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Authors

Dessouky, Maged M.
Hall, Randolph W.
Shah, Rutvij
et al.

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Evaluating the Impact of ITS on Personalized Public Transit

Maged M. Dessouky, Randolph W. Hall,
Rutvij Shah, Majid Aldaihani
University of Southern California

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Evaluating the Impact of ITS on Personalized Public Transit

Interim Project Report

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Maged M. Dessouky

Randolph W. Hall

Rutvij Shah

Majid Aldaihani

Department of Industrial and Systems Engineering

University of Southern California

Los Angeles, CA 90089-0193

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ABSTRACT

The focus of this project is to study alternative system architectures and ITS technologies that can improve the efficiency of personalized public transit and demand responsive systems such as paratransit. This interim report reviews available and emerging ITS technologies that have been deployed or are being considered for this industry. We also conducted a survey of commercially available computer aided dispatching software. We list the numerous features offered by these software packages. Also, included in this interim report is a statistical analysis of travel patterns of a paratransit provider in Los Angeles County. This data analysis will form the basis for our testbed in the second phase of the project. The second phase will compare the performance of a strictly curb-to-curb system with a hybrid system that is a mixture of curb-to-curb and fixed route.

EXECUTIVE SUMMARY

The passage of the American with Disabilities Act (ADA) has created renewed interest in Demand Responsive Transit (DRT) Services. At the same time, the introduction of Intelligent Transportation Systems (ITS) such as dispatching and scheduling software, automatic vehicle location (AVL) devices, mobile data terminal (MDT), etc. has made such systems less complex to operate because of the automatic processing of information. This advancement in technology, which is recognized by transit providers, has caused many vendors to develop specialized software and other equipment to support management of paratransit and demand responsive service. This interim report summarizes the work to date of the project entitled "Evaluating the Impact of ITS on Personalized Public Transit" funded under MOU 3002. The objective of this research is to investigate the use of ITS technologies to improve the service efficiency of DRT providers and to evaluate the different opportunities it creates to improve the overall performance of DRT systems.

We reviewed different technologies that have been implemented or are being considered for implementation by the transit providers. Technologies that have been implemented include AVL, advanced wireless communication, MDT, computerized vehicle navigation, and geographic database. Emerging technologies that have potential for implementation include internet dispatching, superphones, personal data assistants, and smartmaps.

It is anticipated that the responsiveness and costs of demand responsive transit may be improved by utilizing these ITS technologies. For example, real-time control and decision-making technologies may be applied to improve the quality of transit service and to facilitate intermodality. In most cases specialized software can facilitate this task. As part of the research efforts, we conducted a review of the commercial software in order to record their functionality. We identified twenty vendors who distribute potential commercial software that have the potential to support the paratransit industry. Of these vendors, three firms completed the survey that we administered. The other firms stated that they did not believe their software package was suitable for the industry, they did not currently support the product, or the company no longer exists or changed their address.

Our review shows that most of the software has the capabilities to automate reservation, scheduling, billing and maintenance. The intent of this review was not to make a recommendation of any particular software. The purpose was to list the features of the available software and to identify if they have capabilities to support real-time scheduling and reservation of DRT service within the paratransit industry. We note that this industry is changing very rapidly due to changes in the marketplace. There has been numerous mergers leading to decreasing number of software packages specifically addressing the paratransit market while their capabilities are continuously increasing. Most of the packages have built-in interfaces to accommodate AVL devices, global positioning systems (GPS), and MDT.

In order to document how public agencies are adopting the software and technology, we conducted an in-depth phone interview with OUTREACH, Inc. who is the paratransit provider for the Santa Clara Valley Transportation Authority. Also, we conducted a site visit at Antelope Valley Transit Authority. We met with representatives of the agency as well as the contractor that provides paratransit service for the region, Laidlaw. Antelope Valley was selected based on suggestions from Access Services personnel who felt that this region was where it might be beneficial to use a hybrid fixed route and curb-to-curb system. The travel distances in Antelope Valley are large enough to justify a transfer point between the two different types of transit services. Furthermore, most of the disabled and elderly passengers travel to a central location where most of the hospitals are located. Finally, AVTA is a small to mid-size agency so that there is opportunity for effective communication between their fixed route and paratransit services. AVTA provided data of their operations including pickup time, travel distances, fleet size, etc. This data was used to form statistical distributions of representative paratransit operations.

In the next phase of the research, we will concentrate on studying alternative system designs. In particular, we will compare a strictly curb-to-curb system with a hybrid curb-to-curb and fixed route system. Clearly, a curb-to-curb system as opposed to a hybrid system minimizes the travel time for the passenger. However, shifting some of the demand to fixed routes may alleviate some of the demand pressures caused by ADA requirements. The fundamental question that will be addressed in the next phase of the research is whether transferring passengers to fixed routes will result in significant reduction in service level. The alternative configurations will be tested using the AVTA data.

1.0 Introduction

The growth of personalized public transit and demand responsive transit (DRT) began in the late 1970s and early 1980s with large demonstration projects developed in Rochester, NY and Santa Clara County, CA among others. These early systems failed to meet expectations due to low demand requests and deficiency in communication and computer technology to effectively manage such systems (Lave, Teal, and Piras, 1996). However, with the passage of the Americans with Disabilities Act (ADA), which requires that transit agencies provide paratransit or on demand service for the disabled, there has been renewed interest in demand responsive transit. The passage of ADA has increased the obligations of the transit providers to adhere to strict service standards. In addition the demand of these of type transit services is also likely to continue increasing rapidly (Levine, 1997). For example, as reported in the June 24, 1993 issue of the *Wall Street Journal*, the paratransit market was a $500 million industry. Today, it is around a $1 billion industry. In Los Angeles County alone more than 5000 vans and 4200 cabs provide service, generating 8 million trips per year.

Due to the lack of advanced communication and tracking technologies, the early systems tended to operate as advanced reservation systems with some service providers requiring users to place a reservation at least one day in advance of their travel. As reported in the Transit Cooperative Research Program Report #18 (Lave, Teal, and Piras, 1996), this mode of operation has been associated with much lower service productivity. Despite these problems, they are commonplace because they ration capacity easily and are much less complex to implement than on-line real-time reservation systems. However, with the introduction of Intelligent Transportation Technologies (ITS) such as mobile data terminals (MDTs), automatic vehicle location (AVL) devices , and geographic information system (GIS), a real-time system becomes less complex to operate due to the automation of information processing. The increase in demand and the need to provide a high quality of service has forced this industry to consider adopting these technologies as well as studying alternative transit delivery methods. Examples of the introduction of some of these information technologies include:

- Vehicle tracking, such as GPS, which allows to locate vehicles within 3-meter accuracy

- Wireless communication, via satellite, cellular and paging networks, which enable 2-way communication with mobile fleets
- Navigable map databases, from which point-to-point distances can be calculated
- Real-time information services, which allow for dynamic calculation of travel speeds

It is anticipated that the responsiveness and costs of personalized public transit and demand responsive transit may be improved by utilizing certain ITS technologies. For example, real-time control and decision-making technologies may be applied to improve the quality of transit service and to facilitate intermodality. In most cases, specialized software such as Computer Aided Dispatching (CAD) software can facilitate this task.

As part of the research efforts, we have completed the following tasks:

- reviewed and identified technologies that are currently being implemented and emerging technologies that have the potential to improve system performance,
- surveyed commercial scheduling and dispatching software in order to record their functionality,
- conducted in-depth phone interviews and held site visits at transit agencies in order to document how public agencies are adopting the software,
- and statistically analyzed travel pattern data from Antelope Valley Transit Authority (AVTA), a representative paratransit provider in Los Angeles County.

This interim report describes these efforts. In the next phase of the research, we will concentrate on studying alternative system designs. In particular, we will compare a strictly curb-to-curb system with a hybrid curb-to-curb and fixed route system. The alternative configurations will be tested using the analyzed data provided by AVTA. The performance metrics that will be studied include:

- *productivity* - This metric is often measured as the number of riders per trip. By increasing productivity, transit service providers can decrease their direct costs (e.g., gasoline, labor) and capital costs (e.g., fleet size). In Los Angeles County, the average number of riders per trip is around 1.1. Ridesharing in demand responsive transit is low because schedulers mostly dispatch vehicles in a manner similar to taxis. Access

Services Inc. (ASI), the agency responsible for coordinating paratransit service within Los Angles County, believes that through improved vehicle scheduling, there is a potential in Los Angeles County to increase this metric to at least 1.8.

- *on-time performance* - This metric is measured as the percentage of times a vehicle picks-up a passenger within the scheduled arrival time window.
- *travel time* - Clearly, curb-to-curb systems minimize travel time over a hybrid system. However, it may be possible to shift some of the demand to accessible fixed route lines without significantly increasing passenger travel times, thereby alleviating some of the high demand pressure generated by the ADA requests. This issue will be one of the primary focuses of the next phase of the research.

The remainder of this report is organized as follows. A review of past studies on DRT systems is provided in section 2. Section 3 reviews the existing and emerging ITS technologies that can support DRT systems. Section 4 surveys available software for scheduling and dispatching of paratransit vehicles with a detailed comparison of the available features. Section 5 presents a case study of a paratransit service provider implementing ITS. The statistical analysis of data provided by Antelope Valley Transit Authority is presented in section 6. Concluding comments are made in section 7.

2.0 Literature Review

The Americans with Disabilities Act (ADA) has drastically augmented the responsibility of transit service providers and costs associated with it. Levine (1997) lists the ADA requirements for transit service providers. ADA required all agencies to provide accessibility, including wheelchair accessibility to all new and renovated transit vehicles, offer complementary paratransit service to individuals who, because of their disability, are unable to make use of mainline public transportation. Such complementary paratransit was to be phased in over a five-year period ending in 1997. Levine describes the relationship between a standard fare based approach and an incentive fare based approach for paratransit planning. Comparing the two systems, he finds that a very low fare of $0.35 has a dramatic effect on the demand pattern. By using a regression model, he concludes that even low cross price elasticities can lead to cost savings.

There are numerous paratransit delivery methods such as single contracts, multiple contracts, or direct service (Simon, 1998). Rufolo, Strathman and Peng (1997) show in a case study in Portland, Oregon that the service cost for demand responsive transit decreased by a half when switching from direct service to contract service primarily due to labor cost differences. Gilbert and Cook (1999) state that a Federal Transit Administration Study found that 7.6% of total expenditures by transit operators was spent on purchased transportation.

Nalevanko and Cook (1999) describe a methodology that provides guidance to rural and small urban transit operators in selecting appropriate Advanced Public Transportation Systems (APTS) to meet their unique needs. The methodology tries to answer two general questions: Where Do We Start? How Far Should We Go? A decision tree assesses the information provided by a user and decides the appropriate technology to implement. The following factors are considered in the decision tree:

1.System Characteristics

2.Fleet Size

3.Average Requests and Subscription Trips

4.Available Funds and Resources

They also developed a web site that identifies appropriate and adequate technology that supports paratransit service in small urban and rural areas. The address of the web site is: http://www2.ncsu.edu/eos/service/ce/research/stone_res/tahmed_res/www/index.html

Chira-Chavala (1999) and Chira-Chavala and Venter (1997) describe the benefits of implementing ITS Technology at Santa Clara Valley Transportation Authority. They study the cost and productivity impact of implementing an ITS based system. After implementing ITS, they show a 17% increase in ridesharing, 13% savings in transportation cost, and 28% reduction in total personnel salaries. Higgins, Laughlin and Turnbull (2000) evaluate the impact on the performance of implementing ITS at Houston METROLift paratransit service. By deploying AVL and an Advanced Paratransit Scheduling System, service efficiency has increased by 10.3% in four years, even though the service area during this period has been increased by 26.9%.

Wallace (1997) describes a novel way of deriving results by modeling customer satisfaction. Using the results of customer surveys and to avoid problems of redundancy and repetitiveness that generally plague regression analysis a casual model of the factors and variables contributing to customer satisfaction is developed. The modeling efforts show that satisfaction with both the reservation system and on-board service contributes to overall customer satisfaction. This work revealed a strong link between the quality of the customer service and satisfaction with the trip scheduling process.

Balog, Morrison, and Hood (1997) describe the integration of curb-to-curb paratransit service with fixed route transit services and the importance of vehicle transfer requirements to customers. A conjoint analysis technique is used in determining the effect of the two services and a utility value is established which indicate the relative importance of the attributes. The results show the importance of providing easy and secure transfers between the two modes of transportation. Furthermore, transfer stops should be located in sheltered locations.

In summary, the previous work shows the potential benefit of deploying ITS in DRT systems. However, deploying ITS alone is not the complete answer for meeting the increased demand of these types of services and for satisfying the strict guidelines of ADA. New innovative service delivery methods that complement the technology need to be studied. As previously stated, the objective of this study is to compare the productivity and service effectiveness of a curb-to-curb system with a hybrid system. In the next sections, we identify the technologies that can support these types of systems. We also present the results of a statistical analysis of actual data from a representative paratransit operation that will be used in the comparison.

3.0 Intelligent Transportation Systems

ITS technologies have the potential to improve the service and productivity of personalized public transit systems. These technologies are useful for both strictly curb-to-curb systems and hybrid systems. Various ITS technologies currently being used by the transit agencies include:

- Scheduling and dispatching software
- Automatic vehicle location devices (AVL)
- Advanced wireless communication
- Mobile data terminals (MDT)
- Computerized vehicle navigation
- Geographic database

The following emerging technologies are under development:

- Internet dispatching
- Wireless internet dispatching
- Superphones
- Personal data assistants (PDA)
- Smartmaps
- Smart bus technologies

The above technologies are described in detail next.

3.1 Scheduling and Dispatching Software

Different tasks such as reservation, scheduling, dispatching, routing, billing etc. lead DRT providers to adopt computer assistance for efficient handling of passenger request and transport. The complexity associated with DRT operations necessitates that the providers use some form of computer assisted dispatching and scheduling system, which creates opportunities for vendors to develop custom and generic software applications for DRT systems. In Section 3, we review some of the commercially available CAD software. Due to increasing demand, strict ADA guidelines, and complexity of operating such systems, many DRT providers are purchasing off-the shelf

CAD software or developing customized software to meet their specific needs. A large number of software packages are available in the marketplace which can support either manual or fully automated systems. The automated systems have built-in functionality to interact with other technologies such as AVL, MDT, etc. For example, Houston METROLift has implemented the Trapeze PASS paratransit scheduling system which interacts with their AirTouch AVL system. Houston METROLift current service efficiency of 2.35 passengers per hour ranked among the highest of paratransit providers of comparable size. This improvement has occurred despite a 26.9 percent increase in service area (Higgins, Laughlin and Turnbull, 2000).

3.2 Automatic Vehicle Location Devices

Automatic vehicle location devices are an electronic communication system for tracking and reporting the location of the vehicles to a central dispatching center. By knowing the location of the vehicle at the time of scheduling (assigning a specific trip request to a specific vehicle), it may be possible to improve the productivity of the system by better matching the passenger's request location with the vehicle location. AVL systems also have the potential to reduce fleet sizes significantly. AVL systems based on GPS are now well established in the marketplace and are becoming the dominant AVL technology. The table in Appendix A shows the DRT providers that are using different types of AVL systems. The ratio of the agencies using GPS based AVL to the agencies using other AVL is very high.

3.3 Advanced Wireless Communication

Due to possible inaccuracies of AVL technologies, it is preferable to augment these systems with the use of radio get the correct location and to help the driver in cases like flat wheels, accidents, traffic problems, and many unavoidable disruptions. Commercial radios are widely used for both voice and digital data transmission. They will continue to be used for some time, especially in conventional communications that require relatively little data transmission. These devices are simple and relatively inexpensive. Rather expensive, cellular phones are used in many systems as effective means of communication. Transit agencies do not have to build the radio infrastructure like transmission towers; rather they can rent the service of a cellular provider (Stone, Ahmed, and Nalevanko, 2000). However, because of the increasing use of MDTs and the expensive nature of these devices, their usage is very limited. METROLift is integrating their AVL system with the dispatching and scheduling software and radio communication. They hope this integration will enable them to schedule the vehicle trips more efficiently in the case of cancellations and no-shows (Jim Laughlin-Houston METROLift).

3.4 Mobile Data Terminals (MDT)

An MDT is an in-vehicle piece of equipment that receives and sends digital messages, which can be displayed on the screen. MDTs serve as the communication hub between the vehicle and computers at the control center. They automatically send vehicle location, passenger counts, mileage, status of the passenger, and other information. They communicate digitally with a host computer system, display messages to the driver, process and collect data generated in the course of operation. Advancements in microelectronics has made the development of comparatively powerful, sturdy and inexpensive processing units possible. MDTs are widely available for transportation applications in various forms with different ranges of performance characteristics.

3.5 Emerging Technologies

The information on the emerging technlogies was collected from the following web site at North Carolina State University.

http://www2.ncsu.edu/eos/service/ce/research/stone_res/tahmed_res/www/Sec2.html#S9

Wireless Internet Dispatching

Wireless Internet Dispatching systems depend upon “superphones" with Internet access, and server capacity at the provider.

Superphones

Superphones are basically compact hand-held, lightweight computers with two-way phone capability and Internet access. They provide drivers with e-mail access in the vehicle, and direct two-way data transmission and talk facility. They come with a built-in cell phone and Internet access so that they can send e-mail and access special web pages for dispatching and other usages. Other benefits include but are not limited to getting access to phone number lookups, map directions, and traffic and weather reports.

Personal Data Assistant (PDA)

A Personal Data Assistant is a palm computer that creates a driver profile. They are the best alternative to manual data entry by drivers. This helps to speed up data collection and allows quick processing in billing, performance reports, etc. A PDA can be given to the driver each morning to record the log of the day. When the driver returns to the depot, the data can be downloaded into a central computer.

4.0 Paratransit Software

We conducted a review of the commercially available DRT scheduling and dispatching software in order to record their functionality. One reference source used to identify the vendors who distribute this software was the *Software in Transit Handbook* by APTA (American Public Transit Association). Although this is a comprehensive handbook, this industry is changing very fast. Companies are consistently merging and disappearing so the information gets out of date in a short amount of time. Thus, we supplemented the handbook by searching recent transportation magazines and the Internet for related articles and advertisements. Based on the search, a list of companies was identified. Table 1 shows the list of the companies that were contacted.

Table 1. List of DRT Scheduling and Dispatching Software Providers

Software Company
Ramos Systems, Inc.
GIRO, Inc.
Les Conseillers Consultants INC.
Inventek, Inc.
Spear Technologies
Multisystems, Inc.
StrataGen Systems
RouteLogic, Inc.
Intelect Corporation
Teleride, Inc.
Edgar Consultants
TRW Communications
Aleph Computer Systems, Inc.
Fleet-Net Corporation
Trapeze Software, Inc.
Bernardin Lochmueller & Associates, Inc.
BG Consulting
Arrowhead Technologies, INC.
Melton Technoligies, Inc.
Computer Technology
Digital Dispatch Systems

Of the twenty contacted vendors, three firms completed the survey that we administered. They were Stratagen Systems, Trapeze Software Inc., and RouteLogic Inc. The other firms stated that they did not believe their software package was suitable for the industry, they did not currently support the product, or the company no longer exists or changed their address.

4.1 Evaluation Criteria

Each of the different software packages offers a numerous amount of features and capabilities. The features were grouped in seven main categories:

User Management	Fields that are related with the overall management of the paratransit service such as whether an individual is ADA eligible
Reservation	Fields that handle the passenger pick-up reservation process whether made in advance or in real-time
Scheduling	Fields that are related to vehicle scheduling to determine passenger pick-up or drop-off times
Software Features	Fields that describe the operating characteristics of the software such as its security and networking capabilities
Vehicle/Driver Data	Fields that contain records and information regarding the drivers and vehicles
Statistical Reports	Fields that contain statistical results regarding system performance
External Modules	Fields that describe the hardware, which can interact with the paratransit software

These evaluation criteria are categorized in subfields and are listed in Table 2. We developed a comprehensive set of fields in order to understand the complete functionality of these systems that are useful for paratransit scheduling and other operations.

Table 2. Evaluation Criteria

User Management Fields	
Eligibility determination for ADA specification	A field specifying whether the software supports the ADA specifications to determine if the passenger is covered by this law
Special driver preference	A field specifying a pickup driver for each passenger
Individual loading times	An unique loading/ unloading time for each passenger
"Problem passenger" determination	A field indicating any special treatment of the passenger associated with past behavior
Max time in vehicle for individual	Specifying maximum travel time for an individual passenger
Special needs for individuals	Allows to input characteristic of individual (for example different types of wheelchairs, other mobility devices, etc.) and to insert different loading times for each characteristic
Reservation Fields	
Advanced trip reservation	Allows the passenger to make advanced reservations
Group reservation	Supports reservations for a group of passengers
Number of riders	Considers the number of riders for one reservation in the scheduling algorithm
Multiple reservation	Allows to open multiple days to schedule multiple reservations in advance for example 14 days prior
Accompanying riders type	Allows to distinguish between Personal Care Attendants (PCAs) and Guests
Call back confirmation	Supports automatic callback confirmation
Call for changes	Notifies the passenger if the pickup time changes
Choice of performance criteria, priority	Different performance criteria or priority for reservation as selected by the operator and allows user to to specify various measures to be captured or calculated
On-line time estimates	Provides on-line time estimates when the passenger makes the reservation and actual vehicle assignments and update in real time when combined with AVL/MDT/GPS
Real time operations	Capability to support real-time reservations
Automatic name search capabilities	Search capability of names of people calling or places they want to go
On-line address verification	Pickup/ Drop-off address verified through a geographic database for existence and correctness
List of common destinations	Provide "indexable" list of common destinations a particular passenger may make
Transfer to fixed route transit	Supports the capability to transfer to a fixed route transit and the fixed route transit schedule is available for scheduling the ride. Furthermore specifies the accessibility of fixed route bus stop
Redundant reservation warning	Informs the operator in real-time that the same reservation was already scheduled

Input verification for errors, completeness	Checks for completeness/correctness before the reservation is scheduled and repeats the booked trip back to the passenger
Cancellation, change of request	Allows for cancellation by a passenger if the pickup time changes or for rescheduling it. If outside the Cancellation Window, add the passenger in "No Show" list.
Pick up/ Drop off Window	If the passenger can specify a pick up/drop off window when calling for a reservation
Scheduling Fields	
On-line scheduling	Scheduling is done on-line versus batched scheduling/off-line
Vehicle routing/mapping system	Vehicle routing/mapping system is used to determine the routes between points
Distance out of the Way	Supports the maximum distance of a traveled route away from a straight line
Fully computerized scheduling / dispatching	The computer software determines the schedule and trip assignments to vehicles with no human intervention
Batch scheduling/dispatching	Determine schedule for a set of many trips all at one time
Dynamic scheduling	Allows for re-optimizing of the schedule when reservations are made
Manual override of computer schedule	Operator can manually influence the schedule of a specific vehicle and override the given solution by the software
Paratransit transfers	Allows for passengers transferring between vehicles for performance improvement
Traffic considerations	Current traffic conditions are considered by the software when the route is selected
Graphical trip display	Graphically displays the current/future trip of a vehicle overlaying the layout of the service area/city
Refueling considerations	Considers the operation time and fuel consumption of a vehicle when the trips are scheduled
Driver schedules and vehicle operation time	Includes individual driver schedules and vehicle operation times in the scheduling algorithm (for example 10 minute break for the driver every 4 hours) with flexibility to shift the breaks/lunch back to accommodate additional rides
No-show / Cancellation	Reschedules the route when no-shows / cancellations are made
Max number of rides/day	Max number of rides/day or by some other time interval the software is able to schedule
Multiple contractors	Handles multiple contractors in the scheduling algorithm
Software Features Fields	
Networking capabilities	Handles multiple operators/ users of the software at the same time over a network
Multi-tiered security	Multi tiered security system is in place to stop unauthorized access to sensitive data of users/system
On-line help system	On-line access to manuals/help screens while scheduling a ride
Operation simulation capabilities	Simulates the operation of a day/ week in advance with statistical/ real data

Required hardware	Necessary hardware required to run the main software (UNIX, PC, Mainframe, Network computer)
Account software included	Handles the accounting parts of the operation (e.g., payroll, billing of customers, accounts payable, …)
Allows "What if" questions	The software allows easy testing of various alternatives by determining the impact of changes in the parameters
Fleet maintenance	Handles the maintenance operations of the fleet and automatically schedules inspections and repairs
Customize report	Provides customized reports of the all accounting details
Vehicle/Driver Data Fields	
Variable/individual vehicle parameters	Allows for specific parameters to be entered for each vehicle and considers them in the scheduling algorithm
Individual driver parameters	Allows for specific parameters to be entered for each drivers and considers them in the scheduling algorithm
Static vehicle assignments	Permits to assign vehicles to a static route/ schedule for continuous scheduled trips (work trips everyday)
Service area size	Specifies a service area for a vehicle
Data feedback into system	Provides driver feedback into the system about passengers/routes
Autonomy of driver for route selection	Allows driver to be responsible for his own route
Statistical Reports Fields	
Driver evaluation	Statistics on the driver are collected
Time statistics on time in motion	Statistics on the time in motion for each vehicle are collected
Time statistics on pickup time	Statistics on pickup time are collected
Time statistics on loading time	Statistics on loading time are collected
Time statistics on no request motion time	Statistics on time vehicle does not serve any requests but still is in motion (e.g., relocation, back to garage, maintenance) are collected
Statistics on "ride reasons"	Statistics on "ride reasons" are collected by the software
Statistics on service use of different riders	Statistic on the use of the service for different riders is collected
Performance statistics	Statistic on the performance of the service is collected
Import/Export	Capability to read and write in a standard format called ASCII, spreadsheet software and word processing software
External Modules Fields	
Smart Card support	Software provides an interface for support for smart card terminals in the vehicles
Mobile Data Terminals	Software provides an interface for mobile data terminals in the vehicles

Automated Vehicle Location (GPS)	Software provides an interface for automated vehicle location system
In-Vehicle Computers	Software provides an interface for in-vehicle computers (computational power in the vehicle itself)
Radio transmission	Software provides an interface for radio transmissions to/ from the vehicle
Paging	Software provides an interface for paging services to the vehicle

4.2 Software Survey

Most of the software packages cover most of the criteria mentioned in Table 2. Some software packages however have more features than others. Table 3 lists the features of each of the evaluated software packages.

Table 3. Software Survey

Features	Stratagen Systems	Trapeze Software Inc.	RouteLogic Inc.
Key			
Criteria is included -> **X**			
Could not be determined -> **##**			
Criteria is not available -> **NA**			
User Management Fields			
Eligibility determination for ADA specification	X	X	X
Special driver preference	X	X	X
Individual loading times	X	X	X
"Problem passenger" determination	X	X	X
Max time in vehicle for individual	X	X	X
Special needs for individuals	X	X	X
Reservation Fields			
Advanced trip reservation	X	X	X
Group reservation	X	X	X
Number of riders	X	X	X
Multiple Reservation	X	X	X
Accompanying riders type	X	X	X
Call back confirmation	##	X	NA

Call for changes	X	X	NA
Choice of performance criteria, priority	X	X	X
On-line time estimates	X	X	X
Real time operations	X	X	X
Automatic name search capabilities	X	X	X
On-line address verification	X	X	X
List of common destinations	X	X	X
Transfer to fixed route transit	X	X	X
Redundant reservation warning	X	X	X
Input verification for errors, completeness	X	X	X
Cancellation, change of request	X	X	X
Pick up/ Drop off Window	X	X	NA
Scheduling Fields			
On-line scheduling	X	X	X
Vehicle routing/mapping system	X	X	X
Distance out of the Way	##	X	NA
Fully computerized scheduling / dispatching	X	X	X
Batch scheduling/dispatching	X	X	X
Dynamic scheduling	X	X	X
Manual override of computer schedule	X	X	X
Paratransit transfers	X	X	X
Traffic considerations	X	NA	NA
Graphical trip display	X	X	X
Refueling considerations	X	X	NA
Driver schedules and vehicle operation time	X	X	X
No-show / Cancellation	##	X	X
Max number of rides/day	X	X	X
Multiple contractors	X	X	X
Software Features Fields			
Networking capabilities	X	X	X
Multi-tiered security	X	X	X
On-line help system	X	X	X
Operation simulation capabilities	X	X	X
Required Hardware	X	X	X
Account Software Included	NA	NA	X
Allows "What if" questions	X	X	X
Fleet Maintenance	X	NA	X
Customize Report	X	X	X
Vehicle/Driver Data Fields			

Variable/individual vehicle parameters	X	X	X
Individual driver parameters	X	X	NA
Static vehicle assignments	X	X	X
Service area size	X	X	NA
Data feedback into system	X	X	X
Autonomy of driver for route selection	##	X	##
Statistical Reports Fields			
Driver Evaluation	X	X	X
Time statistics on time in motion	X	X	X
Time statistics on pickup time	X	X	X
Time statistics on loading time	X	X	NA
Time statistics on no request motion time	X	X	X
Statistics on "ride reasons"	X	X	X
Statistics on Service use of different riders	X	X	X
Performance statistics	X	X	X
Import/Export	X	X	X
External Modules Fields			
Smart Card support	X	X	X
Mobile Data Terminals	X	X	X
Automated Vehicle Location (GPS)	X	X	X
In-Vehicle Computers	X	X	X
Radio transmission	X	X	X
Paging	X	X	X

Our review shows that most of the software has capabilities to automate reservation, scheduling, billing and maintenance. The intent of this review was not to make a recommendation of any particular software. The purpose was to list the features of the available software and to identify if they have the capabilities to support automated operation of DRT service within the paratransit industry. We note that this industry is changing very rapidly due to changes in the marketplace. There has been numerous merges leading to decreasing number of software packages specifically addressing the paratransit market while their capabilities are continuously increasing. Most of the packages have built in interfaces to accommodate AVL, global positioning systems (GPS), and MDT. We note that the functionality of these systems can be easily extended to also support hybrid systems.

5.0 ITS AT OUTREACH

5.1 Background

OUTREACH Inc. is the paratransit provider for Santa Clara Valley Transportation Authority. Our phone interview contact was Mr. Jarrod Clark. Appendix B contains the list of questions that we prepared for the interview.

They provide services to the elderly and customers under ADA compliance. OUTREACH provides these services for the entire Santa Clara County District. The service area is approximately 328 sq. miles. OUTREACH contracts the service to private taxi and van operators. A customer can make a reservation14 days prior to the requested pickup time and must make it at least before 5 p.m. of the previous day. In some cases, OUTREACH can provide same day service based on vehicle availability. OUTREACH has almost 200 contracted vehicles and provides 2500 trips per day. They perform only booking and scheduling of the contracted vehicles. The private taxi and van operators are responsible for the actual delivery of the passengers. OUTREACH also provides Will-Call service, which is a service request with an open return time when the trip is booked. These trips are deployed using a different set of vehicles.

The number of trips per year has increased dramatically for this region. According to one study in 1995, OUTREACH provided about 326,000 person-trips to about 10,500 clients (Chira-Chavala and Venter, 1997). In order to serve this volume of demand, OUTREACH first implemented automated scheduling and routing software and digital geographic database. In the second phase of implementation, AVL was deployed.

5.2 Implemented ITS

OUTREACH has completed Phase III of the ITS implementation with the help of $750,000 from the federal-and-state funded Smart Paratransit Project.

The technologies implemented include:

- <u>Automated trip scheduling and dispatching software</u> – Trapeze

  When a customer requests are made, the software inserts the trip into the schedule and shared rides are built automatically. The system assigns the trip to a vehicle based on minimizing a weighted objective function of productivity and service level. This schedule is given to the vehicle contractors. The contractor is responsible for dispatching the vehicles. However, OUTREACH employees can assist the contractor in dispatching.

- Automatic vehicle location devices – Trimble System
  Out of 200 vehicles operating for OUTREACH, 85 vehicles have AVL. The system displays the movement of the vehicle on a map. This provides the flexibility of tracking the vehicle and enables OUTREACH employees to determine better estimates of sojourn time. Due to this, they are better able to answer questions from customers who are waiting for the vehicle to arrive. The information regarding trip cancellations and insertions can be transferred directly to the vehicle through AVL. It also allows the dispatcher to help drivers who are facing unusual problems like flat tire, lost, uncertain of directions, traffic congestion, etc.
- Digital geographic database
  The Digital geographic database (DGD) contains city, street names and the address of each block. It also includes some traffic characteristics. Geocoding of addresses is done using a longitude/latitude coordinate system. Distances between two points can be calculated, and street locations can be viewed on a computer screen. Data files of the street addresses can be managed using this system.

5.3 Benefits of ITS

Chira-Chavala and Venter (1997) concluded that without the automated trip scheduling system OUTREACH would not have been able to accommodate the increases in paratransit demand nor able to meet the full ADA compliance. They describe the following benefits of ITS implementation.

- Increase in the percent shared rides (the percentage of time that there are two or more requests in vehicle) from 38% to 55%
- 13% savings in the unit transportation cost per passenger mile
- Total personnel salaries decreased by 28%

- Clients did not perceive a significant difference in the level of service between before and after ITS. Hence, service costs decreased without a resulting drop in service level.

5.4 Future Technology Implementation

After the current phase of technology implementation, OUTREACH would like to implement the following technologies:

- Smartcard
- Automated Interactive Voice Response
- Online booking and cancellation
- Wireless communication devices / Palm computers

OUTREACH is also investigating methods to move some of the requests to accessible fixed routes, in order to better meet the increase in demand.

6.0 AVTA Data Analysis

6.1 Background

Antelope Valley Transit Authority (AVTA) was selected based on suggestions from Access Services personnel, the agency responsible for coordinating paratransit service within the county, who felt that this region was where it might be beneficial to use a hybrid fixed route and curb-to-curb system. The travel distances in Antelope Valley are large enough to justify a transfer point between the two different types of transit services. Furthermore, most of the disabled and elderly passengers travel to a central location where most of the hospitals are located. Finally, AVTA is a small to mid-size agency so that there is opportunity for effective communication between their fixed route and paratransit services. AVTA provided data of their operations including pickup time, travel distances, fleet size, etc. This data will be used to form statistical distributions of representative paratransit operations, which will form the basis for our testbed in comparing the performance of a strictly curb-to-curb system with a hybrid system.

Antelope Valley Transit Authority provides fixed route and paratransit services in Lancaster County. The total service area is divided in three parts, Urban Zone, Rural Zone 1 and Rural Zone 2 as shown in Figure 1.

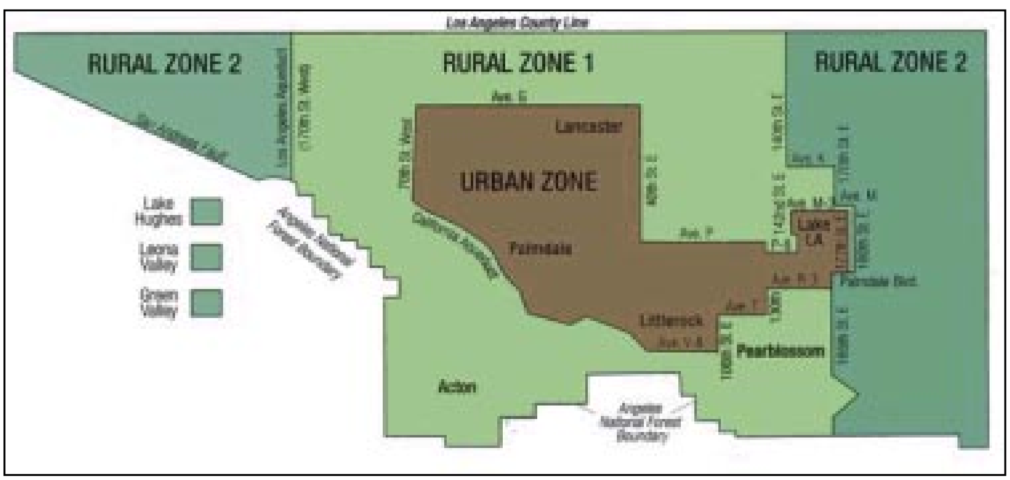

Figure 1. Dial-A-Ride Service Area for AVTA

We received data in the hard format for the period of two weeks, February 14, 2000 to February 25, 2000. We only considered weekdays. Thus, we received ten days of data. AVTA operates from 6:00 AM to 7:30 PM during the weekdays. The total number of requests served during these days was 1242. The number of drivers per day varied from 4 to 12 during this period (Average=9.22). The average number of requests served per day per driver was 15.79 with the maximum number being 30.33 on any given day. The data provide the following details for each requested trip:

- The unique identification number
- Number of attendants and companions
- Pick-up/Drop-off destinations
- Requested pick-up/drop-off time window
- Actual pick-up/drop-off time
- Cumulative miles

We entered these data in a spreadsheet and the distributions for vehicle travel time, pick-up time, travel distance and other important results were tabulated.

6.2 Statistical Data Analysis

The collected data was analyzed to determine the travel patterns of a representative DRT operation. All summary statistics are presented in Table 4.

6.2.1 Miles Traveled per Request

Figure 2 shows a histogram of the distance traveled in miles. As the figure shows, the most common request is within the range of 6 to 10 miles. However, there still is a significant amount of passengers traveling greater than 10 miles which is significant enough of a distance to justify a transfer to an accessible fixed route bus.

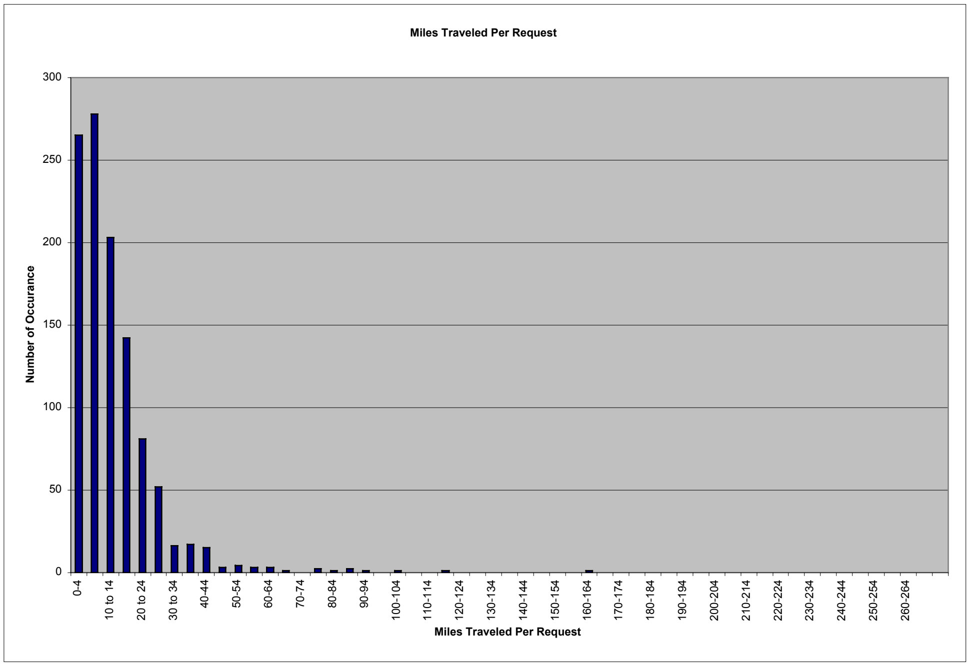

Figure 2. Miles Traveled Per Request

6.2.2 Pick-up Time

Figure 3 shows the frequency of the actual pick-up times. Most of the requests were during late morning and early afternoon. The number of requests after 7:00 pm is very low since the working hours for AVTA is from 6:00 am to 7:30 pm. Almost in all the cases, the demand was satisfied within the requested time window. We note that the peak of the pick-up time distribution matches closely with the high frequency periods of the fixed routes.

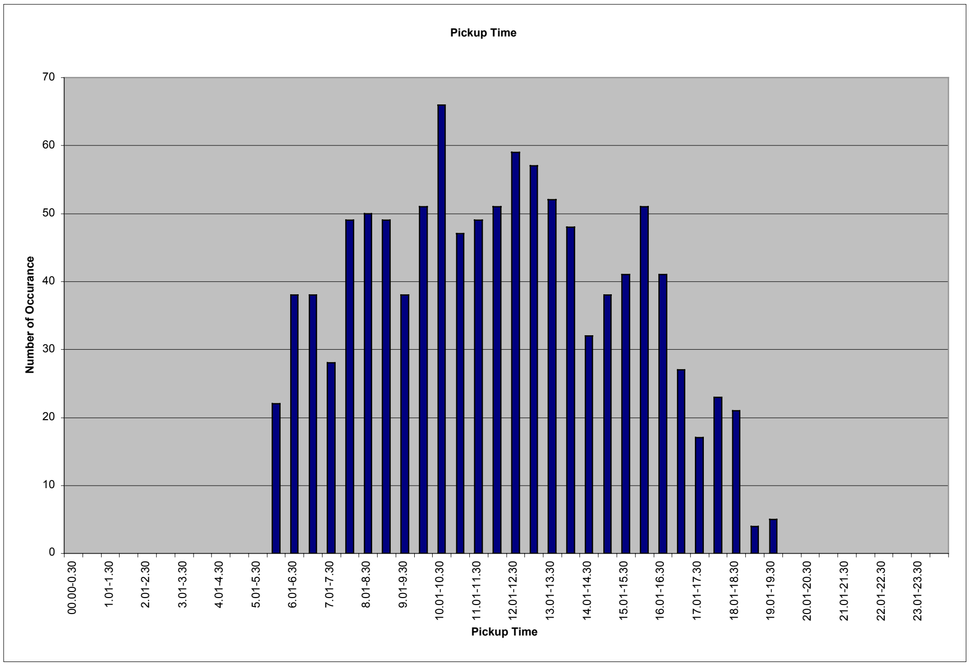

Figure 3. Actual Pick-up Time

6.2.3 Drop-off Time

Figure 4 shows the frequency of the actual drop-off times. There were no drop-offs between 6:00 and 6:30 am because it is the start of the day. Although AVTA closes at 7:30 pm, there are some drop-offs after this time since the request was accepted during the working day, and AVTA is responsible for dropping off these requests even after working hours. As can be seen, the shape of the drop-off time distribution is similar to that of the pick-up time distribution except slightly shifted to the right

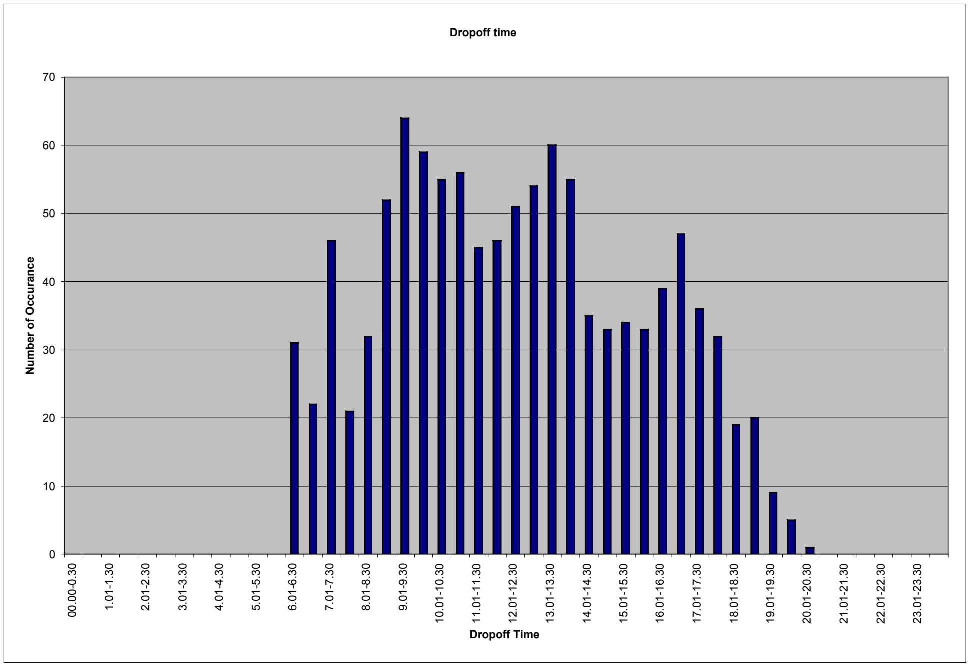

Figure 4. Actual Drop-off Time

6.2.4 Vehicle Occupancy Rate

Figure 5.1 shows the fraction of the total travel time during which the vehicle was occupied by a request. When occupied, there may be more than one passenger in the vehicle. As is shown in the figure, more than half of the time the vehicle is empty implying possibly that the vehicle travels great distances to pickup passengers. Improved coordination between pickup locations in the schedule could improve this performance measure. Figure 5.2 shows the results based on miles instead of time. Note there is not much difference in the figures.

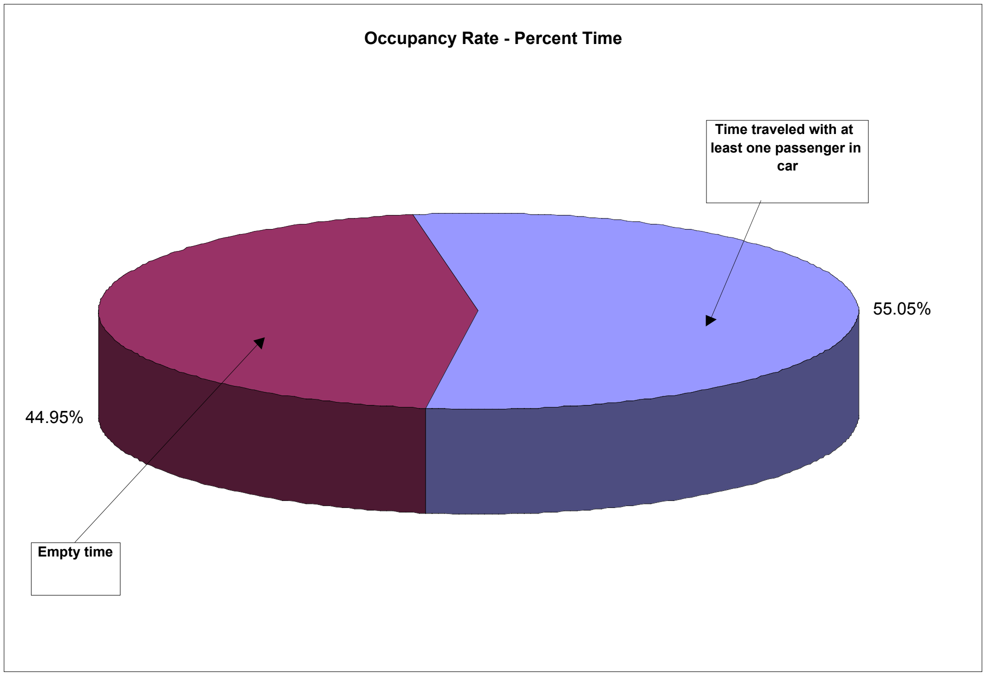

Figure 5.1. Occupancy Rate – Percentage Time

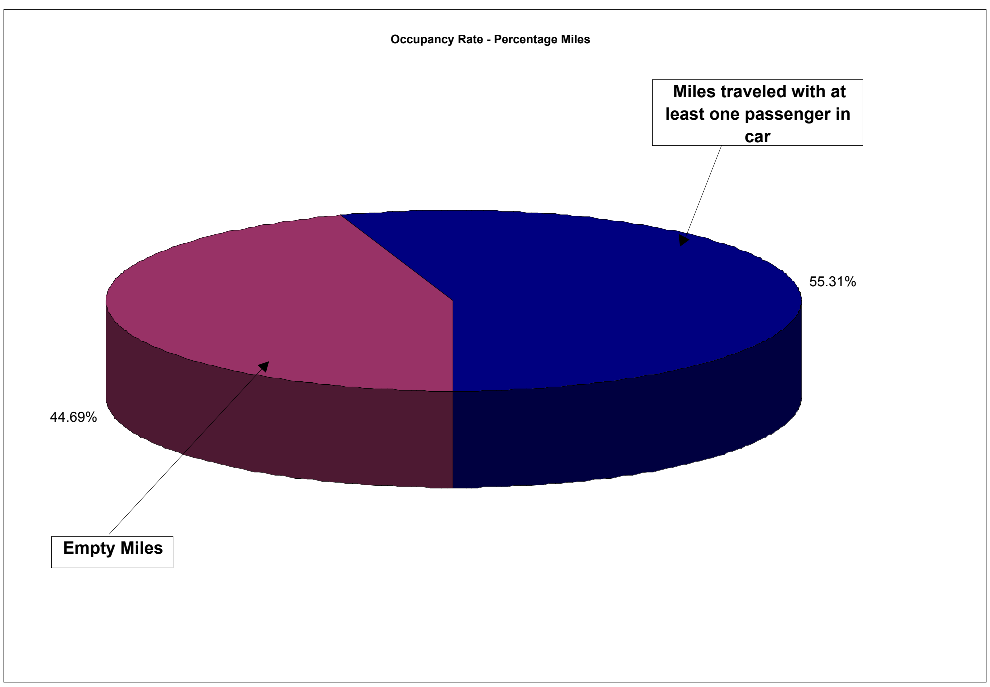

Figure 5.2. Occupancy Rate – Percentage Miles

6.2.5. Number of Passengers per Request

Figure 6 provides details on the number of passengers picked up per request. In some cases, elderly, disabled and patients need one more person as their attendant to assist them. Also a companion can travel with the passenger. As shown in the graph, in almost 90% of the cases, there is only one passenger associated with each request. In some cases, there are two passengers associated with each request and in rare cases there are three. These results are useful for determining vehicle capacity requirements.

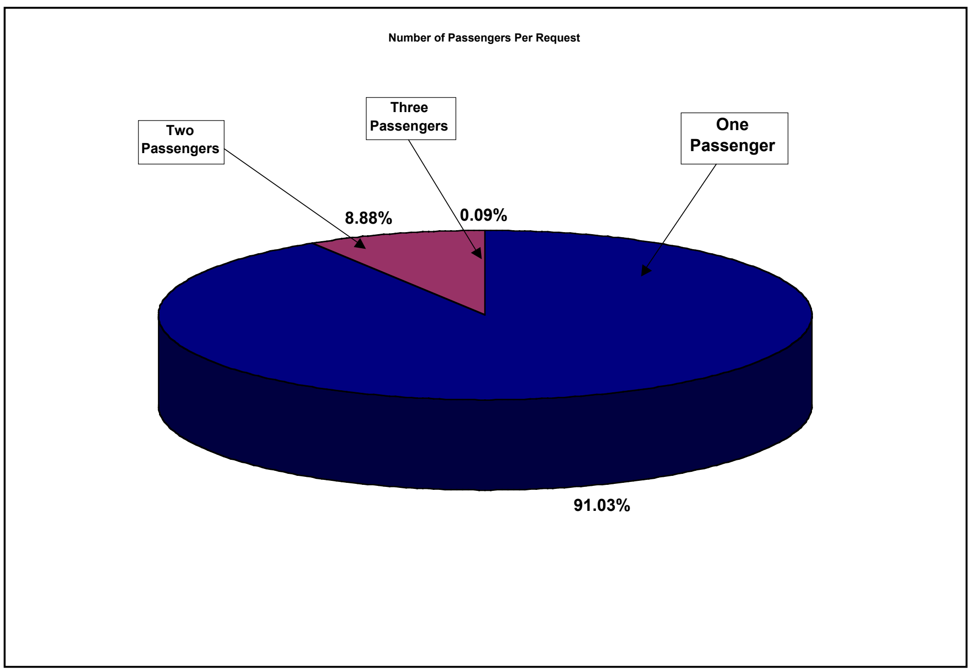

Figure 6. Number of Passengers per Request

6.2.6 Ridesharing

Figure 7 shows the fraction of time in which there was more than one request in the vehicle. As shown in the figure, around a third of the time there were more than two requests in the vehicle. We differentiate between number of requests and number of passengers since each request can be associated with more than one passenger. We consider the case only when there are multiple requests currently being served by the vehicle as ridesharing.

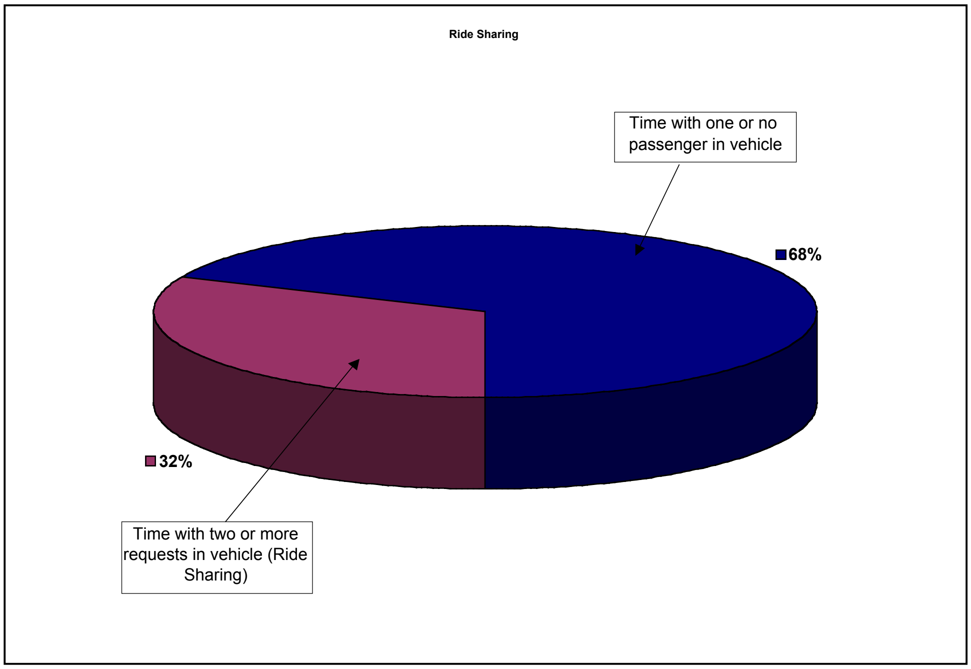

Figure 7. Ridesharing

6.2.7 Miles Traveled per Day

Figure 8 shows the distribution of the number of miles traveled by a driver per day. We can see from the graph that the maximum that was driven by a driver was over 180 miles. The average number of miles driven by a driver is around 165 miles. Note that a hybrid system has the potential to reduce these averages.

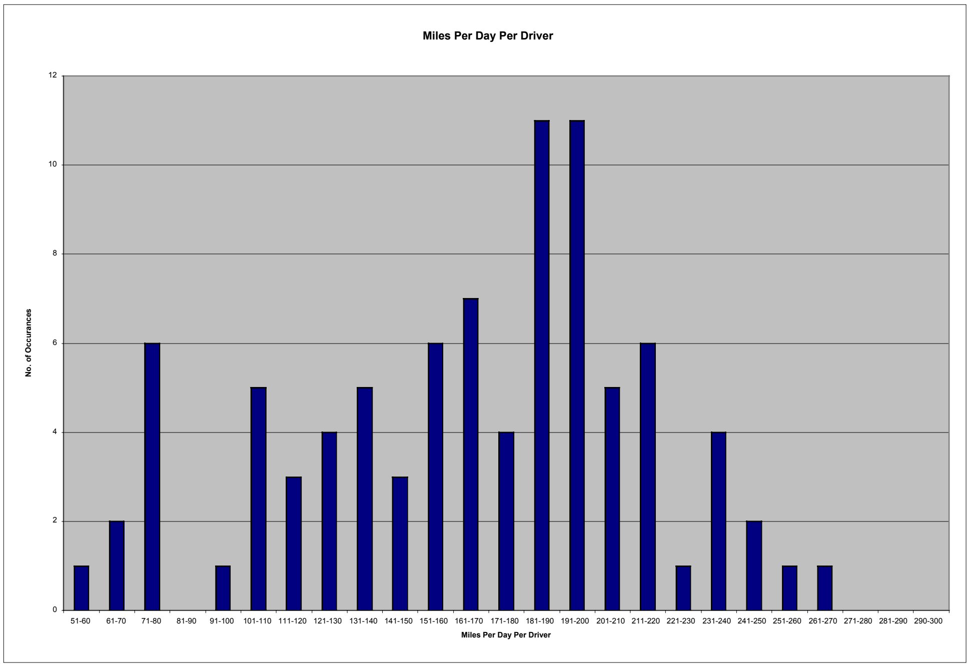

Figure 8. Miles Traveled Per Day

6.2.8 Summary

Table 4 summarizes the results of the statistical analysis.

Table 4. Summary of the Statistics

1	Travel Distance Per Request in Miles	
	Average	12.75
	Standard Deviation	13.00
	Median	10
	Mode	4
	Maximum	163
	Minimum	0
2	Pickup Time	
	Average	11.87
	Standard Deviation	3.41
	Median	11.58
	Mode	9.55
	Maximum	20.07
	Minimum	5.48
3	Drop-off Time	
	Average	11.89
	Standard Deviation	3.41

	Median	11.58
	Mode	9.55
	Maximum	20.07
	Minimum	5.48
4	Total Number of Requests Served	1242
5	Total Number of Passengers Transported	1872
7	Number of passengers per request (%)	
	One passenger	91.03
	Two passenger	8.88
	Three passenger	0.09
8	Percentage of time more than one request in vehicle (Ridesharing)	31.78
9	Percentage of time traveled with passenger	55.05
10	Percentage of time traveled empty	44.95
11	Percentage of distance traveled with passenger	55.31
12	Percentage of distance traveled empty	44.69
13	Average number of requests served per day per driver	15.79
14	Maximum number of requests served per day per driver	30.33
15	Average distance traveled per day	1132.69
16	Distance traveled per driver per day	
	Average	165.45
	Standard Deviation	49.06
	Median	174
	Mode	166
	Maximum	262
	Minimum	53

7. Conclusion

We have reviewed and identified technologies that are currently being implemented and emerging technologies that have the potential to improve system performance, surveyed commercial scheduling and dispatching software in order to record their functionality, and conducted in-depth phone interviews and held site visits at transit agencies in order to document how public agencies are adopting the software. Although this review shows the potential benefit of deploying ITS in DRT systems, it alone is not the complete answer for meeting the increased demand of these types of services and for satisfying the strict guidelines of ADA. New innovative service delivery methods that complement the technology need to be studied.

In the next phase of the research, we will concentrate on studying alternative system designs. In particular, we will compare a strictly curb-to-curb system with a hybrid curb-to-curb and fixed route system. Clearly, a curb-to-curb system as opposed to a hybrid system minimizes the travel time for the passenger. However, shifting some of the demand to fixed routes may alleviate some of the demand pressures caused by ADA requirements. The alternative configurations will be analyzed using the statistical distributions developed from the AVTA data.

Acknowledgement

This research was entirely supported by PATH and Caltrans. The research team greatly appreciates the continuous support of Access Services, Inc. (ASI) for providing both technical expertise and data in this research. In particular, we thank Lance Millar from ASI for his support in providing the AVTA data.

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Internet Sites

http://www2.ncsu.edu/eos/service/ce/research/stone_res/tahmed_res/www/index.html

http://www2.ncsu.edu/eos/service/ce/research/stone_res/tahmed_res/www/Sec2.html#S9

Software vendor web sites for information

Others

Wall Street Journal, Issue June 24, 1993

Appendix A

This information is taken from the APTS Deployment Report developed by the U.S. Department of Transportation in 1999.

Table A.1. List of Transit Agencies Deploying AVL

Sr No.	Transit Authority	Automatic Vehicle Location System
1	Birmingham-Jefferson County Transit	GPS
	Authority, Birmingham, AL	
2	City of Mesa, Mesa, AZ	Unspecified
3	Regional Public Transportation	GPS
	Authority, Phoenix, AZ	
4	Sun Tran, Tucson, AZ	GPS
5	ASI, Los Angeles, CA	GPS
6	Alameda Contra Costa Transit	GPS
	District, Oakland, CA	
7	Antelope Valley Transit Authority	GPS
	Lancaster, CA	
8	Arcadia Transit, Arcadia, CA	GPS
9	Camarillo Area Transit, Camarillo, CA	GPS
10	Central Contra Costa Transit Authority	GPS
	Concord, CA	
11	City of Alameda Ferry Services,	DGPS
	Alameda, CA	
12	City of Glendale, Glendale, Ca	GPS
13	City of Riverside Special Transportation,	GPS
	Riverside, CA	
14	Eastern Contra Costa Transit Authority	GPS
	(Tri-DeltaTransit),Antioch,CA	
15	Emery Go Round, Oakland, CA	GPS
16	Fairfield-Suisan Transit, Fairfield, CA	GPS
17	Fresno Area Express, Fresno, CA	GPS
18	Gardena Municipal Bus Line	GPS
	Gardena, CA	
19	Golden Empire Transit District,	Unspecified
	Bakersfield, CA	
20	Golden Gate Bridge, Highway and	Unspecified
	Transportation District, San Francisco, CA	
21	Livermore/Am adore Valley Transit Authority,	GPS
	Livermore, CA	
22	Los Angeles County Metropolitan Transportation	SO, DGPS
	Authority, Los Angeles, Ca	
23	Modesto Area Express, Modesto, CA	GPS

24	North San Diego County Transit District,	GPS
	Oceanside, CA	
25	Norwalk Transit System, Norwalk, CA	GPS
26	Omnitrans, San Bernardino, CA	DGPS
27	Orange County Transportation Authority,	GPS
	Orange, CA	
28	Outreach and Escorts Inc., San Jose, CA	DGPS
29	Riverside Transit Agency, Riverside, CA	DK
30	San Diego Transit Corporation, San Diego, CA	GPS
31	San Diego Trolley, San Diego, CA	GPS
32	San Francisco Municipal Railway,	SO
	San Francisco, CA	
33	San Joaquin Regional Transit District,	DGPS
	Stockton, CA	
34	San Mateo County District (Samtrans),	GPS
	San Carlos, Ca	
35	Santa Clara Valley Transit Authority,	DGPS
	San Jose, CA	
36	Santa Monica Municipal Bus Lines,	OTR
	Santa Monica, CA	
37	Simi Valley Transit, Simi Valley, CA	Unspecified
38	Sonoma County Transit, Santa Rosa, CA	GPS
39	Stanislaus Regional Transit, Modesto, CA	GPS
40	Sunline Transit Agency, Thousand Palms, CA	GPS
41	The Vine/Napa Valley Transit, Napa, CA	GPS
42	Thousand Oaks Transit, Thousand Oaks, CA	GPS
43	Vallejo Transit and Baylink Ferry, Vallejo, CA	GPS
44	Avon/Beaver Creek Transit, Avon, CO	GPS
45	Colorado Springs Transit, Colorado Springs, CO	DGPS
46	Eagle County Regional Transportation Authority,	Unspecified
	Avon, CO	
47	Mesa County, Grand Junction, CO	GPS
48	Regional Transit District, Denver, CO	DGPS
49	Transfort, Fort Collins, CO	Unspecified
50	Connecticut Limousine, Milford, CT	DGPS
51	Greater New Heaven Transit District, Hamden, CT	GPS
52	DART First State, Delaware Transit Core,	GPS
	Dover, DE	
53	Arc Transit, Palatka, FL	GPS
54	Broward County Mass Transit, Pompano Beach, FL	GPS
55	Central Florida Regional Transportation Authority	GPS
	(LYNX), Orlando, FL	
56	Gainsville Regional Transit System, Gainsville, FL	Unspecified
57	Hillsborough Area Regional Transit Authority,	SO
	(HART), Tampa, FL	
58	St. Lucie County Council on Aging,	GPS
	Prot St. Lucie, FL	

59	Tri-County Commuter Rail Authority,	GPS
	Ft Lauderdale, FL	
60	Metropolitan Atlanta Rapid Transit Authority,	DGPS
	(MARTA) Atlanta, GA	
61	Oahu Transit Services (The Bus), Honolulu, HI	GPS
62	City of Davenport, Davenport, IA	Unspecified
63	City of Dubuque-Keyline Transit, Dubuque, IA	GPS
64	Des Moines Metropolitan Transit Authority,	GPS
	Des Moines, IA	
65	Five Seasons Transportation and Parking,	GPS
	Cedar Rapids, IA	
66	Metropolitan Transit Authority of Black Hawk County,	GPS
	Waterloo, IA	
67	Sioux City Transit System, Sioux City, IA	Unspecified
68	University of Iowa, CAMBUS, Iowa City, IA	GPS
69	Chicago Transit Authority, Chicago, IL	DK
70	Cook-Dupage Transportation Company Inc.,	OTR
	Chicago, IL	
71	PACE Suburban Bus, Arlington, Heights, IL	GPS
72	Rock Island County Mass Transit (METROLINK),	GPS
	Rock Island, IL	
73	Urbana Champaign Mass Transit District, Urbana, IL	GPS
74	Bloomington Public Transportation Corporation,	GPS
	Bloomington, IN	
75	Muncie Indiana Transit System, Muncie, IN	Unspecified
76	Northern Indiana Commuter Transportation District,	Unspecified
	Chesterton, IN	
77	Wichita Metropolitan Transit Authority, Wichita, KS	GPS
78	Transit Authority of River City, Louisville, KY	SO
79	City of Alexandria, Alexandria, LA	Unspecified
80	Crescent City Connection Division, New Orleans, LA	Unspecified
81	Cape Cod RTA, Dennis, MA	GPS
82	Cape Island Express Lines Inc., New Bedford, MA	Unspecified
83	GATRA, Attleboro, MA	DGPS
84	Maryland Transit Administration (MARC Train	OTR
	Service), BWI Airport, MD	
85	Montgomery County Transit, Rockville, MD	DGPS
86	Monhegan-Thomston Boat Line, Port Clyde, ME	GPS
87	Ann Arbor Transportation Authority, Ann Arbor, MI	SO
88	Battle Creek Transit, Battle Creek, MI	Unspecified
89	Capital Area Transportation Authority, Lansing, MI	GPS
90	Detroit Transportation Corporation, Detroit, MI	Unspecified
91	Suburban Mobility Authority For Regional	GPS
	Transportation (SMART), Detroit, MI	

92	Mankato Heartland Express, Mankato, MN	Unspecified
93	Metro Transit, Minneapolis, MN	GPS
94	St. Cloud Metropolitan Transit Commission,	GPS
	St. Cloud, MN	
95	Kansas City Area Transit Authority, Kansas City, MO	SO
96	Asheville Transit Authority, Asheville, NC	SO
97	Capital Area Transit, Raleigh, NC	Unspecified
98	Greensboro Transit Authority, Greensboro, NC	GPS
99	Rocky Mount Transit, Rocky Mount, NC	GPS
100	Winston-Salem Transit Authority, Winston-Salem, NC	Unspecified
101	Transit Authority of City of Omaha, Omaha, NE	GPS
102	COAST, Portsmouth, NH	GPS
103	New Jersey Transit, Newark, NJ	SO, GPS
104	City of Santa Fe (Santa Fe Trails), Santa Fe, NM	Unspecified
105	SunTran, Albuquerque, NM	GPS
106	Citizen Area Transit, Las Vegas, NV	DGPS
107	Regional Transportation Commission of Washoe	Unspecified
	County, Reno, NV	
108	Capital District Transportation Authority, Albany, NY	NY
109	Liberty Lines Transit, Yonters, NY	SO
110	Long Island Bus, Garden City, NY	GPS
111	New York City Department of Transportation,	GPS
	New York, NY	
112	New York City Transit, Brooklyn, NY	DGPS
113	Niagara Frontier Transportation Authority, Buffalo, NY	GPS
114	Rockland County DO Public Transport, Pomona, NY	Unspecified
115	Suffolk County Department of Public Works-	Unspecified
	Transportation Divison, Yaphank, NY	
116	Westchester County DOT, White Plains, NY	SO, GPS
117	Central Ohio Transit Authority, Columbus, OH	SO
118	Greater Cleveland Regional Transit Authority,	DGPS
	Cleveland, OH	
119	Lake Tran, Grand River, OH	GPS
120	Metro Regional Transit Authority, Akron, OH	GPS
121	Miami Valley Regional Transit Authority, Dayton, OH	Unspecified
122	Southwest Ohio Regional Transit Authority,	GPS
	Cincinnati, OH	
123	Western Reserve Transit Authority, Youngstown, OH	GPS
124	Metropolitan Tulsa Transit Authority, Tulsa, OK	GPS
125	Lane Transit City Bus, Eugene, OR	GPS
126	Tri-County Metropolitan, Portland, OR	DGPS
127	Area Transportation Authority of North Central	Unspecified

	Pennsylvania, Johnsonburg, PA	
128	Beaver County Transit Authority, Rochester, PA	GPS
129	County of Lackawanna Transit System (COLTS),	GPS
	Scranton, PA	
130	Luzerne County Transportation Authority, Kingston, PA	GPS
131	Southeastern Pennsylvania Transportation Authority,	DGPS
	Philadelphia, PA	
132	Metropolitan Bus Authority, San Juan, PR	SO, GPS
133	Puerto Rico Highway and Transportation Authority,	OTR
	San Juan, PR	
134	Rhode Island Public TA, Providence, RI	GPS
135	Pee Dee Regional Transportation Authority,	GPS
	Florence, SC	
136	Santee Wateree Regional Transportation Authority,	GPS
	Sumter, SC	
137	Johnson City Transit System, Johnson City, TN	GPS
138	Metropolitan Transit Authority, Nashville, TN	Unspecified
139	Corpus Christi Regional Transportation Authority,	Unspecified
	Corpus Christi, TX	
140	Dallas Area Rapid Transit (DART), Dallas, TX	GPS
141	Metro Transit Authority of Harris County, Houston, TX	Unspecified
142	Sun Metro, El Paso, TX	Unspecified
143	Via Metropolitan Transit, San Antonio, TX	DGPS
144	Blacksburg Transit, Blacksburg, VA	GPS
145	Potomac and Rappahannock Transportation Commission,	GPS
	Woodbridge, VA	
146	Tidewater Transportation District Commission (TTDC),	Unspecified
	Norfolk, VA	
147	Virginia Railway Express, Alexandria, VA	Unspecified
148	Ben Franklin Transit, Richland, WA	GPS
149	King County Metro, Seattle, WA	SO, GPS
150	Kitsap Transit, Bremerton, WA	GPS
151	Spokane Transit Agency, Spokane, WA	GPS
152	Kenosha Transit, Kenosha, WI	GPS
153	Milwaukee County Department of Transportation,	DGPS
	Milwaukee, WI	
154	Sheboygan Transit System, Sheboygan, WI	LC

Appendix B

List of Questions for Phone Interview

- What intelligent transportation system technologies are you using?
- How do you use software in scheduling, dispatching, reservation, real time scheduling, maintenance, vehicle tracking, data transferring etc.? (for example, are the schedules determined manually or by the computer software?)
- How do you find the performance of these systems? (In terms of system effectiveness and cost)
- Does your system offer the facility of dynamic scheduling? (New trip insertion as new requests are made)
- When do you intervene in the system to accommodate changes?
- Do you provide same day services? Within what time period?
- What are the main features of these systems that attract you to use it?
- What do you do at the time of "No Shows"?
- Do you think that with the use of these technologies that ridesharing is increased?
- How do you encourage individuals with disabilities to travel on accessible fixed routes?
- Do you consider the demand of disabled individuals in constructing your routes for fixed bus lines?
- What is your total daily demand?
- What types of training programs would improve your service?
- Do you subcontract the services of individuals with disabilities to private contractors?
- Would you consider integrating your dial-a-ride program with your fixed route service?