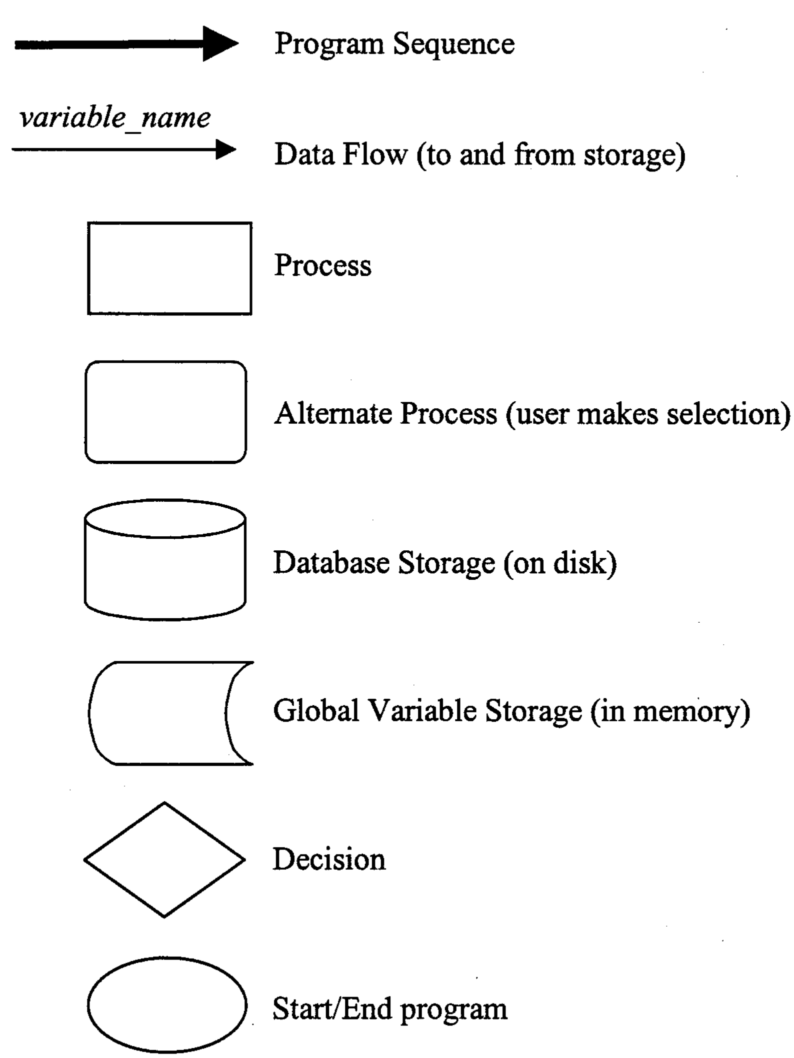
System Behavioral Design

October 27, 1998

PROCESS DIAGRAMS

The diagrams that follow describe the sequence of procedures executed by the program. Processes, storage, and decisions made by the program are each represented by different symbols in the diagrams. The legend below describes each of the symbols used in the flow diagrams. The sequence of processes executed by the program is represented by bold arrows on the figures while data flow to and from storage is represented by thin arrows. Data flow arrows are accompanied by the name of the variables that are transferred to or from storage.

DIAGRAM LEGEND



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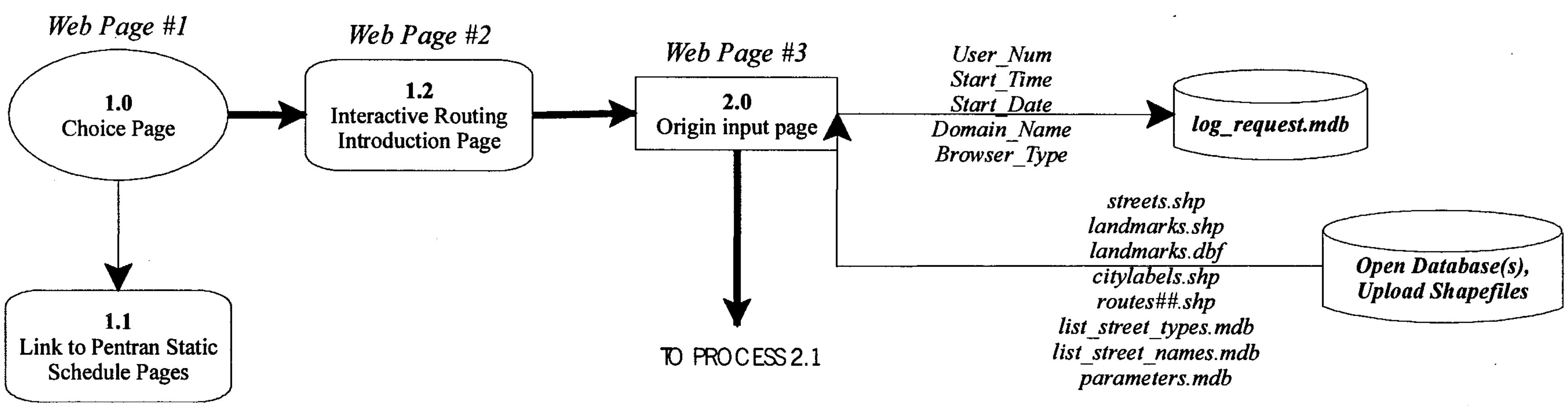
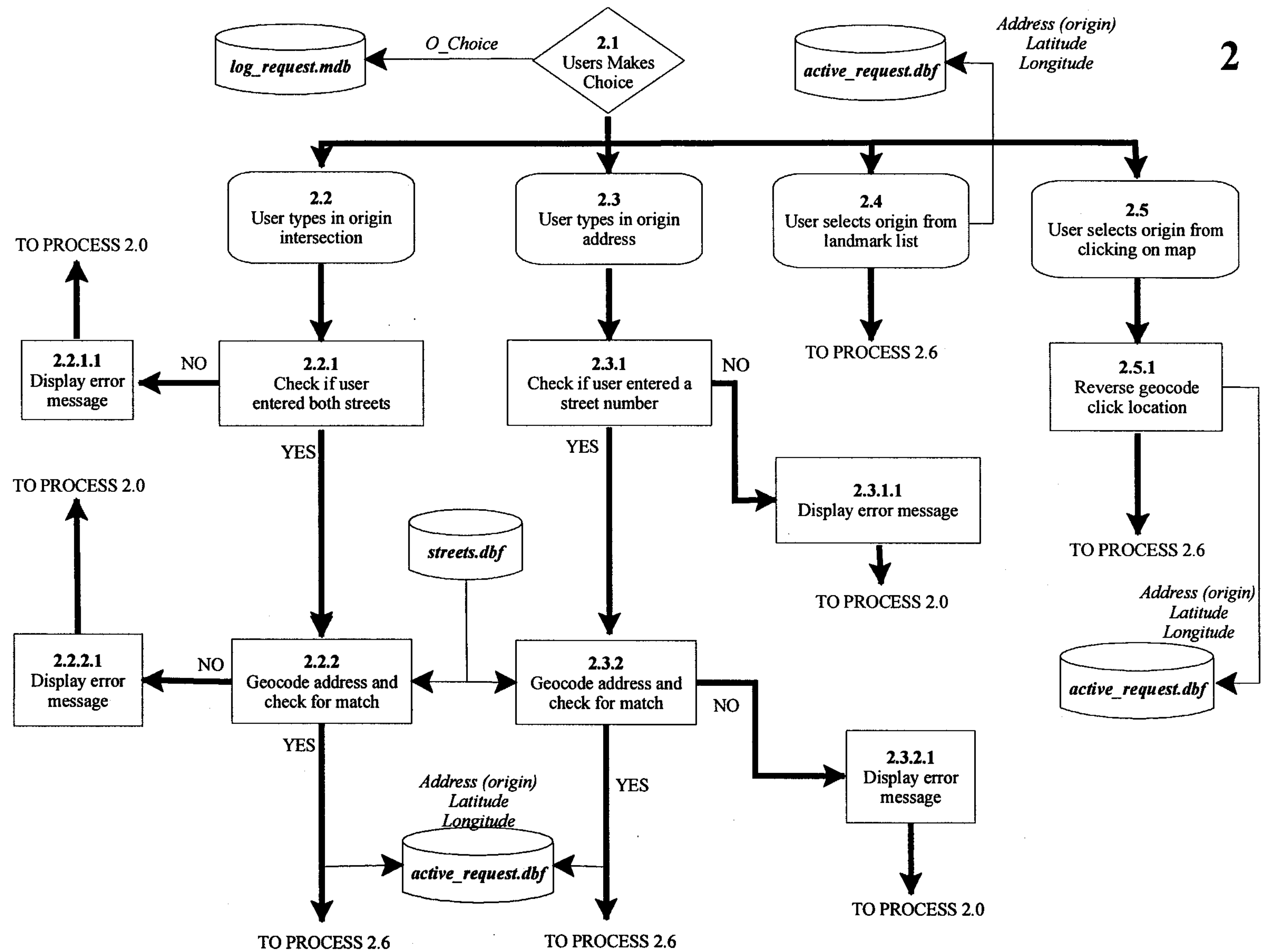
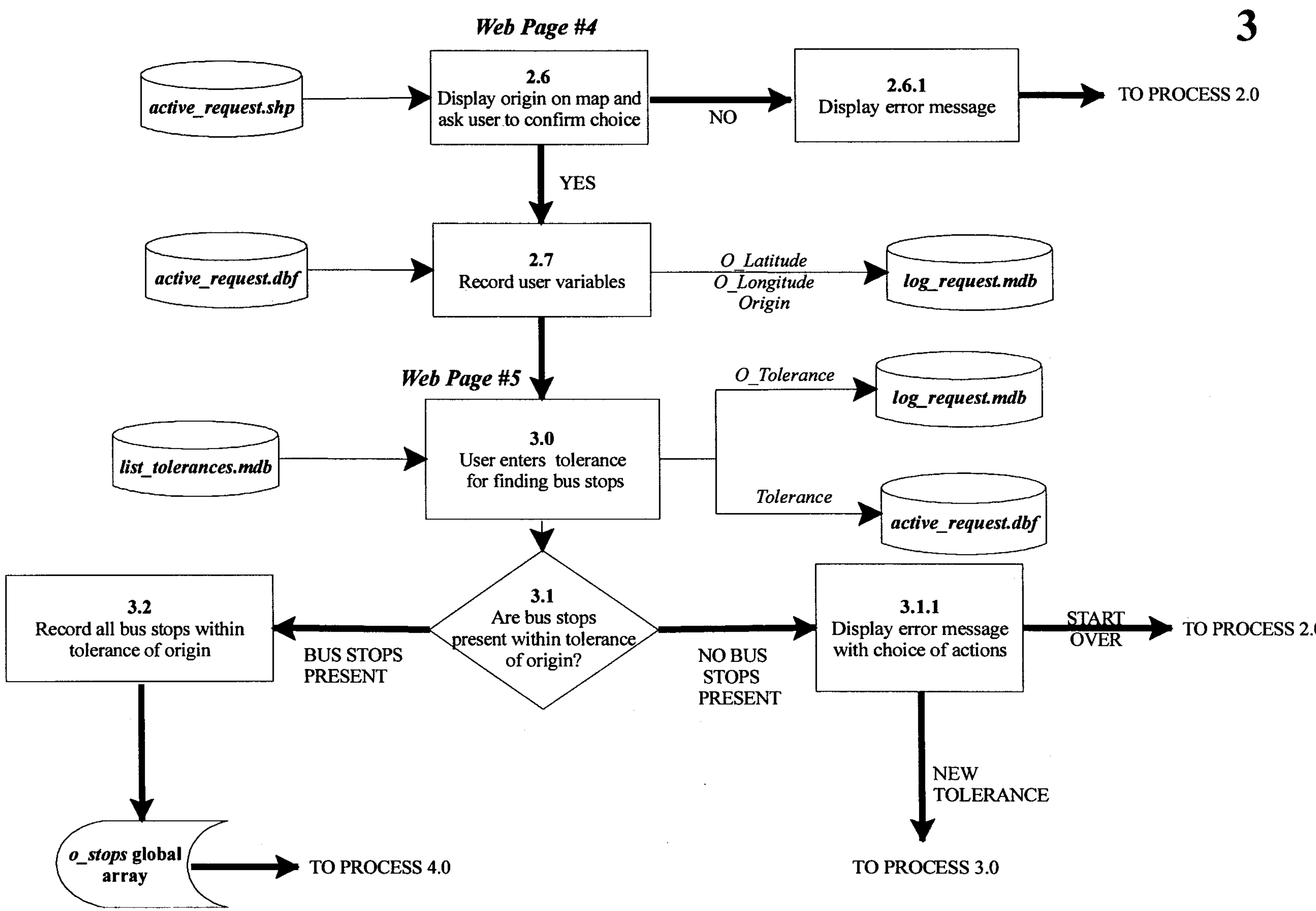
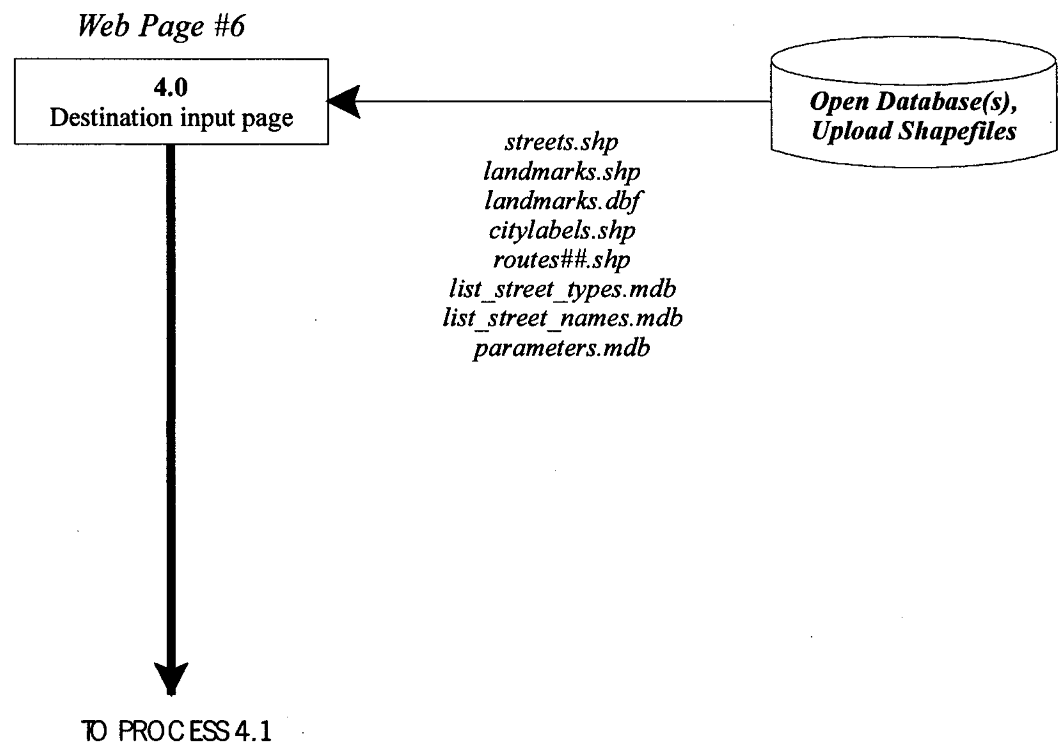
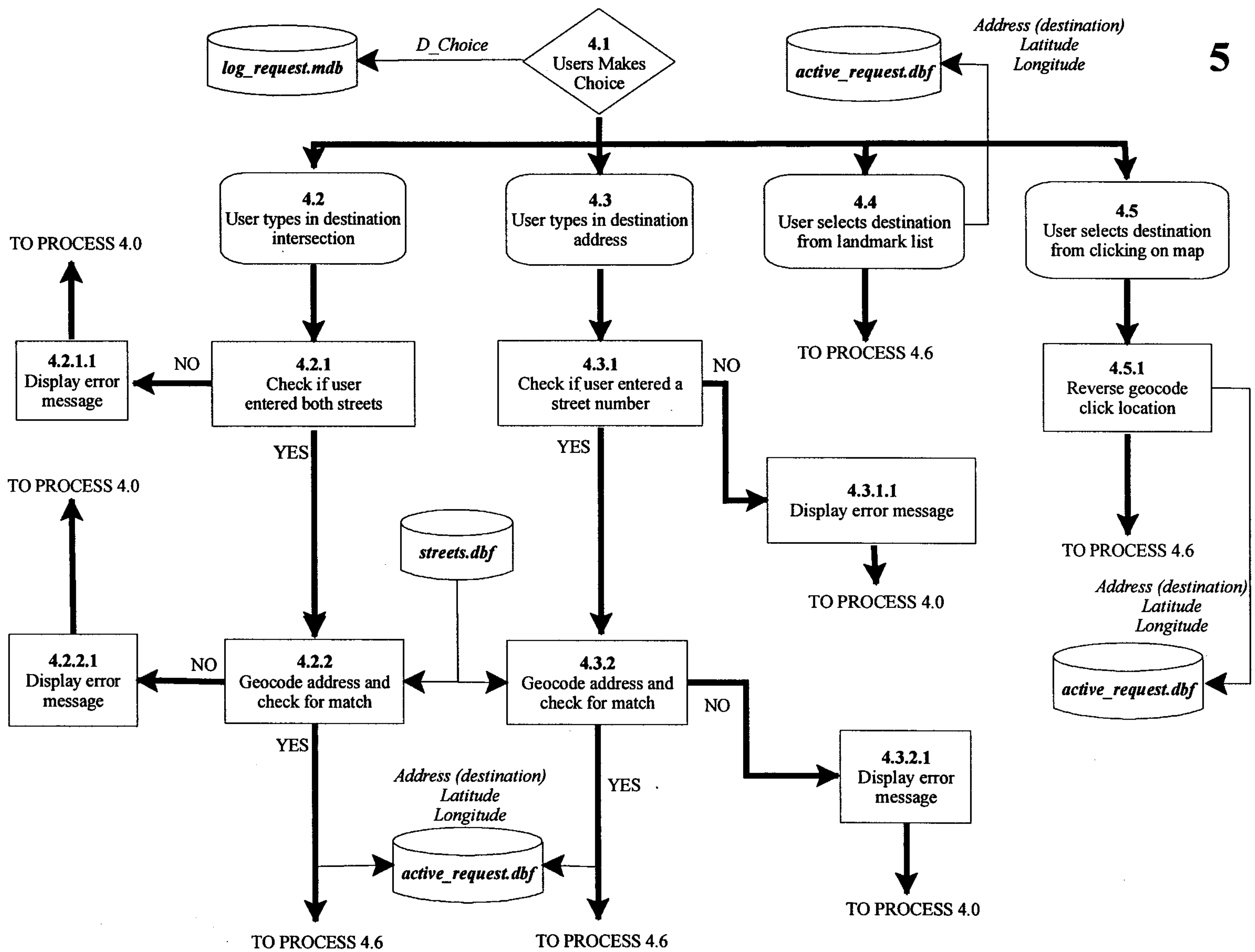

Web Page #1
1.0
Choice Page
Web Page #2
1.2
Interactive Routing
Introduction Page
Web Page #3
2.0
Origin input page
User_Num
Start_Time
Start_Date
Domain_Name
Browser_Type
log_request.mdb
1.1
Link to Pentran Static
Schedule Pages
TO PROCESS 2.1
streets.shp
landmarks.shp
landmarks.dbf
citylabels.shp
routes##.shp
list_street_types.mdb
list_street_names.mdb
parameters.mdb
Open Database(s),
Upload Shapefiles

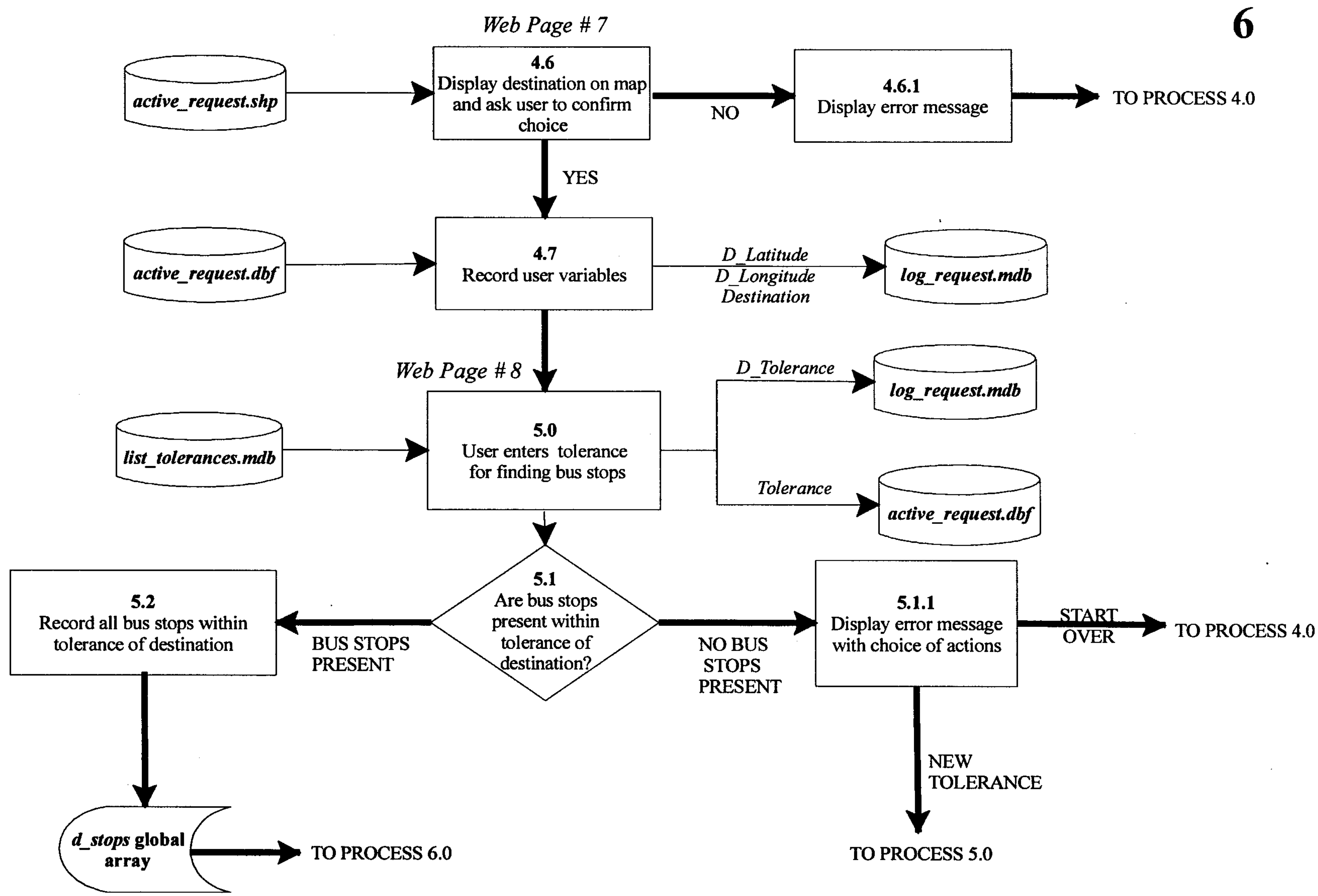

2
2.1
Users Makes
Choice
O_Choice
log_request.mdb
active_request.dbf
Address (origin)
Latitude
Longitude
2.2
User types in origin
intersection
2.3
User types in origin
address
2.4
User selects origin from
landmark list
2.5
User selects origin from
clicking on map
2.2.1
Check if user
entered both streets
2.2.1.1
Display error
message
TO PROCESS 2.0
NO
YES
2.3.1
Check if user entered a
street number
NO
YES
2.3.1.1
Display error message
TO PROCESS 2.0
TO PROCESS 2.6
2.5.1
Reverse geocode
click location
TO PROCESS 2.6
Address (origin)
Latitude
Longitude
active_request.dbf
streets.dbf
2.2.2
Geocode address and
check for match
NO
2.2.2.1
Display error
message
TO PROCESS 2.0
YES
2.3.2
Geocode address and
check for match
NO
2.3.2.1
Display error
message
TO PROCESS 2.0
YES
Address (origin)
Latitude
Longitude
active_request.dbf
TO PROCESS 2.6
TO PROCESS 2.6


3
Web Page #4
active_request.shp
2.6
Display origin on map and ask user to confirm choice
NO
2.6.1
Display error message
TO PROCESS 2.0
YES
active_request.dbf
2.7
Record user variables
O_Latitude
O_Longitude
Origin
log_request.mdb
Web Page #5
O_Tolerance
log_request.mdb
list_tolerances.mdb
3.0
User enters tolerance for finding bus stops
Tolerance
active_request.dbf
3.2
Record all bus stops within tolerance of origin
BUS STOPS PRESENT
3.1
Are bus stops present within tolerance of origin?
NO BUS STOPS PRESENT
3.1.1
Display error message with choice of actions
START OVER
TO PROCESS 2.0
NEW TOLERANCE
o_stops global array
TO PROCESS 4.0
TO PROCESS 3.0

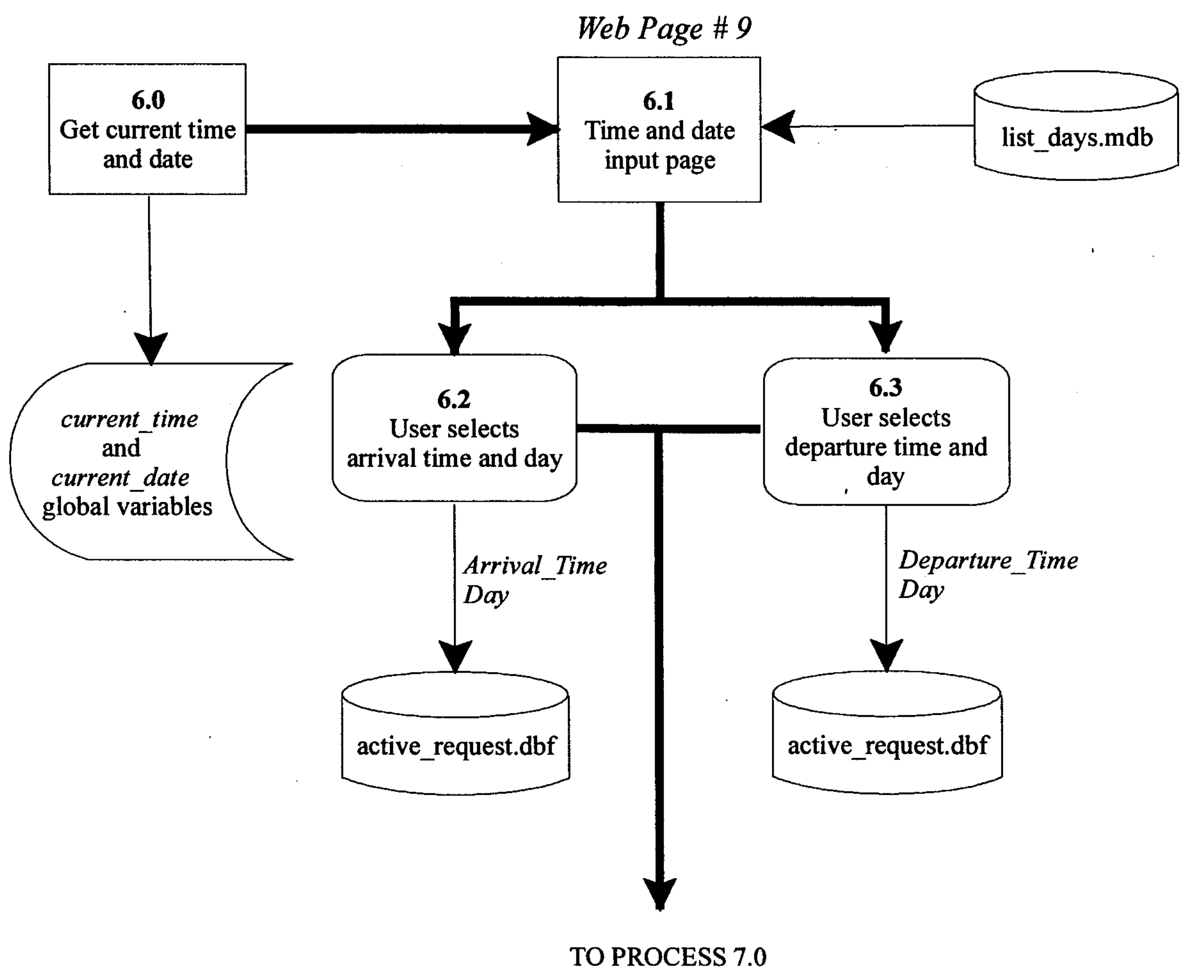
4


Web Page #6
4.0
Destination input page
Open Database(s),
Upload Shapefiles
streets.shp
landmarks.shp
landmarks.dbf
citylabels.shp
routes##.shp
list_street_types.mdb
list_street_names.mdb
parameters.mdb
TO PROCESS 4.1

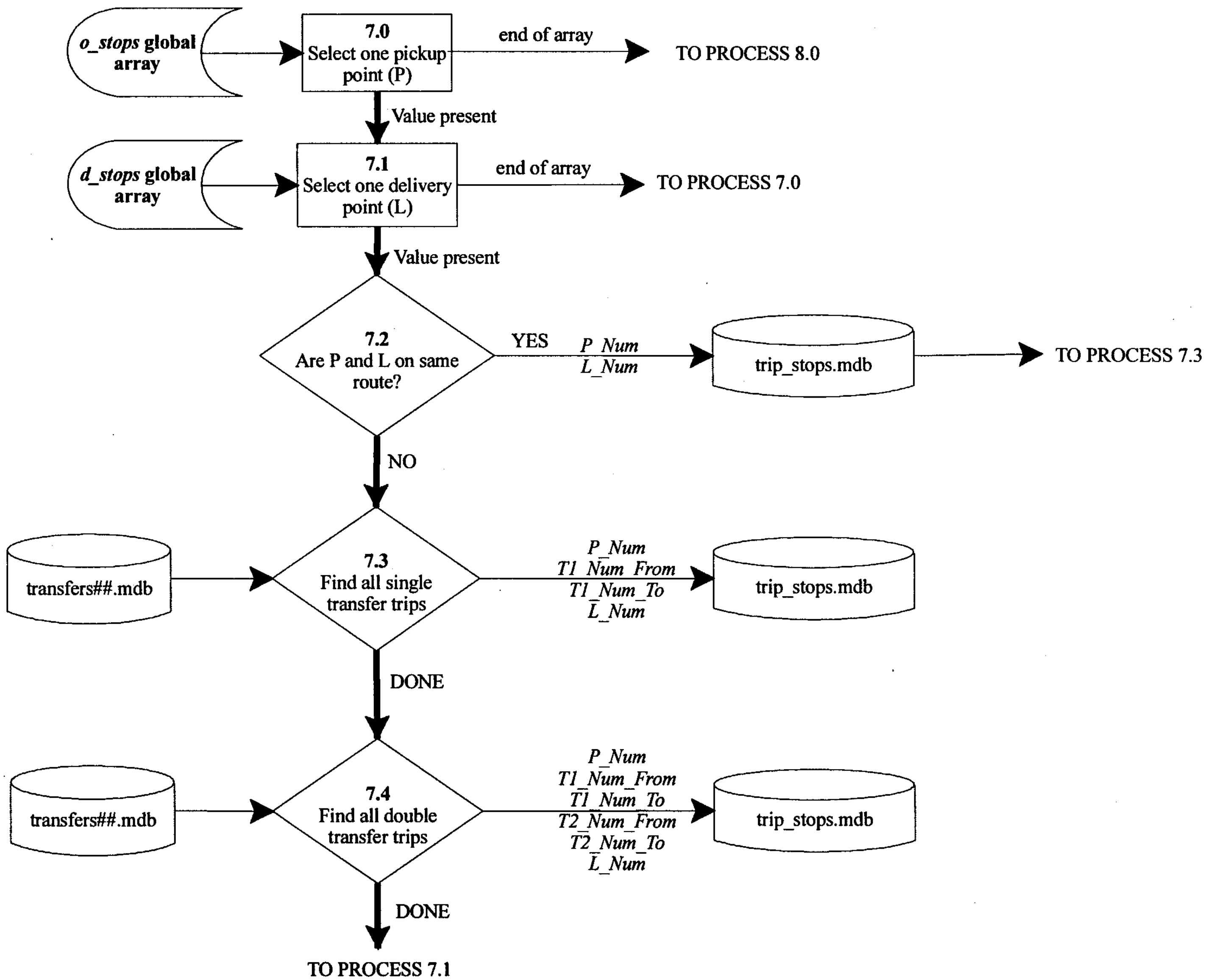

5
4.1
Users Makes Choice
D_Choice
log_request.mdb
active_request.dbf
Address (destination)
Latitude
Longitude
4.2
User types in destination intersection
4.3
User types in destination address
4.4
User selects destination from landmark list
4.5
User selects destination from clicking on map
TO PROCESS 4.0
4.2.1.1
Display error message
NO
4.2.1
Check if user entered both streets
YES
4.3.1
Check if user entered a street number
NO
YES
TO PROCESS 4.6
4.5.1
Reverse geocode click location
4.3.1.1
Display error message
TO PROCESS 4.0
TO PROCESS 4.6
Address (destination)
Latitude
Longitude
active_request.dbf
streets.dbf
TO PROCESS 4.0
4.2.2.1
Display error message
NO
4.2.2
Geocode address and check for match
YES
4.3.2
Geocode address and check for match
NO
YES
4.3.2.1
Display error message
TO PROCESS 4.0
Address (destination)
Latitude
Longitude
active_request.dbf
TO PROCESS 4.6
TO PROCESS 4.6

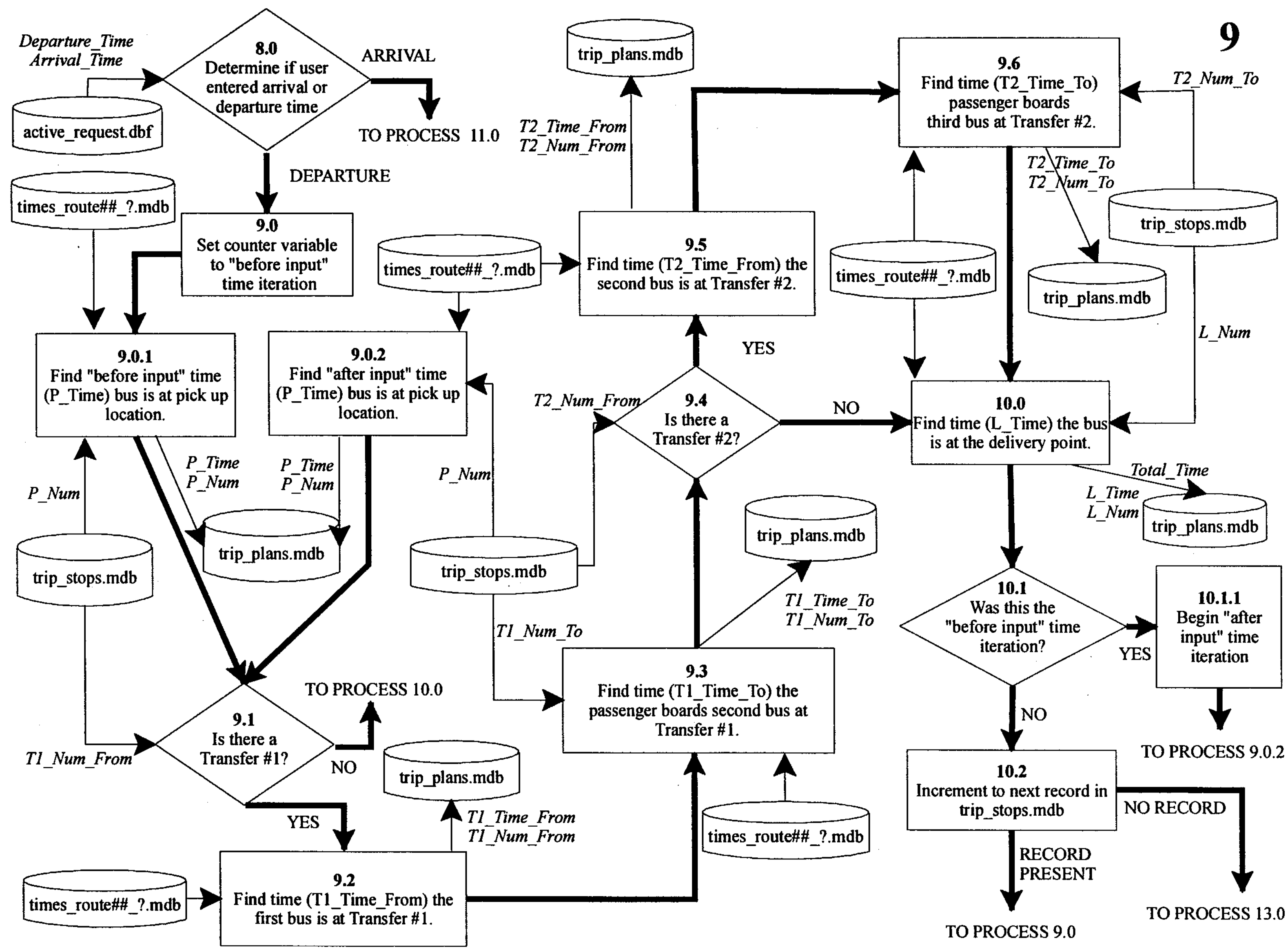

6
Web Page # 7
active_request.shp
4.6
Display destination on map and ask user to confirm choice
NO
4.6.1
Display error message
TO PROCESS 4.0
YES
active_request.dbf
4.7
Record user variables
D_Latitude
D_Longitude
Destination
log_request.mdb
Web Page # 8
list_tolerances.mdb
5.0
User enters tolerance for finding bus stops
D_Tolerance
log_request.mdb
Tolerance
active_request.dbf
5.1
Are bus stops present within tolerance of destination?
BUS STOPS PRESENT
5.2
Record all bus stops within tolerance of destination
NO BUS STOPS PRESENT
5.1.1
Display error message with choice of actions
START OVER
TO PROCESS 4.0
NEW TOLERANCE
TO PROCESS 5.0
d_stops global array
TO PROCESS 6.0

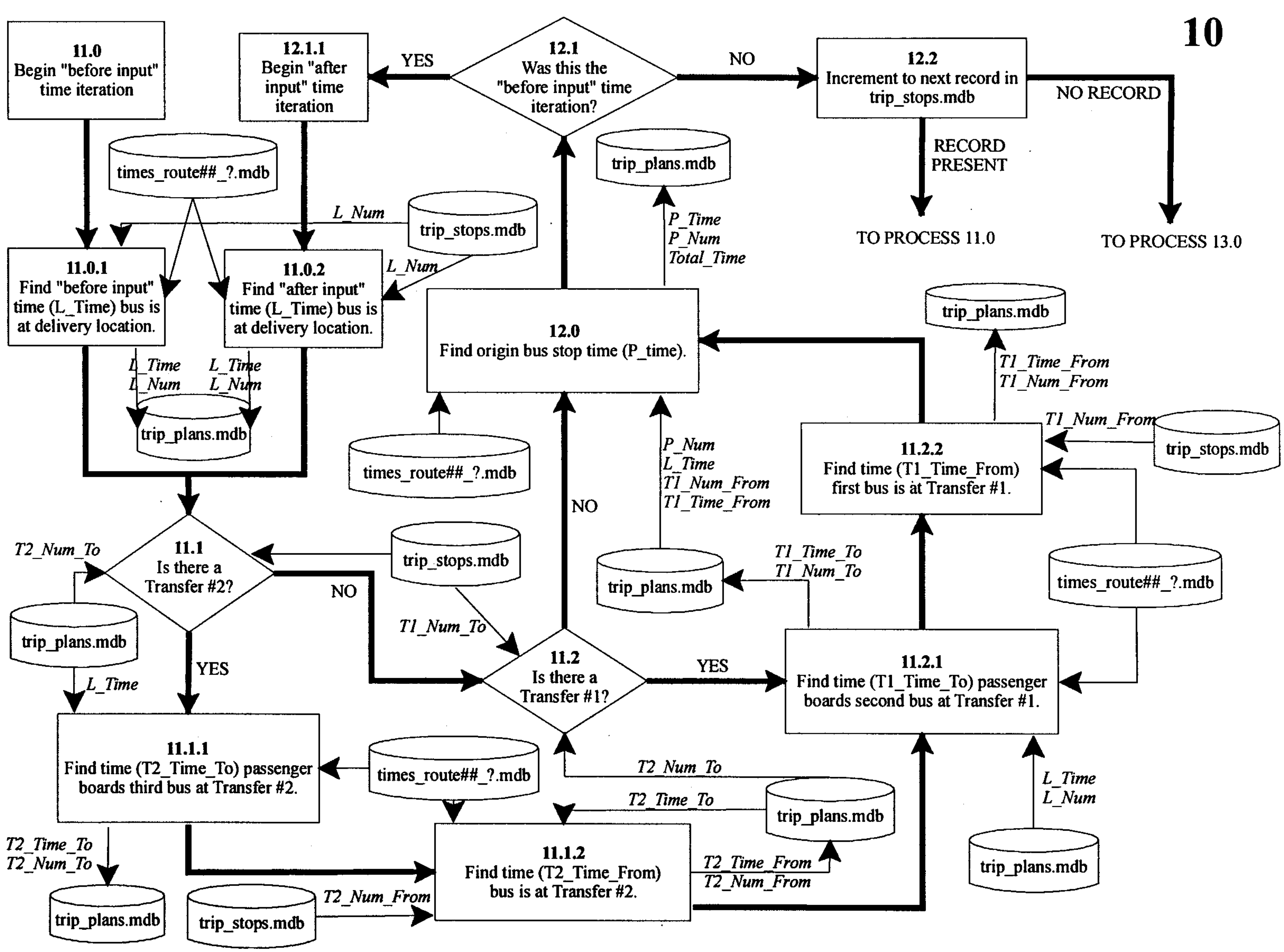
7


Web Page # 9
6.0
Get current time
and date
6.1
Time and date
input page
list_days.mdb
current_time
and
current_date
global variables
6.2
User selects
arrival time and day
6.3
User selects
departure time and
day
Arrival_Time
Day
Departure_Time
Day
active_request.dbf
active_request.dbf
TO PROCESS 7.0

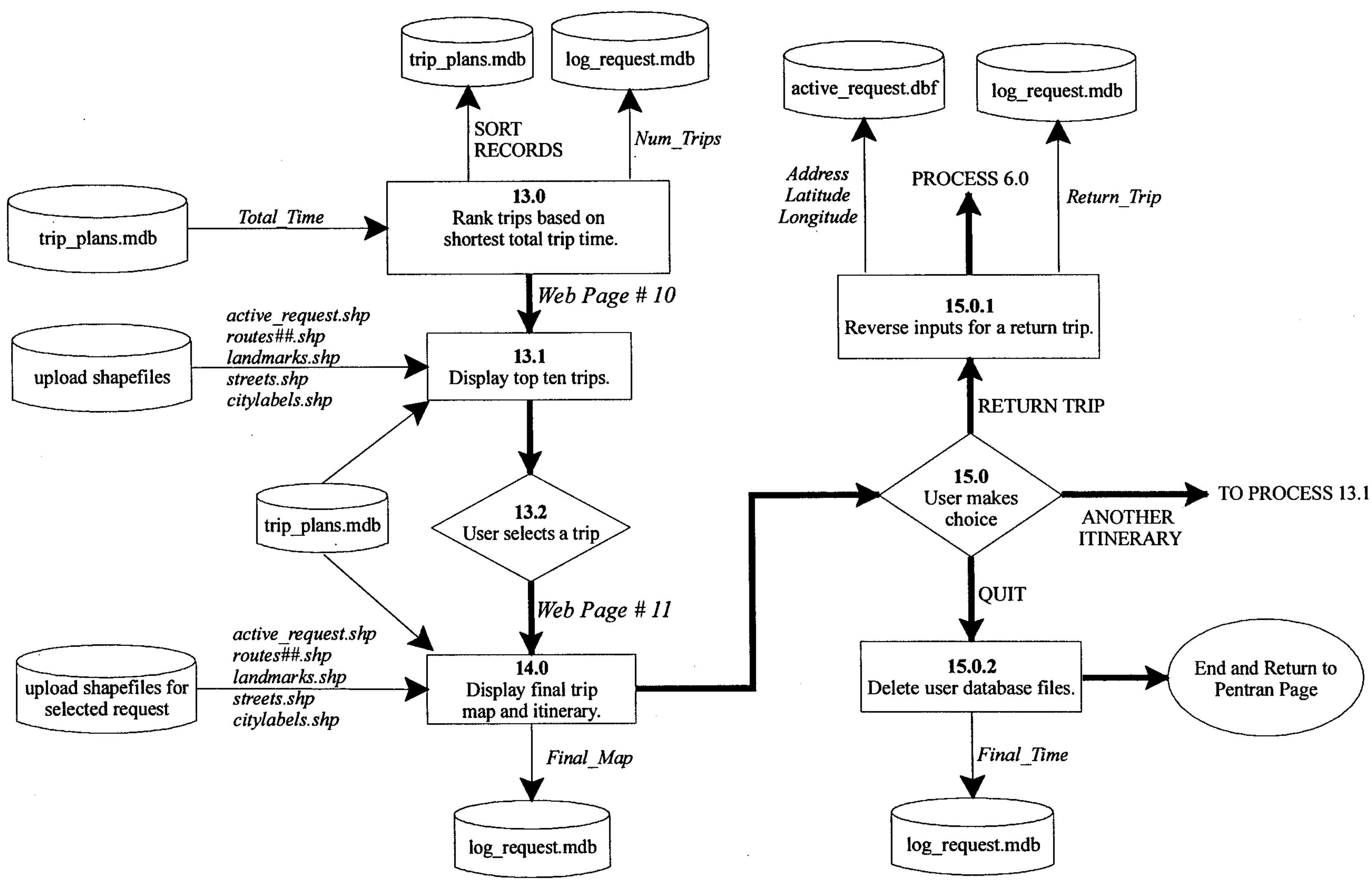
8


o_stops global array
7.0
Select one pickup point (P)
end of array
TO PROCESS 8.0
Value present
d_stops global array
7.1
Select one delivery point (L)
end of array
TO PROCESS 7.0
Value present
7.2
Are P and L on same route?
YES
P_Num
L_Num
trip_stops.mdb
TO PROCESS 7.3
NO
transfers##.mdb
7.3
Find all single transfer trips
P_Num
T1_Num_From
T1_Num_To
L_Num
trip_stops.mdb
DONE
transfers##.mdb
7.4
Find all double transfer trips
P_Num
T1_Num_From
T1_Num_To
T2_Num_From
T2_Num_To
L_Num
trip_stops.mdb
DONE
TO PROCESS 7.1


9
Departure_Time
Arrival_Time
active_request.dbf
8.0
Determine if user entered arrival or departure time
ARRIVAL
TO PROCESS 11.0
DEPARTURE
times_route##_?.mdb
9.0
Set counter variable to "before input" time iteration
9.0.1
Find "before input" time (P_Time) bus is at pick up location.
P_Time
P_Num
trip_plans.mdb
P_Num
trip_stops.mdb
times_route##_?.mdb
9.0.2
Find "after input" time (P_Time) bus is at pick up location.
P_Time
P_Num
P_Num
trip_stops.mdb
T1_Num_From
9.1
Is there a Transfer #1?
NO
TO PROCESS 10.0
YES
times_route##_?.mdb
9.2
Find time (T1_Time_From) the first bus is at Transfer #1.
trip_plans.mdb
T1_Time_From
T1_Num_From
T1_Num_To
9.3
Find time (T1_Time_To) the passenger boards second bus at Transfer #1.
times_route##_?.mdb
trip_plans.mdb
T1_Time_To
T1_Num_To
T2_Num_From
9.4
Is there a Transfer #2?
YES
NO
times_route##_?.mdb
9.5
Find time (T2_Time_From) the second bus is at Transfer #2.
trip_plans.mdb
T2_Time_From
T2_Num_From
9.6
Find time (T2_Time_To) passenger boards third bus at Transfer #2.
T2_Num_To
T2_Time_To
T2_Num_To
trip_plans.mdb
trip_stops.mdb
times_route##_?.mdb
L_Num
10.0
Find time (L_Time) the bus is at the delivery point.
Total_Time
L_Time
L_Num
trip_plans.mdb
10.1
Was this the "before input" time iteration?
YES
10.1.1
Begin "after input" time iteration
TO PROCESS 9.0.2
NO
10.2
Increment to next record in trip_stops.mdb
NO RECORD
TO PROCESS 13.0
RECORD PRESENT
TO PROCESS 9.0


10
11.0
Begin "before input" time iteration
12.1.1
Begin "after input" time iteration
YES
12.1
Was this the "before input" time iteration?
NO
12.2
Increment to next record in trip_stops.mdb
NO RECORD
RECORD PRESENT
TO PROCESS 11.0
TO PROCESS 13.0
times_route##_?.mdb
trip_stops.mdb
L_Num
trip_plans.mdb
P_Time
P_Num
Total_Time
11.0.1
Find "before input" time (L_Time) bus is at delivery location.
11.0.2
Find "after input" time (L_Time) bus is at delivery location.
L_Time
L_Num
12.0
Find origin bus stop time (P_time).
T1_Time_From
T1_Num_From
11.2.2
Find time (T1_Time_From) first bus is at Transfer #1.
P_Num
L_Time
T1_Num_From
T1_Time_From
11.1
Is there a Transfer #2?
T2_Num_To
NO
T1_Num_To
11.2
Is there a Transfer #1?
YES
T1_Time_To
T1_Num_To
11.2.1
Find time (T1_Time_To) passenger boards second bus at Transfer #1.
11.1.1
Find time (T2_Time_To) passenger boards third bus at Transfer #2.
T2_Time_To
T2_Num_To
11.1.2
Find time (T2_Time_From) bus is at Transfer #2.
T2_Time_From
T2_Num_From
T2_Num_From
L_Time
L_Num

11


trip_plans.mdb
log_request.mdb
SORT RECORDS
Num_Trips
trip_plans.mdb
Total_Time
13.0
Rank trips based on shortest total trip time.
Web Page # 10
upload shapefiles
active_request.shp
routes##.shp
landmarks.shp
streets.shp
citylabels.shp
13.1
Display top ten trips.
trip_plans.mdb
13.2
User selects a trip
Web Page # 11
upload shapefiles for selected request
active_request.shp
routes##.shp
landmarks.shp
streets.shp
citylabels.shp
14.0
Display final trip map and itinerary.
Final_Map
log_request.mdb
active_request.dbf
log_request.mdb
Address
Latitude
Longitude
PROCESS 6.0
Return_Trip
15.0.1
Reverse inputs for a return trip.
RETURN TRIP
15.0
User makes choice
TO PROCESS 13.1
ANOTHER ITINERARY
QUIT
15.0.2
Delete user database files.
End and Return to Pentran Page
Final_Time
log_request.mdb