

**FRAMEWORK FOR ENHANCING SCHEDULING SOFTWARE  
FOR SMALL TO MEDIUM SIZE PARATRANSIT AGENCIES**

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# 1. INTRODUCTION

## 1.1 Background

When most small to medium size paratransit agencies started up they used a manual system for reserving and scheduling trips and they would require that trip reservations be made at least 24 hours in advance. Two types of manual systems were typical: the “clipboard” and the “trip ticket.”

The clipboard system is the simplest method and is practical for only very small agencies. Five clipboards representing the next five business days are hung on hooks on the wall. Each clipboard contained one or more lined forms for each vehicle. Each line on a sheet represented a 15 to 20 minute time interval. When a client called in to reserve a trip, the client’s name and pickup and drop off times and addresses were written into the empty line corresponding to the client’s requested trip time. If the line at that time was already filled, then the client either adjusted their desired times or the trip was denied. Each day the sheets for that day are removed from the clipboard and become the driver manifests. New forms are placed on the clipboard and it then became the manifest for the fifth day in the future. If the agency accepted subscriptions, each subscription was written on a separate sheet of paper and kept in file folders for each day of the week. Typically, when a new fifth-day clipboard was created, the subscription trips were written onto the forms before any telephone reservations were accepted. The manifests are collected from the drivers at the end of each day, and these provided the data for the monthly reports.

In the trip ticket system, each trip was hand written onto a color-coded sheet of paper or index card (e.g. yellow for a single trip, blue for a subscription (recurring) trip, pink for a subscription with variations, etc.). The basic information for each trip was recorded on the trip ticket (e.g. client name, pickup and drop off times and addresses, purpose of the trip, etc.). These sheets of paper or cards were called trip tickets. All of the trip tickets for a given day were assembled on the afternoon of the day preceding the trips. They were then sorted into piles, where each pile contained the trips for a particular vehicle. A lined form was then used to record the information from each trip ticket in a pile. The lines on the form may represent 15 or 20 minute intervals. Once filled out, these forms became the driver manifests. During the day, the driver recoded the status of each trip onto his/her manifest and returned it at the end of the day to the accounting person. The accounting person assembled all of the trip tickets and driver manifests for the accounting period (usually a month) and extracted, aggregated and summarized the data for the necessary reports and invoices.

As agencies grew the scheduling and reporting requirements became more complex, the administrative workload began to require a disproportionate share of the agency’s time and resources. At some point during the growth process most agencies looked for computer technology to help with the scheduling and reporting functions. Several commercial packages were available to choose from, ranging in price from about \$2,500 to over \$75,000. The software features varied with the price from basic spreadsheet type applications to sophisticated geographical information systems (GIS) with automatic trip scheduling. Agency personnel, who were not skilled in computer use, were faced with the necessity to evaluate the trade-offs between cost and features.

## 1.2 Typical Software Features for Small Agencies

Software products have evolved at the lower end of the cost scale for small agencies. They are typically developed to run on Microsoft Windows operating systems and are often based on Microsoft applications such as Excel and Access. All of these products provide similar features that address the most important common needs of small to medium-sized agencies. Most of the applications emulate the old manual trip ticket methodology except they use electronic instead of paper forms and, consequently, can accommodate a richer set of information. The general flow of work utilized by these systems is shown in Figure 1.1.

### 1.2.1 Data and Interface

Computer programmers generally refer to this type of software as having a “back end” and a “front end.” The back end is the storage unit for the data, a database, and usually contains many features for data manipulation and reporting. The back end database should be nonproprietary so that the agency does not have to depend on a single outside source for accessing their data. Typical commercial databases for small applications are MS Access® and Corel Paradox®. Typical databases for larger applications are MS SQL Server® and Oracle®.

The front end, generally called the interface, provides the custom input and output features for the specific application. When it utilizes point-and-click and drag-and-drop technology it is referred to as a graphical user interface (GUI). Higher end products use geographical information system (GIS) for the GUI. Software for rural communities should have a commercial database back end coupled with a GUI front end: the commercial database provides open access to the data and the front end provides the convenient usability.

### 1.2.2 Typical Schema

Figure 1.1 depicts a typical database and interface schema. The blocks up the left-hand side of the figure indicate the important types of data stored in the database. The notes opposite each block indicate the interface features that are necessary for adding, editing, deleting, and summarizing data in the block. The interface features are those that are necessary to support the responsibilities of the system administrator, reservationist, scheduler, and dispatcher.

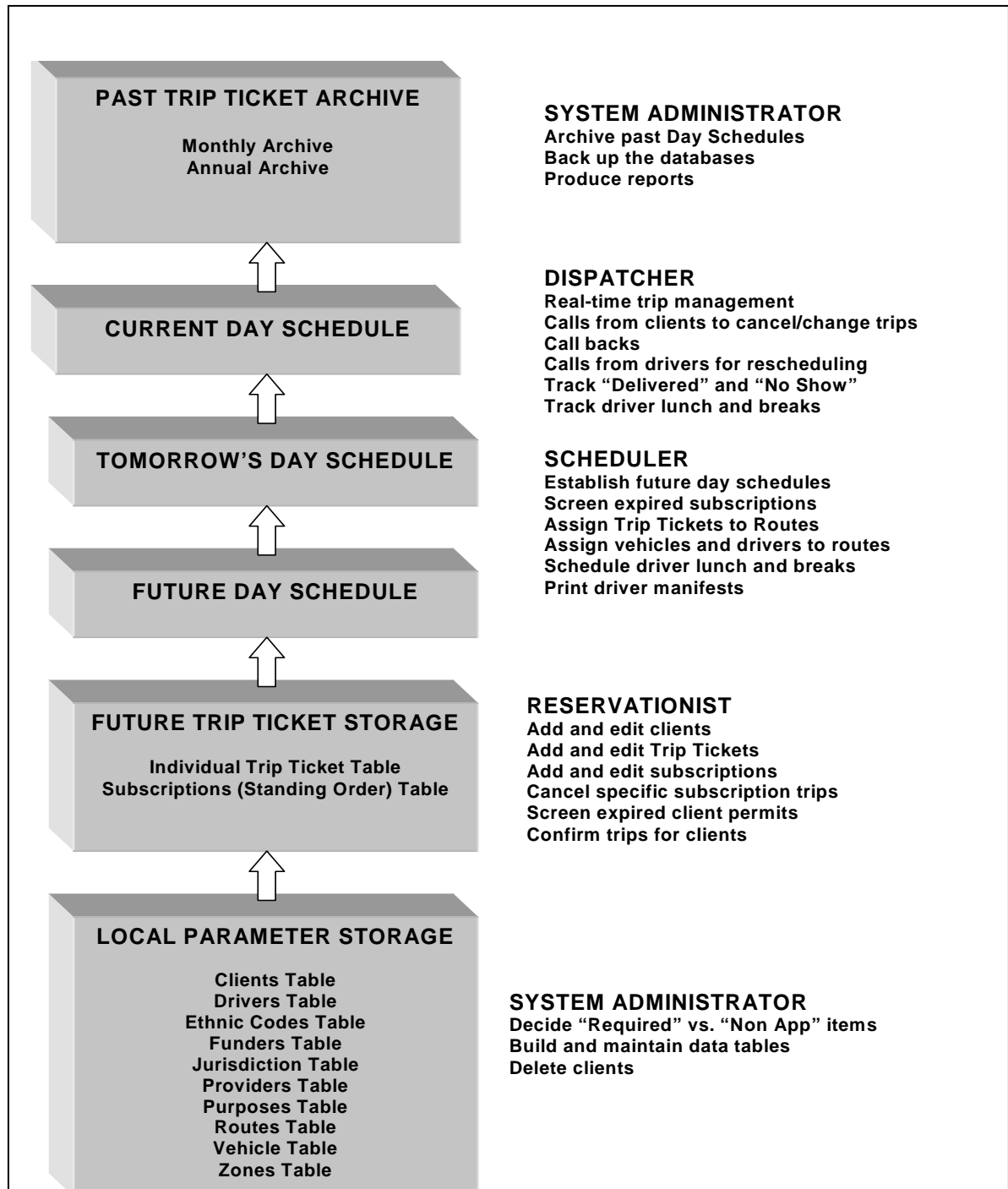
At the bottom of the diagram is a database containing parameters that can be customized for an agency’s own local situation. The system administrator is responsible for these data.

Moving from bottom to top, the next element in the diagram contains two tables: one for the storage of trip tickets for future rides and the other for the storage of subscription (standing order) templates. Subscription trip tickets are created at the time a new day schedule is established. The reservationist is responsible for the future trip ticket storage.

The scheduler establishes day schedules and assigns trips and drivers to vehicles. In a rural system much of the association of a trip ticket with a vehicle and driver is done by the reservationist at the time that the trip ticket is created. The scheduler prints the driver manifests.



The dispatcher manages the current day schedule. He/she is responsible for keeping track of the active trip tickets, and reassigning trips on the fly as necessary.



**Figure 1.1 Data Storage and Interface Features**

Often in small systems, duties of the administrator, reservationist, scheduler, and dispatcher are all the undertaken by one or two people. All but a few agencies found the computer programs based on this schema were a great improvement over the manual systems. The agencies that were unable or unwilling to abandon the manual system were those where the personnel lacked even the most basic computer skills.

## 2. VISUAL TRIP TICKET SCHEMA (VTTS)

Because the trip ticket methodology is easy to comprehend by agency personnel, most moderately priced scheduling software packages targeting small to medium sized agencies base their scheduling procedures and screen displays on the trip ticket concept. Electronic trip tickets replace the paper tickets and screen displays replace the paper schedule forms. Because this class of software is based on arranging trip tickets on screen displays, they will be referred to as visual trip ticket schema (VTTS) applications.

### 2.1 Example Trip Ticket

An electronic trip ticket can contain much more information than the old paper method. Figure 2.1 shows a typical trip ticket form. A trip ticket is created for each leg of a trip.

The trip ticket is linked directly to the database backend. Selection lists are loaded from standard values in the database so the reservationist need only select items from the lists rather than typing them in. The form contains personal information about the client, information about the trip, information about the funding for the trip, information for reporting, and general information.

The screenshot displays a 'Trip Form' window with a blue header. The form is organized into several sections:

- Client Information:** Fields for Client Name (Blow, Joe), ID (2674), Age, Phone (( ) - ), Client Status (Ambulatory), Special Needs (Ambulatory), and Vehicle Type.
- Trip Date and Schedule:** A date selector set to 5/24/2005, a 'Group Ticket/Run' checkbox, and a 'Conditional Trip' dropdown set to 'Schedule'.
- Addresses and Locations:** Fields for Pickup (Base), Delivery (Farmers Mkt behind Tony Romas), Apartment, Site (LTD Offices), and Route (CAR 1).
- Timing and Stop Information:** Fields for Request (2130), Times (2130), Stop (2145), and a 'Next Leg' button.
- Funding and Rates:** Fields for Provider (NA), Rate Type (NA), Fare/Amount (\$ 0), and Fare (NA). A dropdown menu is open for 'Fare' with options: None, Full Stop, DO Stop, Both, and GAP.
- Passenger and Service Details:** Fields for Nbr. Psngs (1), Purpose (NA), Reference (NA), DB List 3 (NA), Nbr. Atndts (0), P. Funder (NA), Serv Type (Call-A-Ride), DB List 4, Nbr. Escrts (0), S. Funders, Elig Type (Unconditional), and Stopovers (0).
- Notes and Directions:** Fields for Trip Note, Client Note, Pickup Direction, and Dropoff Direction, all currently set to 'NA'.
- Buttons:** 'OK' and 'Cancel' buttons at the bottom right.

Figure 2.1 Typical Electronic Trip Ticket Form

### **2.1.1 Client Information**

Generally includes name, age, phone number, client status (sight impaired, disabled, hearing impaired, wheelchair, walker/cane, etc.), client eligibility, boarding time, and special needs such as a particular vehicle.

### **2.1.2 Trip Information**

Generally includes the pickup address and time; the drop off address and time; Route (bus) assignment; number of passengers, attendants, and escorts; and the number of stopovers (i.e. short stops during a single trip). At the bottom of the screen, space may be provided to provide directions for the driver.

### **2.1.3 Trip Funding**

Generally includes the rate type (fixed rate, mileage rate, zone rate, etc.), fare amount, fare type (cash, pass, prepaid ticket, etc.), provider, primary funder, and secondary funders.

### **2.1.4 Reporting Information**

Generally includes the purpose of the trip, and information on disabilities etc. from the other fields on the form.

### **2.1.5 General Information**

Generally includes short notes for the driver about this trip and short notes about proclivities of the client.

### **2.1.6 Bus Driver Manifest**

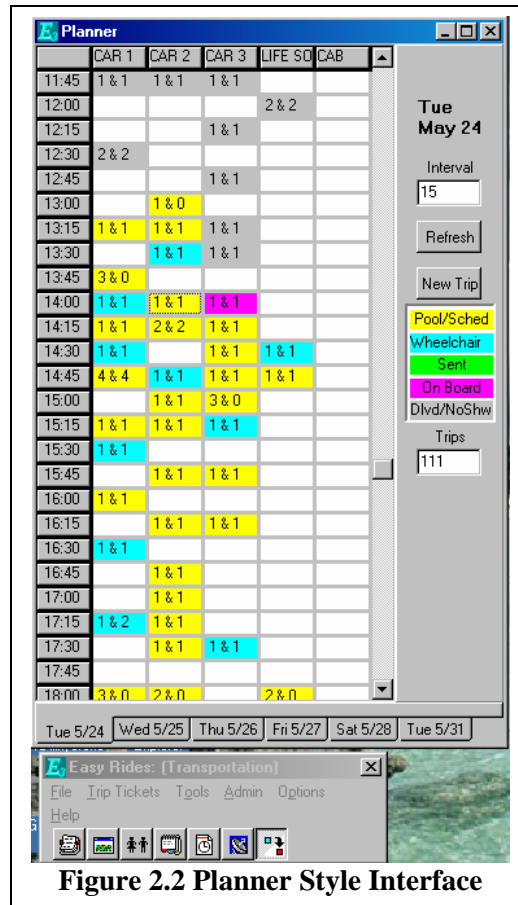
Generally a printed sheet listing selected information from all of the trip tickets assigned to a bus for the day.

Two styles of manual scheduling displays will be briefly reviewed here: the planner style and the schedule board style.

## 2.2 Example of a Planner Style Interface

Figure 2.2 shows a typical window for displaying trip tickets for a particular day. Tabs across the bottom of the window provide schedules for future days. Buses are represented by columns on the form and Tickets are slotted into fixed time slots represented by the rows.

Color coding may be used to flag certain items for the scheduler: for example that a wheelchair is required for this client.



## 2.3 Example of a Schedule Board Style Interface

Figure 2.3 shows the dispatch window for a typical software package<sup>1</sup> designed for small to medium-size agencies. Screen shots from this VTTs will be used in this report to demonstrate how advanced features could be added to software of this type without major modifications. The screen in Figure 2.3 displays the “day schedule” – the trip tickets for the current day. The Day Schedule shows the status of the trip tickets at the current time, and it provides powerful features for adding, editing and updating the tickets. The major sections of the day schedule are outlined below.

<sup>1</sup> Mobilitat. 1605 Green River Way. Green River, WY.

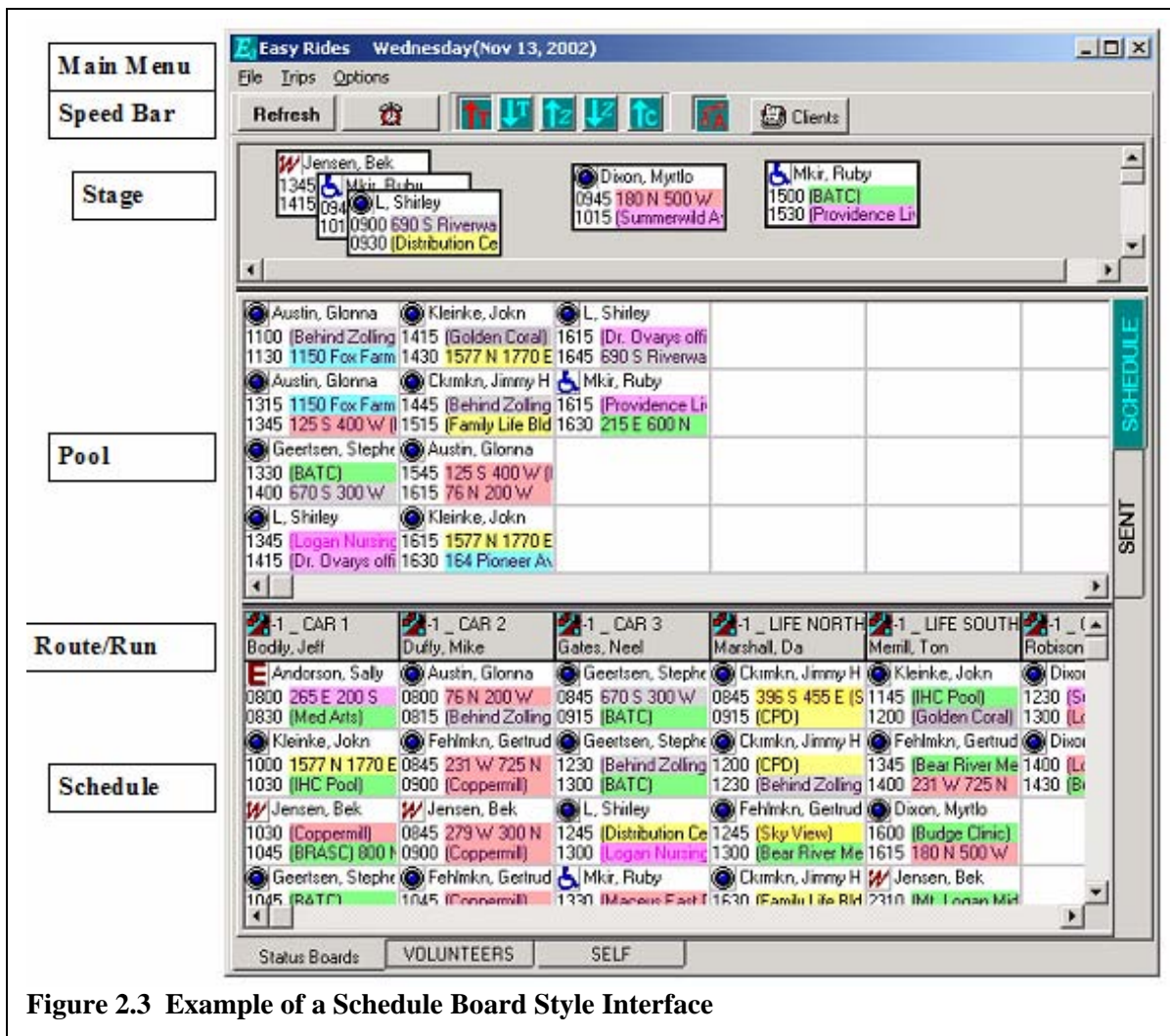


Figure 2.3 Example of a Schedule Board Style Interface

### 2.3.1 Main Menu

Provides access to numerous forms for adding, editing, and updating trip tickets and client information.

### 2.3.2 Speed Bar

Provides speed buttons for the refresh, alarm, sort, attach, and clients features.

### 2.3.3 Trip Tickets

Represented by rectangles on the screen. Each ticket displays an icon identifying the status of the rider. For example, the wheelchair icon represents a rider who requires a wheelchair. The user may select from two format options for displaying the trip tickets. The large (three row) format shown on the Stage contains the client name, pickup time, delivery time, pickup address, and delivery address. The addresses are color coded according to geographical zone. The small (two

row) format shown on the pool and schedule displays pickup time, pickup address, and delivery address.

#### **2.3.4 Stage**

A place where tickets can be placed for temporary storage. Tickets can be positioned by dragging and dropping on the stage.

#### **2.3.5 Pool**

Contains trip tickets that have not yet been assigned to a route/run. Trip tickets on a status board can be sorted by pickup time, delivery time, pickup zone, or delivery zone. Trip ticket details can be displayed by clicking on the trip ticket. Trip tickets can be moved from the pool to a route/run by first clicking on the trip ticket icon (to make it “hot”), followed by a Ctrl+Click (holding down the control key while clicking) on the icon of the desired route/run.

#### **2.3.6 Route/Run Columns**

There is a considerable difference between a fixed route and a paratransit route. Whereas fixed routes will not change for months or years, paratransit routes change daily and even hourly. The route/run bar sits on top of the schedule board. A route/run is simply a column for collecting trip tickets. A driver and a vehicle must be assigned to each route/run. The column below each route/run shows the trip tickets assigned to the driver and vehicle for the current day. The route and run terms are used interchangeably in this document.

#### **2.3.7 Schedule Board**

Displays the trip tickets that have been assigned to a route. Trip tickets are listed in the column below the Route, and may be sorted in the order of pickup time, delivery time, pickup zone, or delivery zone.

A manifest is printed each day for each driver listing all trip tickets on his/her route. The schedule board contains many features for adding and editing trip tickets. The color-coding by geographical zone helps the scheduler efficiently assign trips to routes.

#### **Schedule and Sent Tabs**

Toggle between the schedule board and the sent and on-board boards. These three boards (schedule, sent and on-board) are collectively referred to as the status boards. The sent and on-board boards are used during dispatching. When a vehicle is dispatched to pick up a customer the customer's trip ticket is moved to the sent board. When the customer is on board the vehicle the trip ticket is moved to the on-board board. Thus the schedule, sent, and on-board status boards display the status of all trip tickets on all vehicles at any given time.

### **2.3.8 Volunteer and Self Tabs**

Toggle separate displays. Trip tickets that are assigned to volunteer drivers using their own vehicles are listed on the volunteer form. Tickets that are assigned to clients who are driving themselves using their own vehicles are listed on the self form.



### 3. REQUESTS FOR INCREASED FUNCTIONALITY

As agencies got used to the electronic trip ticket procedure and recognized the potential of the computer as a tool to make their jobs easier, they began to demand more functionality. The highest priorities for these enhancements were in two areas where schedulers were making the most mistakes:

1. preventing schedulers from assigning trips that violate agency policy, and
2. scheduling trips automatically.

Software developers diverged in their strategies to incorporate these advanced features. One approach was to recast the software in commercially available GIS tools such as the ones provided by ESRI Corporation in Redlands, CA. ([www.esri.com](http://www.esri.com)). These types of tools required a significant royalty fee for distribution. In addition, they required a skilled computer person at the agency to install, update, and maintain the software. All of this effort greatly increased the initial and maintenance cost of the products. To effectively utilize the advanced functionality, a substantial amount of training was needed for the personnel doing the scheduling.

A second strategy was to build on the existing trip ticket schema and extend it by incorporating an inexpensive mapping component and providing a non-proprietary database structure. This approach would provide the desired functionality at much lower cost and with greater ease of use.

#### 3.1 Route Constraints

Problems were frequently occurring when schedulers would assign a trip ticket to a vehicle in violation of agency policy or after the bus was out of service. For example, in the first case a provider may be funded exclusively for a single purpose such as transporting the blind, and schedulers were scheduling trips for others on this provider's vehicle. In the second case buses may have a staggered or irregular schedule based on the availability of volunteer drivers, and schedulers were scheduling rides when the bus was not in service. Although these situations were causing many problems, they are easy to fix in a VTTS-type computer program.

The schedule/dispatch board (Figure 2.3) provides a useful visual display of unscheduled and scheduled trip tickets. Unscheduled tickets are grouped in an area called the pool. Scheduled tickets are aligned in columns below the pool, where each column represents a route (run). Each route is assigned a vehicle and driver, and the trip tickets aligned under a route are the trips for the vehicle for that day. The set of route columns is referred to as the schedule board. The scheduling process involves moving trip tickets from the pool to an appropriate route/vehicle on the schedule board. Typically the trip tickets can be moved between the pool and the schedule board by the scheduler/dispatcher using point-and-click actions.

Two features for screening tickets by times and constraints can be built into this schema.

## 3.2 Trip Verification

When the trip verification option is active, a trip ticket is evaluated before the move from the pool to the schedule board. If the pickup or drop off time violates the route start and end times, a warning message is displayed. The scheduler/dispatcher can override the warning and assign the ticket anyway. Also, if for example, a trip ticket has been assigned to a specific provider, and that provider is constrained from the route, then a warning message will be displayed. The scheduler/dispatcher can override the warning. Neither GIS nor auto-schedule functionality are necessary to use a trip verification feature of this type.

## 3.3 Route Time Boundaries and Constraint Parameters

Each Route can be assigned a starting time and an ending time, and constraints to prevent certain types of trip tickets from being scheduled on certain routes/vehicles. For example, if a route is reserved (constrained) for a certain provider, then only trip tickets assigned to that provider may be scheduled onto the route.

### 3.3.1 Adding/Editing Route Time Limits

The starting and ending times for a route can be added/edited using convenient forms activated from a menu like the one shown in Figure 3.1. These times will be the default values associated with the route in the day schedule. These times can also be edited for a route in a day schedule by right-clicking on a route's header row and displaying the popup menu shown in Figure 3.2. Clicking on the change route times item displays the form shown in Figure 3.1 where the times can be edited.

Accessible Days	Route	Driver	Bus	Start Time	End Time	Constraints
Mon Jul 05	A	AKERS, ANTHONY	15 FORD VAN	600	1500	Providers: "CHERRY LIFT", CARTS
Tue Jul 06	B	ALGECIRAS, JOHN	17 HIGH TOP FORD	600	1500	
Wed Jul 07	D	AXELSON, JACK	18 1-HIGH TOP	730	1830	
Yesterday	E	BARNHART, JIM	19 2-HIGH TOP	700	1800	
	F	BOBICK, JINNI	22 1-FORD BUS	700	1800	
	H	BOGUE, LEROY	23 2-FORD BUS	730	1830	

Assign Categories:

- ☒ Drivers
- ☒ Buses
- ☒ Times
- ☒ Constraints

Cancel OK

Figure 3.1. The Route-Parameter-Replication Form

### 3.3.2 Adding/Editing Route Constraints

Clicking on the change route constraints item in the popup menu shown in Figure 3.2 will display the form shown in Figure 3.1. The constraining groups field in Figure 3.1 would allow the user to select an item from a drop down list that he/she wishes to constrain for a particular route. For example items like provider, funder, or other parameters associated with a bus or a route could be constrained.

The check-box list below the constraining groups is a list of all of the members in the group. For example Figure 3.1 lists all of the members of the Provider group. Checking one or more of the check-boxes will permit only trip tickets with those providers to be scheduled on the route. If no

check-boxes are checked, then a ticket with any provider can be assigned to the route. For example only cherry lift tickets will be assigned to the route associated with Figure 3.1.

### 3.4 Route Parameter Replication

Schedulers/dispatchers frequently assign the same vehicle and constraints to a route every day or on a periodic basis (e.g. every Thursday Route A typically has the same vehicle, driver, and constraints). A very useful feature could be incorporated to copy these parameters from a previous day schedule to a new one.

A logical location for the route parameter replication item would be in the trips menu on the schedule/dispatch board as shown in Figure 3.2. Clicking on this item would display the form shown in Figure 3.2. Clicking on one of the days in the accessible days box would display that day's parameters in the table to the right. Clicking on the OK button would copy the parameters from the previous day schedule into the current one. The form shown in Figure 3.2 has multiple uses for assigning route times and constraints, and for replicating them for future days.

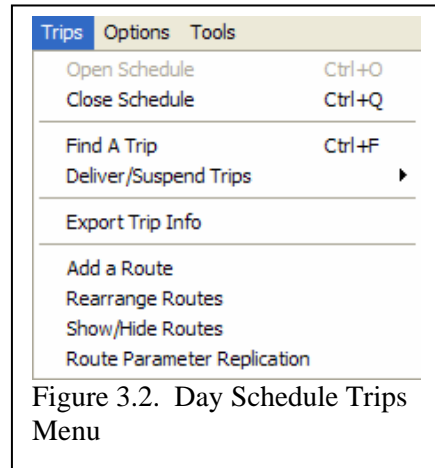


Figure 3.2. Day Schedule Trips Menu

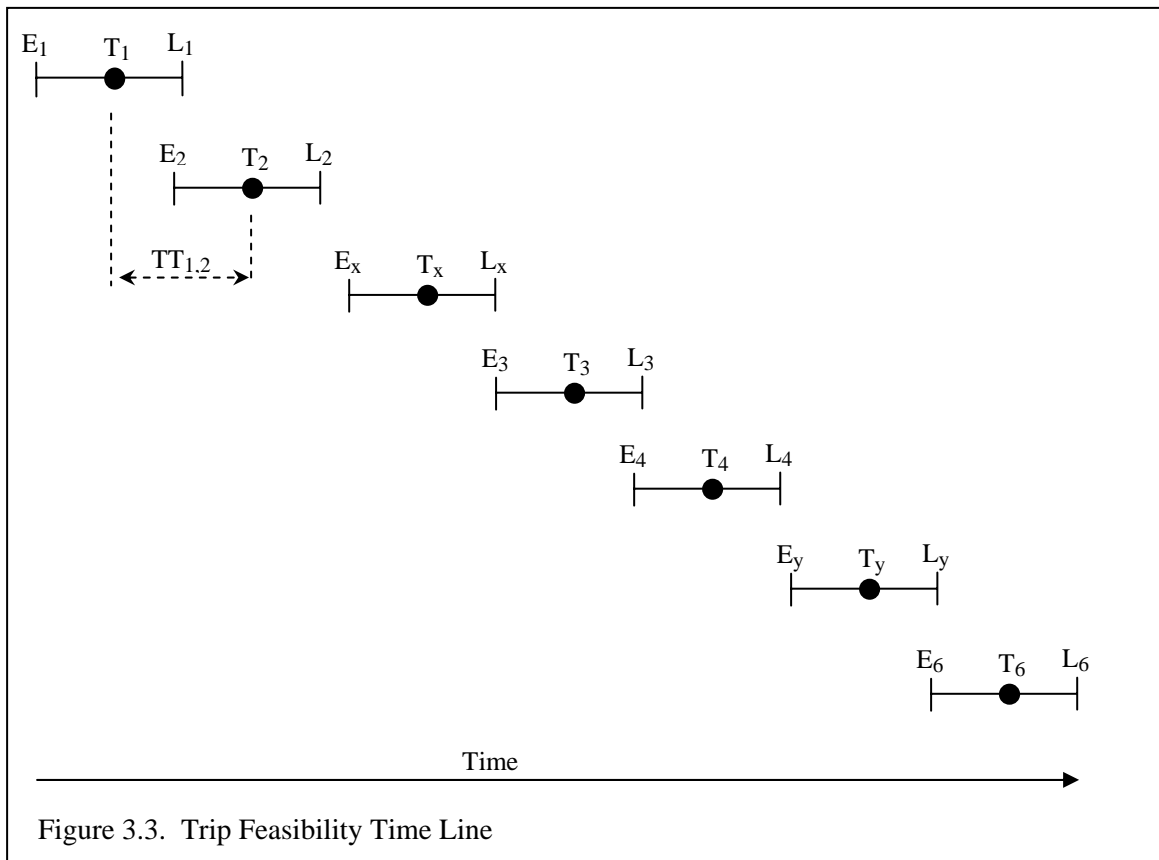
### 3.5 Trip Feasibility

A great deal of research has been devoted to creating algorithms for automating the paratransit scheduling process (see Mitrovic-Minic, Snezana 1998, Nary, William P. and J. Wesley Barnes 2000, Li, Y. et. al. 1995, Tan, K. C., et. al. 2001). This research has resulted in a variety of complex algorithms for solving various aspects of the comprehensive scheduling problem involving multiple buses providing service for many individual point-to-point trips.

However, although the agencies included in this report would like to have fully automatic scheduling they identified a feature that is much less complex and expensive, but that could solve a significant recurring scheduling problem. One of the most difficult activities for a scheduler is to determine whether or not another trip can be placed onto a partially loaded bus. This section describes a straight-forward and robust algorithm for helping the scheduler to resolve this problem.

Consider the diagram shown in Figure 3.3. Each rider will have times scheduled for the pick up and drop off stops. The stops are represented by the dots in the figure. The horizontal scale represents time from left to right. The symbols in the figure are defined below.

- i: The identifying number of the stop
- $T_i$ : The scheduled arrival time for stop i
- $E_i$ : The earliest permissible arrival time for stop i
- $L_i$ : The latest permissible arrival time for stop i
- $TT_{ij}$ : The minimum travel time from stop i to stop j



Assume that stops 1 through 6 are already scheduled on the bus. The question that the scheduler must answer is “can another ride be scheduled having a requested pickup time of  $T_x$  and a requested drop off time of  $T_y$ ?” The following logical tests could be performed to determine if  $T_x$  is a feasible stop. Let i and j be the identifiers for the stops bracketing  $E_x$  and let k and l be the identifiers for the stops bracketing  $L_x$ .

1. Given that  $T_i < E_x < T_j$

If  $((T_j - T_i) > (TT_{i,x} + TT_{x,j}))$  AND  $((T_j - E_x) \geq TT_{x,j})$  then this stop may be scheduled at time  $T_x = T_j - TT_{x,j}$

2. Given  $T_k < L_x < T_l$

If  $((T_l - T_k) > (TT_{k,x} + TT_{x,l}))$  AND  $((T_l - L_x) \geq TT_{x,l})$  then this stop may be scheduled at time  $T_x = T_k + TT_{k,x}$

3. If either test 1 or 2 is true for both  $T_x$  and  $T_y$ , then the trip can be scheduled.

The procedure described above simply helps the scheduler decide if a trip can be fit into an existing schedule without rescheduling other trips. The procedure is not intended to result in an optimal schedule, it is just a decision support tool that can be easily added to an existing VTTS-type computer program. It is simple, straight forward, and can help the scheduler with one of his/her most difficult tasks with very little added complexity or expense.

### 3.6 Advanced Trip Feasibility Parameters

Once the basic trip feasibility algorithm is established it can be extended to incorporate additional logic in order to make the scheduling more economical. For example Figure 3.4 shows a form providing input for parameter that could be added to the trip feasibility functionality.

- Early window and late window: the permissible length of time that a stop can be scheduled earlier or later than the time requested by the client in order to make room for another trip.

**Auto Schedule Settings**

Timeline diagram showing: Ticket's Pickup Time, Wait Time, Expected Travel Time, Maximum Travel Time Factor, Ticket's Drop-off Time.

Parameters:

1. Early Window	15	5. Early Drop-off	15
2. Late Window	15	6. Late Drop-off	15
3. Early Pickup	15	7. Wait Time	7
4. Late Pickup	15	8. Travel Time Factor	3

Advanced:

☒ Evaluate Past Trips    Address Radius: 0.0028

OK Cancel

Figure 3.4. Advanced Trip Feasibility Parameters

- Early pickup and late pickup: the length of time before or after the scheduled stop time that the client is required to be ready for the bus arrival.
- Early drop-off and late drop-off: the permissible length of time before or after the scheduled stop that the client can be dropped off.
- Late time: the length of time that the bus driver is required to wait for a passenger before driving off without him/her.
- Travel time factor: a factor that is multiplied times the trip travel time to give a maximum ride time. The maximum ride time is the length of time that a client would have to be on the bus for a trip. For example if the point-to-point ride time was 10 minutes and the travel time factor was 3, then the maximum time that the client would have to ride on the bus while other clients were being serviced would be 30 minutes.
- Address radius: if addresses have been geocoded and the latitude and longitude are stored with each address, then trips in the same vicinity having approximately the same stop times may be able to be grouped onto the same bus. The address radius is a parameter representing the radius around a particular address that defines such a vicinity.

## 4. GEOGRAPHICAL DISCRIMINATION

For the trip feasibility feature to work, the travel times ( $TT_{ij}$ ) must be known between all stops on the schedule. The customary approach for estimating these times is to employ a geographical information system (GIS) and utilize its features to calculate the distance and travel times between each street address. When the scheduling software is built into a GIS, then the travel times may be calculated for each trip as they are needed during the scheduling process. As an alternative, the GIS can be run in a batch process to calculate travel times between all possible combinations of addresses; the travel times are stored in a large data table for look-up as needed.

Most small agencies do not have a GPS. A less sophisticated but sufficiently accurate method has been developed for small agencies to determine travel times. It is based on providing several levels of geographical discrimination that provide not only for the estimation of travel times, but provide a rational basis for aggregating data for reporting purposes.

### 4.1 Implementation of Geographical Discrimination

Geographical discrimination is important for at least four purposes: scheduling, dispatching, reporting, and performance evaluation. Geographical discrimination may be appropriately applied at three hierarchal levels:

- Addresses
- Sites
- Zones

#### 4.1.1 Addresses

Recorded as point coordinates on the map and represent the exact pickup and drop off locations for trips.

#### 4.1.2 Sites

Relatively small areas representing neighborhoods. They are represented by polygons on the map. The typical size of a site is such that the travel time from the center to any boundary is about 3 to 5 minutes. Sites provide symbolic identity to collections of addresses. Our experience indicates that schedulers/dispatchers prefer to visualize their service area as districts with local names divided by natural geographic boarders such as main arterials. Figure 4.1 shows the type of form that could be used to enter Sites into the database.

#### 4.1.3 Zones

Areas containing one or more sites. The trip tickets displayed on the schedule/dispatch board (Figure 2.3) are color coded with the zone colors of the pickup and drop off addresses. This provides useful visual indicators for the schedulers when they are assigning trips. The zone that each site is associated with may also be entered using the form shown in Figure 4.1.

#### 4.1.4 Jurisdictions

In addition to sites and zones, political jurisdictions can be assigned for reporting purposes. For example, a county commissioner may request the number and types of trips in his/her jurisdiction, and summary reports can be easily generated if the jurisdictions have been delineated. Jurisdictions are collections of sites. The Jurisdiction that each site is associated with may also entered using the form shown in Figure 4.1.

Site ID	Site Order	Site Name	City	Zone	Jurisdiction	Code Nbr	Custom E
0	100	Campell Scienti	Logan	NW Logan	NA	-1	3
8	100	Canyon Road	Logan	SE Logan	NA	-1	2
10	100	Cliffside	Logan	SE Logan	NA	-1	3
3	100	Fair Grounds	Logan	SW Logan	NA	-1	3
6	100	Hospital	Logan	NE Logan	NA	-1	3
19	100	Hyde Park	Hyde Park	N County	NA	-1	3
18	100	Hyrum E	Hyrum	S County	NA	-1	3
24	100	Hyrum W	Hyrum	S County	NA	-1	3
9	100	Island	Logan	SE Logan	NA	-1	3
2	100	LTD Offices	Logan	NW Logan	NA	-1	2
14	100	Lundstrom	Logan	NE Logan	NA	-1	3
4	100	Macys	Logan	SW Logan	NA	-1	3
16	100	Milville	Milville	S County	NA	-1	3
21	100	N Highway 91	Richmond	N County	NA	-1	3
12	100	N Logan East	Logan	NE Logan	NA	-1	3
-1	100	NA	NA	NA	NA	-1	3
17	100	Nibley	Nibley	S County	NA	-1	3
15	100	Providence	Providence	S County	NA	-1	4
5	100	Research Park	Logan	NE Logan	NA	-1	3
22	100	Richmond	Richmond	N County	NA	-1	3
11	100	River Heights	Logan	SE Logan	NA	-1	3
1	100	Sams Club	Logan	NW Logan	NA	-1	3
20	100	Smithfield E	Smithfield	N County	NA	-1	3
23	100	Smithfield W	Smithfield	N County	NA	-1	3
7	100	Transit Center	Logan	NE Logan	NA	-1	3
13	100	USU	Logan	NE Logan	NA	-1	3

Figure 4.1. Entry Form for Adding and Editing Sites

## 4.2 Estimating Travel Times Manually

Agencies not having access to GIS systems must estimate Travel times ( $TT_{i,j}$ ) manually. It would be unreasonable to attempt to estimate the travel times between all combinations of addresses by hand. For example a community like Logan, UT with 390 clients would need to measure more than 75,500 travel times. However, given the uncertainty associated with traveling from point to point in an actual situation, estimating travel times within 3 to 5 minutes is sufficiently accurate for all practical purposes. Consequently, if sites were laid out to identify more or less homogeneous areas with interior travel times of about 3 to 5 minutes, then travel times from site to site would be sufficiently accurate for determining trip feasibility. For example, the Logan service area was divided into 15 sites as shown in Figure 4.2.

The travel times and distances were measured using a car and a stop watch during periods of time that were considered to experience average congestion. The survey took two people a total of less than 6 hours to complete. The results are shown on Figure 4.3. Average travel times between all 95 combinations of sites were estimated from these data and entered into a database table. Figure



4.4 shows the estimated travel times estimated by this process. The value, 3 minutes, on the diagonal represents the approximate travel time within the site. A form was developed to facilitate the input of the travel times as shown in Figure 4.5. For each combination of sites the mileage, travel time and a factor could be entered. This was intended to be used to increase the average travel time during rush hour periods. It took a data entry person less than 8 hours to input the data using this form.

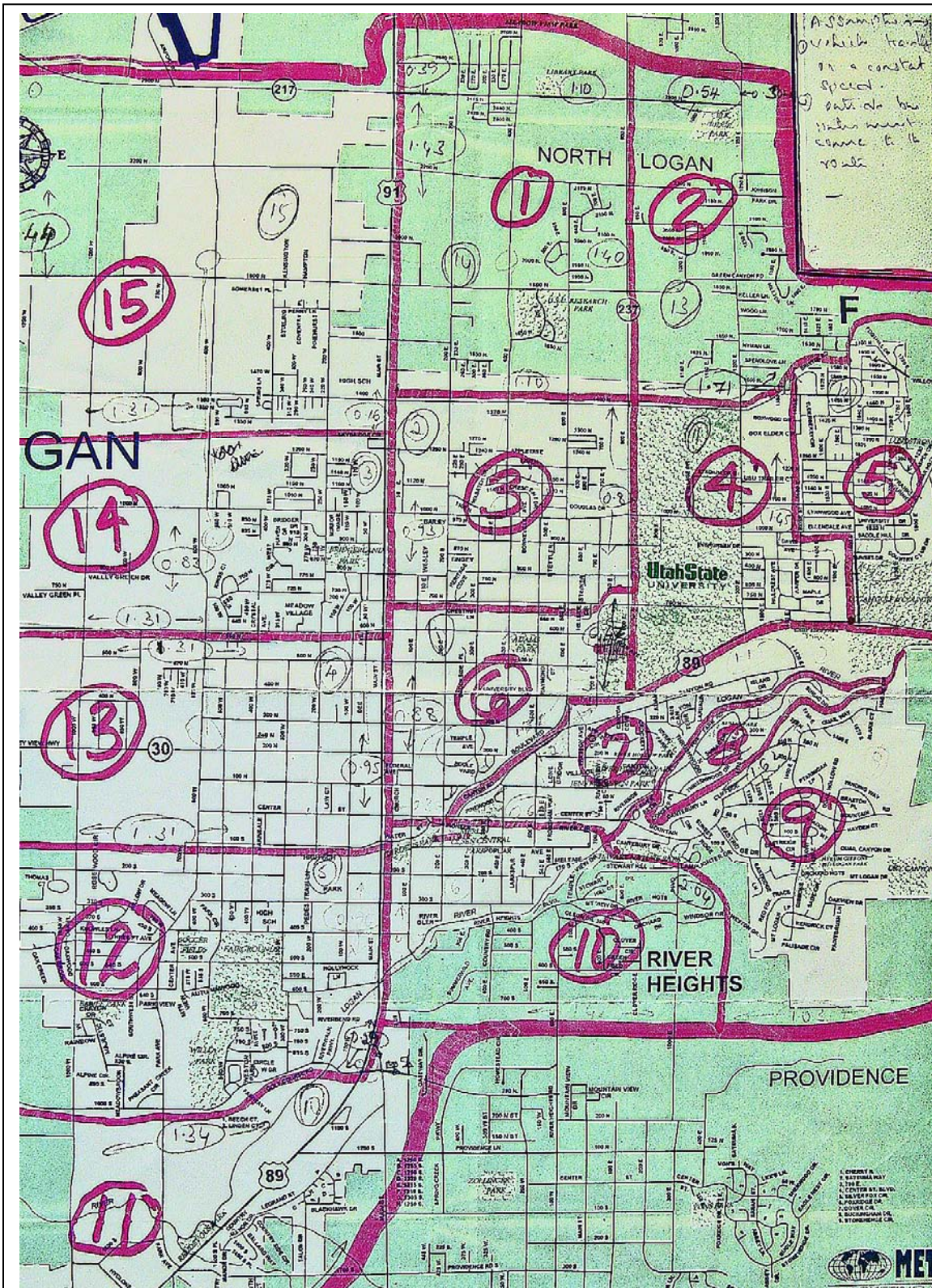


Figure 4.2. Logan City Sites



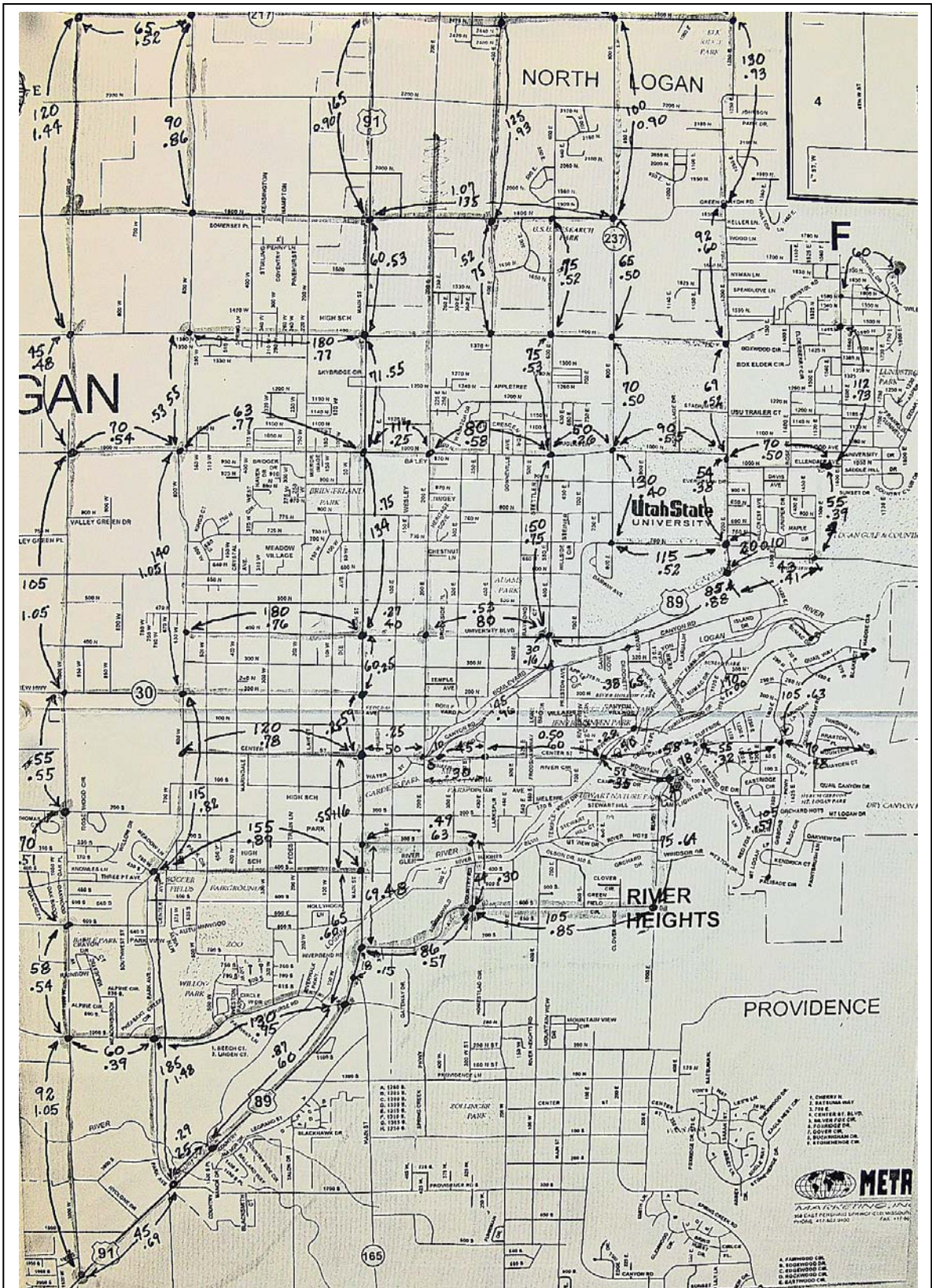


Figure 4.3. Travel Times and Distances

View Sites	Campell	Canyon	Cliffside	Fair Gro	Hospital	Hyde Pa	Hyrum E	Hyrum W	Island	LTD Off	Lundstro	Macys	Millville	N Highw	N Logan	NA	Nibley	Providence	Research	Richmond	River
Campell Scienti	3.00																				
Canyon Road	10.02	3.00																			
Cliffside	13.40	5.43	3.00																		
Fair Grounds	9.92	9.85	12.28	3.00																	
Hospital	6.50	7.13	11.30	9.18	3.00																
Hyde Park	8.87	13.68	17.07	14.95	9.75	3.00															
Hyrum E	21.48	20.05	22.48	17.72	19.38	25.15	3.00														
Hyrum W	23.00	21.57	24.00	17.32	20.90	26.67	13.47	3.00													
Island	14.23	4.03	8.70	13.12	11.67	17.90	23.32	24.83	3.00												
LTD Offices	6.03	7.50	10.02	3.88	6.05	11.82	18.10	19.62	10.85	3.00											
Lundstrom	9.08	9.73	15.38	13.57	8.12	11.50	23.77	25.28	14.27	10.43	3.00										
Macys	9.47	8.03	10.47	4.62	7.37	13.13	13.93	13.53	11.30	6.08	11.75	3.00									
Millville	20.32	18.25	19.77	16.55	18.22	23.48	13.50	22.13	21.52	16.93	22.60	12.77	3.00								
N Highway 91	12.22	17.03	20.42	18.30	13.05	9.88	28.50	30.02	21.25	15.17	16.60	16.48	26.83	3.00							
N Logan East	6.18	9.17	14.82	12.77	5.42	9.05	22.97	24.48	13.70	9.63	2.90	10.95	21.80	13.70	3.00						
NA	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00					
Nibley	17.97	16.53	18.97	12.28	15.87	21.13	10.27	11.90	19.80	14.58	20.25	8.50	13.17	24.48	19.45	3.00	3.00				
Providence	16.53	12.10	12.20	12.27	14.43	20.20	15.22	21.12	15.37	13.28	18.82	8.48	9.65	23.55	18.02	3.00	14.88	3.00			
Research Park	4.77	9.58	12.97	10.85	3.33	6.42	21.05	22.57	13.80	7.72	6.92	9.03	19.88	10.52	3.72	3.00	17.53	16.10	3.00		
Richmond	15.88	20.70	24.08	21.97	16.72	13.95	32.17	33.68	24.92	18.83	20.27	20.15	30.50	3.67	17.37	3.00	28.15	27.22	14.18	3.00	
River Heights	9.95	6.58	6.68	7.13	7.85	13.62	16.52	19.35	9.85	6.57	12.23	5.82	12.58	16.97	11.43	3.00	14.32	8.00	9.52	20.63	
Sams Club	2.42	8.28	11.67	7.00	3.80	10.07	19.75	21.27	12.50	3.12	10.78	7.73	18.58	13.42	7.88	3.00	16.23	14.80	5.97	17.08	
Smithfield E	10.20	15.02	18.40	16.28	11.03	7.87	26.48	28.00	19.23	13.15	14.58	14.47	24.82	5.72	11.68	3.00	22.47	21.53	8.50	9.38	
Smithfield W	11.68	16.50	19.88	17.77	12.52	9.35	27.97	29.48	20.72	14.63	16.07	15.95	26.30	6.73	13.17	3.00	23.95	23.02	9.98	10.40	
Transit Center	5.98	4.03	8.58	6.60	3.88	9.65	16.80	18.32	8.57	3.47	6.97	4.78	15.63	13.00	6.40	3.00	13.28	11.85	5.95	16.67	
USU	9.17	6.68	12.33	10.52	4.35	11.42	20.72	22.23	11.22	7.38	3.70	8.70	19.95	16.68	2.48	3.00	17.20	15.90	6.20	20.35	

Figure 4.4. Average Travel Times Between Sites.

From Site 1		To Site 2		Site 1 to Site 2	
0	Campell Scienti	0	Campell Scienti	Miles	2.00
8	Canyon Road	8	Canyon Road	Travel Time	3.00
10	Cliffside	10	Cliffside	Factor	1.00
3	Fair Grounds	3	Fair Grounds	<input type="button" value="Next Site 2"/> <input type="button" value="Previous Site 2"/>	
6	Hospital	6	Hospital	<input type="button" value="Miles"/>	
19	Hyde Park	19	Hyde Park	<input type="button" value="Travel Times"/>	
18	Hyrum E	18	Hyrum E	<input type="button" value="Factors"/>	
24	Hyrum W	24	Hyrum W	<input type="button" value="Close"/>	
9	Island	9	Island		
2	LTD Offices	2	LTD Offices		
14	Lundstrom	14	Lundstrom		
4	Macys	4	Macys		
16	Millville	16	Millville		
21	N Highway 91	21	N Highway 91		
12	N Logan East	12	N Logan East		
-1	NA	-1	NA		
17	Nibley	17	Nibley		
15	Providence	15	Providence		
5	Research Park	5	Research Park		
22	Richmond	22	Richmond		
11	River Heights	11	River Heights		
1	Sams Club	1	Sams Club		
20	Smithfield E	20	Smithfield E		

Site 1	
City	Logan
Zone	NW Logan
Jurisdiction	NA
Code Nbr	-1
Site Time	3
Address ID	4
Address	
X Coord	0.0000
Y Coord	0.0000

Figure 4.5. Form to Input Site Travel Time Data

## 5. ROAD AND STREET MAP SOFTWARE

Geographical information systems (GIS) are extremely powerful tools for displaying and analyzing data geographical data. In general commercial GIS products are sophisticated, expensive, and require considerable computer expertise to install and maintain. They contain far more functionality than is needed by small to medium sized paratransit agencies. The subset of GIS features that are needed fall into two categories:

- 1) Features that are needed prior to and during trips for purposes of scheduling and real-time dispatching, and
- 2) Features that are useful for analyzing data after the trips have been taken.

The features in category 1 have very similar characteristics among customer sites; the features in category 2 vary widely among customer sites. Category 1 features include:

- Provide a meaningful map display on the screen (and printable) with zoom and pan.
- Geocode and display the location of addresses on the map.
- Determine the best path for a vehicle to travel between two addresses based on distance or travel time and provide the calculated distance and travel time.
- Provide turn-by-turn directions for the travel path.
- Display the path on the map.
- Provide tools for delineating geographical areas on the map such as sites and zones.

Figure 5.1 is an example of a GIS map of the Corvallis, Ore., area delineating individual client addresses (green points), zone boundaries (blue polygons), and major arteries (red lines). Figure 5.2 shows the same information with the addition of the neighborhood streets.

Several software packages were evaluated during this study. They were compared in terms of compatibility, availability, functionality, and cost. The final selection included products from three companies: ESRI®<sup>2</sup>, MapInfo®<sup>3</sup>, and MS MapPoint®<sup>4</sup>. MapPoint is not a comprehensive GIS application like ESRI and MapInfo; and it should be more properly referred to as a roadway map application. Based on the feature/cost trade-offs, MS MapPoint provides all of the features required to meet the category 1 needs at considerably less cost than the other two. It has the additional advantage that many users are familiar with the Microsoft web site maps & directions feature using MapPoint technology. Figures 5.1 and 5.2 were generated using MS MapPoint. Like the more expensive products, a Visual Basic interface can be linked with the MapPoint mapping features. Following are descriptions on how MapPoint can be used as a low cost alternative for providing the necessary functionality for small to medium size transit agencies.

### 5.1 Geocoding and Redundant Address Consolidation

Figure 5.3 shows the form for entering new addresses. The form could be activated through a main menu item such as tools — Addresses. The complete address is made up of two parts: the place name and the street address. The place name (sometimes called the landmark) is the

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<sup>2</sup> ESRI GIS and Mapping Software, Redlands, CA

<sup>3</sup> MapInfo Corporation, Troy, NY

<sup>4</sup> Microsoft Corporation, Redmond, WA



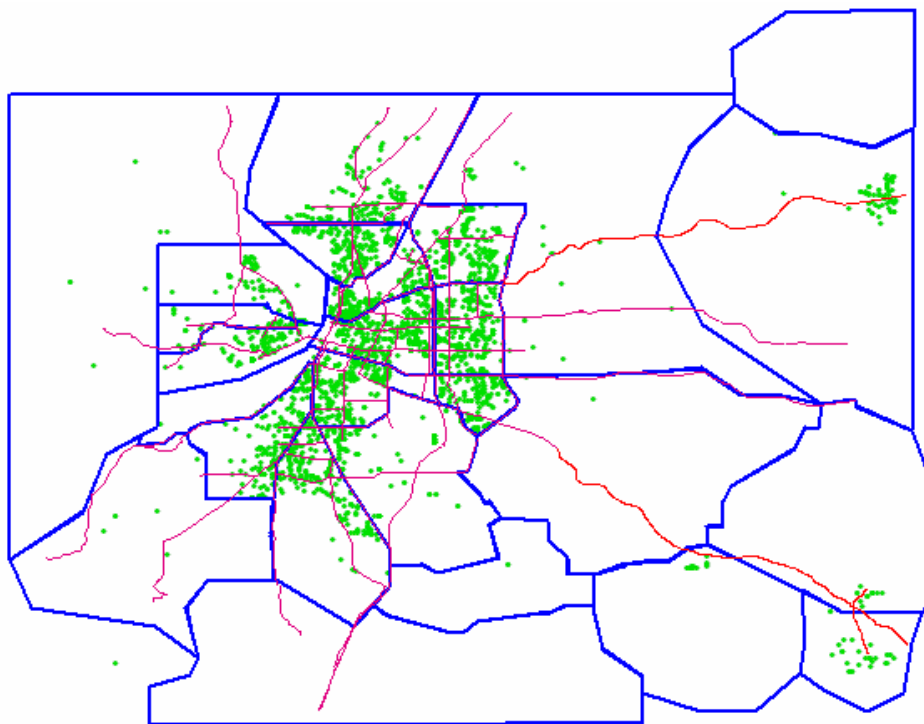


Figure 5.1. GIS Clients (green dots), Artery Streets (red), and Zones (blue).

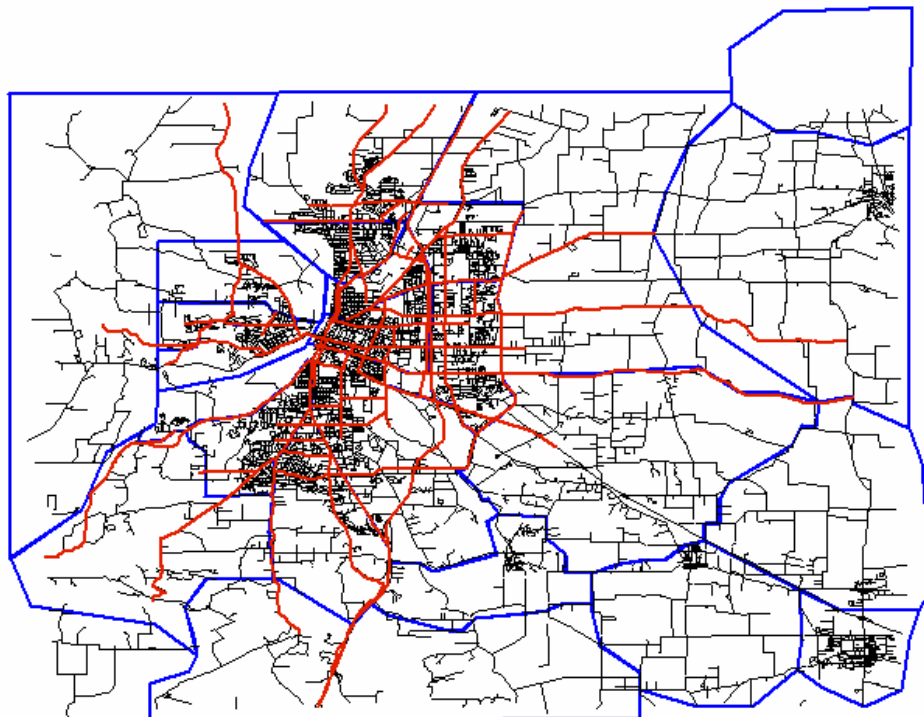


Figure 5.2. GIS Feeder Streets (black), Artery Streets (red), and Zones (blue)

Place Name	Street Address
Safeway 5270 SW Philomath Blvd	5270 SW Philomath Blvd
Safeway (1326 Polk)	1326 Polk
Safeway (590 NE Circle Blvd.)	590 NE Circle Blvd.

Figure 5.3. Form to Add an Address

descriptive name for the address; it is this name that is printed onto the driver manifest. It is customary to append the street address to the place name. After entering the place name and the street address, the user clicks on the add button. The address is automatically geocoded by MapPoint and added to the addresses table in the database.

There are two cases that must be handled separately: 1) when the geocoder cannot find the address, and 2) when multiple place names (landmarks) are associated with the same street address.

### 5.1.1 Case 1: When Automatic Geocoding Fails

Occasionally automatic geocoding fails for some reason such as the street name is misspelled, the address is in a new subdivision that has not yet been mapped, the wrong street number was entered, etc. When this happens, a short list of like addresses is provided as shown in Figure 5.4. The user can double click to select an address from the list. If the correct address is not on the short list then the user can click on the map button and designate the location directly on the map, similar to Figure 5.5.

Figure 5.4. The Geocode Short List

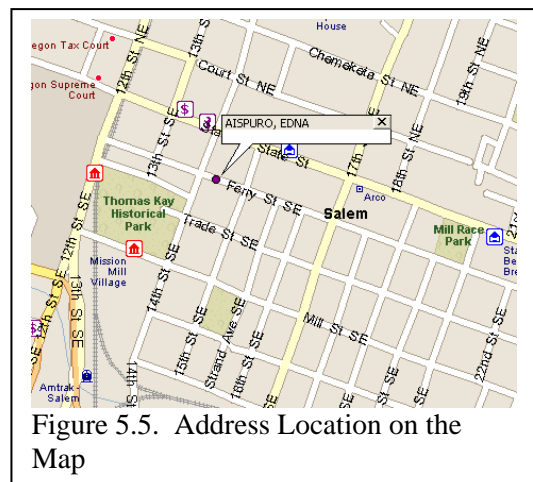


Figure 5.5. Address Location on the Map

### 5.1.2 Case 2: Consolidating Redundant Addresses

Occasionally the same address will be entered with different place names. A utility can be added for consolidating redundant addresses as shown in Figure 19. The form could be activated through a main menu item like tools — consolidate addresses. The procedure for using the form would be as follows:

1. Enter partial or complete information into the place name, street address, and/or the also search on search fields.
2. Click on the find similar addresses button to obtain a list of addresses containing similar text fragments.
3. Double-click on one of the rows to copy data into the search fields. Items in the search fields could be edited.
4. Click on the geocode button to geocode the address in the search fields. The latitude and longitude will appear in their respective fields.
5. Hold down the control key and click on each of the addresses in the list that you wish to replace with the address in the search fields.
6. Click on replace selected addresses to replace the addresses in the selected rows throughout the database with the address in the search fields.

The get next ungecoded button would search for the next ungecoded address in the addresses table. The delete button will delete the address in the selected row.

Place Name	Street Address	Site	Latitude	Longitude
Safeway	11509 Tyler	Witham	44.5726823932499	-123.291392827148
Safeway 5270 SW Philomath Blvd	5270 SW Philomath Blvd	Stoneybrook	44.5549138930917	-123.280107489961
Safeway (1326 Polk)	1326 Polk	Mid-town	44.5717930699356	-123.269365819045
Safeway (590 NE Circle Blvd.)	590 NE Circle Blvd.	Rite Aid	44.5888069927362	-123.251749714479

Figure 5.6. The Form for Consolidating Addresses

## 5.2 Automatic Determination of Travel Times

The automatic routing feature provided by MapPoint could be used to route a trip from one address to another, and to calculate the distance and travel time for the trip. This function could be used to replace the manual method represented in Figure 5.7 for calculating the travel times between sites. Address could be identified near the geographical centroids of two sites and MapPoint could be used to calculate the travel time ( $TT_{i,j}$ ) and distance between the two sites. Using this technique, the data table shown in Figure 4.4 could be generated automatically.



Also using MapPoint the pickup path scheduled for a vehicle could be displayed on the screen as shown in Figure 5.7.

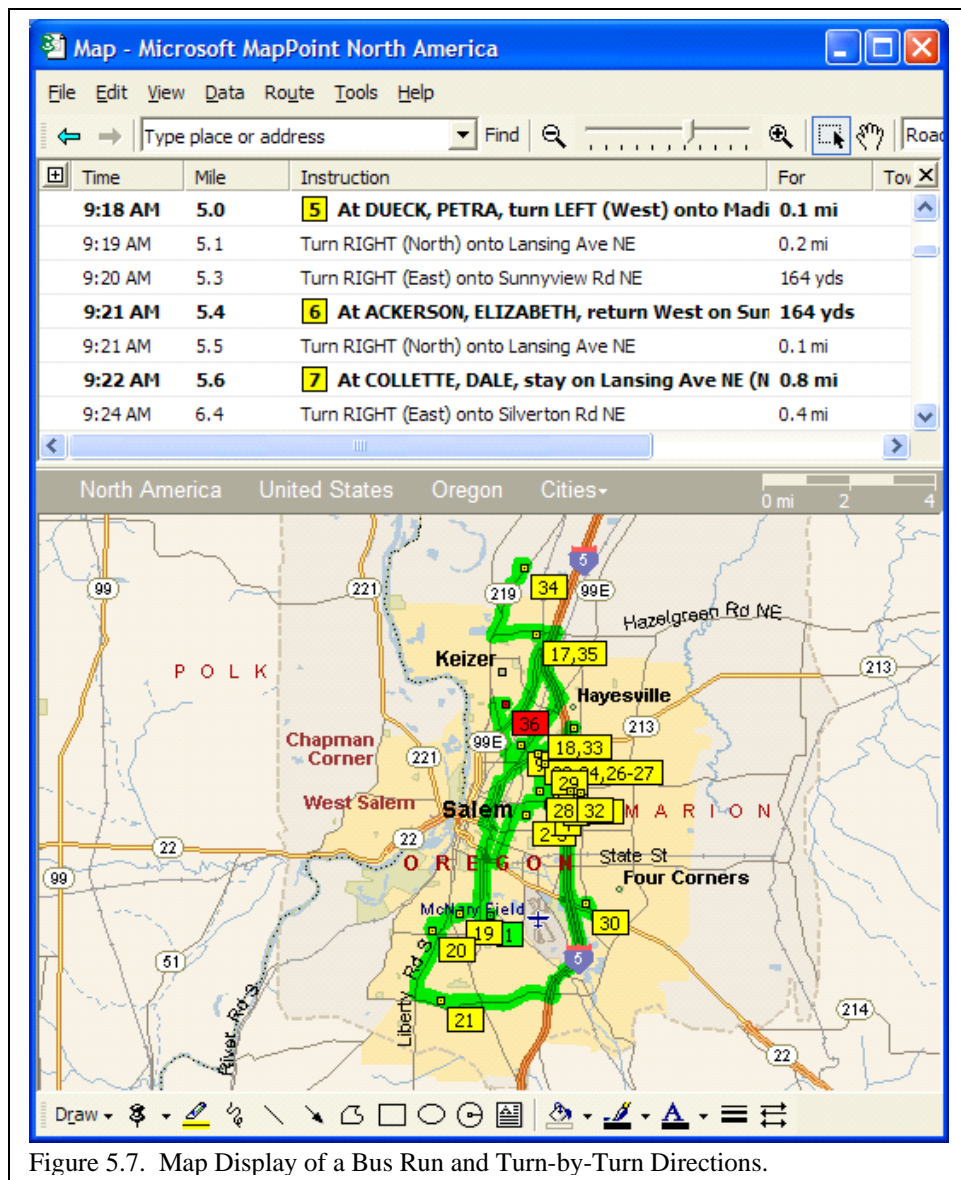


Figure 5.7. Map Display of a Bus Run and Turn-by-Turn Directions.



## 6. SUMMARY AND CONCLUSIONS

This report describes a framework of software extensions that could be added to modest-priced scheduling software to improve the scheduling effectiveness for small to medium size paratransit agencies. The operations at nine paratransit agencies at various locations around the country have been observed and summarized in a previous report.<sup>5</sup> The agencies ranged in size from small to medium (300 to 17,000 rides per month). All of the agencies used low- to moderately-priced software for their scheduling and reporting activities. The type of software they were using can be classified as visual trip ticket schema (VTTS), and it is not based on commercial geographical information system (GIS) packages nor does it include specialized GIS features like displaying street maps, analyzing statistics for geographical sub areas, point-to-point routing of vehicles, or automatic scheduling of their vehicles. The agencies reported two main reasons why they were not using software based on commercial GIS products:

- GIS based software is expensive to acquire and upgrade, and a computer systems type person is generally required to install, maintain, backup, and troubleshoot the system.
- Only a small subset of all of the GIS features are actually needed for the paratransit operations of small to medium sized agencies.

Based on the observations and interviews at the nine agencies, a list of features was derived representing the consensus of additional features that would most improve scheduling performance. The people at the agencies had formulated their opinions based on information they had learned about the advantages of GIS applications from personal experience, transit literature, and at conferences. Some of these desired features would eliminate many manual scheduling errors and could be added to existing software at very little expense. Others would greatly reduce the effort required for scheduling, but would be costly to implement on existing software. Table 6.1 contains a list and description of the features that can be implemented without major expense to extend existing scheduling applications. Where advanced scheduling features are desired, a street and road map type commercial product having fewer features than a comprehensive commercial GIS product is acceptable.

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<sup>5</sup> McGrane, Judy; Grenney, William; and Johnson, Cindy. 2001. Survey of Implementation Strategies By Rural Paratransit Agencies Using Low Cost Software. Final Report Mountain-Plains Consortium. 73 p.

**Table 6.1 Extendable Features**

<b>Feature</b>	<b>Function</b>	<b>Extension</b>
Route Time Boundaries	Prevents the assignment of trips onto a bus that is not scheduled for operation	Add a form to input the beginning and ending times, and implement a simple search algorithm
Route Constraints	Prevents the assignment of unauthorized trips onto a restricted bus	Add a form to input the constraints, and add a simple search algorithm
Route Parameter Replication	Replicates time boundaries and route constraints from past to future days	Add a simple copy algorithm
Trip Feasibility	Calculates whether or not a particular trip can be added to a bus that is partially loaded	Add forms to input scheduling parameters and site-to-site travel times. Add an algorithm that calculates whether or not the proposed trip can be added to each available partially loaded bus.
Geocoding	Identifies the latitude and longitude of client addresses	Purchase and interface a road & street type commercial program
Automatic Scheduling	Automatically assigns trips to buses and creates driver manifests	Purchase and interface a road & street type commercial program that has trip routing functionality. Integrate an algorithm that repetitively uses the trip feasibility feature to automatically assign trips to buses.

## REFERENCES

McGrane, Judy, William Grenney, and Cindy Johnson. 2001. "Survey of Implementation Strategies by Rural Paratransit Agencies Using Low Cost Software. Final Report Mountain-Plains Consortium. 73 p.

Mitrovic-Minic, Snezana. 1998. "Pickup and Delivery Problem with Time Windows: A Survey." Simon Fraser University, CMPT TR 1998-12. 43 p.

Nary, William P. and J. Wesley Barnes. 2000. "Solving the Pickup and Delivery Problem With Time Windows Using Reactive Tabu Search." *Transportation Research Part B* 34 (2000) 197-121.

Li, Y., J. M. Rousseau, and M. Gendreau. 1995. "Real-time dispatching of Public Transit Operations With and Without Bus Location Information." *Computer-Aided Transit Scheduling. Proceedings*, pp. 296-308.

Tan, K.C., L.H. Lee, Q.L. Zhu, and K. Ou. 2001. "Heuristic Methods for Vehicle Routing Problem With Time Windows." *Artificial Intelligence in Engineering*, Elsevier Science Ltd. 15 (2001) 281-295.