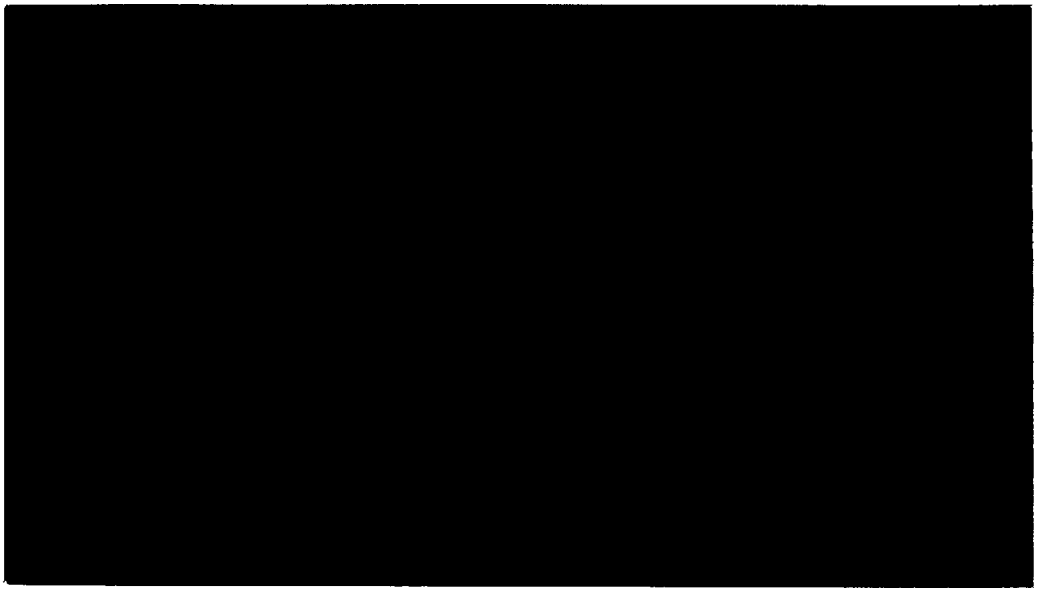

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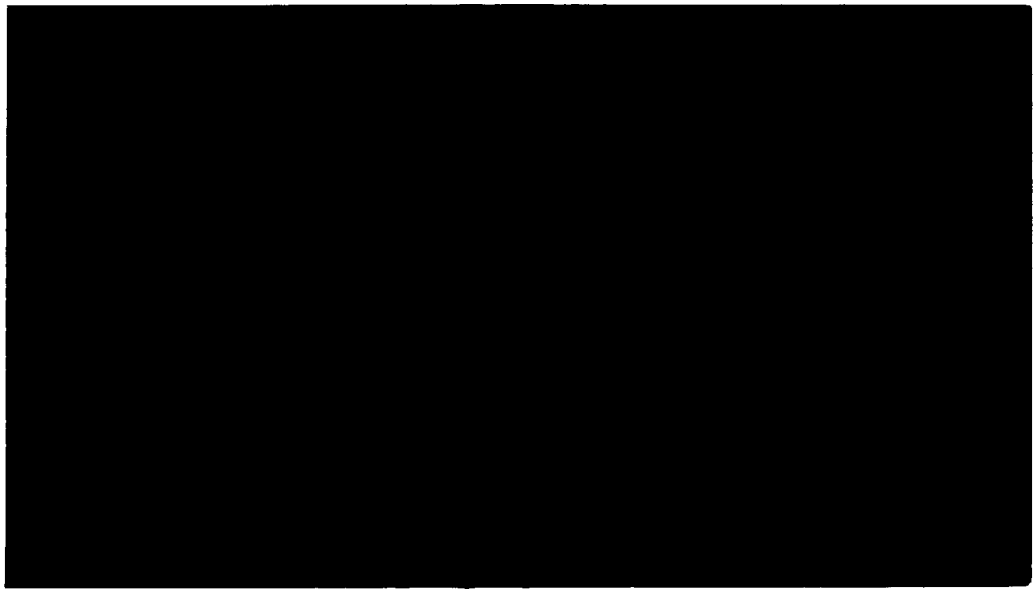

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Advanced Paratransit System: An Application of Digital Map, Automated Vehicle Scheduling and Vehicle Location Systems

T. Chira-Chavala
Christoffel Venter
Geoff Gosling

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16 Abstract

This report documents and evaluates an advanced Paratransit system demonstration project. The Santa Clara Valley Transportation Agency (SCVTA), via OUTREACH, implemented such a system, comprised of an automated trip scheduling system (ATSS) and automated vehicle location (AVL) equipment. The ATSS use resulted in: reduction in the total paratransit operation cost of $0.27 per passenger mile; higher percent shared rides; 28% lower personnel salaries per passenger mile. The user survey revealed that theATSS use resulted in significant productivity gains without degrading tbe service quality to customers. However, the ATSS required higher levels of technical skills; and vehicle deadheading per passenger mile for taxis increased by 13%.

Observed benefits of the AVL system in the first two months of operation include: reduced personnel workload and stress; enhanced operation and management functions; and capability to monitor vehicle on-time performance. Potential longer-term benefits of AVL are also described.

Implications of this demonstration project toward the national APTS objectives include: The ATSS technology is likely to be the conerstone of advanced paratransit systems, and would be particularly useful for large and medium-sized paratransit operations undergoing rapid growth. ATSSs hold promise for coordination and consolidation of paratransit services. Large-scale use of ATSSs would depend on the development of complete and user-friendly system, ability to provide technical assistance to transit agencies to install and operate such systems, and funding. More demonstration projects are needed to derive reliable estimates of tbe benefits under differing conditions.

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PREFACE

This study was conducted with funding from the New Technology, Materials, and Research Division of the California Department of Transportation (Caltrans). The study aimed to document the implementation of advanced paratransit technologies at OUTREACH, and to evaluate their impacts.

Many people contributed to the completion of this report. OUTREACH provided cooperation throughout this study. In particular, Ms. Roberta Gardella, Dr. Katherine Heatley, Mr. William Schwarz, Mr. David Brandauer, and Ms. Pamela Benitez provided information about OUTREACH's paratransit operation as well as various aspects of the new technology implementation and operation. They also facilitated our data collection efforts, including customer surveys and interviews of taxi and van vendors. These individuals and many other staff members of OUTREACH met with the research team many times throughout this study.

Mr. Martin DeNero of the Santa Clara Valley Transportation Authority (SCVTA) provided information about the SCVTA's perspectives on the demonstration project. Mr. Larry Jellison, the Caltrans' project manager, provided information about Caltrans' perspectives on the demonstration project as well as comments on a draft final report.

Managers and drivers of GreyLines, Industrial Passengers, MV Transportation, United Cab, Alpha Cab, and Yellow Cab, who are transportation contractors of OUTREACH, provided information about their perspectives on the use of these advanced paratransit technologies.

Ms. Susan Proctor conducted customer telephone interview surveys. In addition, Mr Charles Dedmon and Abner Gallardo assisted in data collection and analysis.

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EXECUTIVE SUMMARY

INTRODUCTION

The Santa Clara Valley Transportation Agency (SCVTA) is responsible for providing door-to-door paratransit service to the county's disabled persons, in accordance with the 1990 Americans with Disabilities Act (ADA). The SCVTA selected OUTREACH as its paratransit service broker to conduct eligibility screening, contract with taxi and van companies (termed "vendors") to provide rides, take ride requests and reservations, dispatch ride requests to vendors, and monitor service quality.

OUTREACH implemented an advanced paratransit system, which automates vehicle scheduling and trip reservations, monitors service quality, and performs accounting and reporting tasks. It consists of three advanced technologies: a digital geographical database (DGD), automated trip scheduling system (ATSS), and automated vehicle location (AVL) equipment. The DGD and the ATSS were implemented in February 1995; the AVL equipment became operational on 40 accessible vans in June 1996. The California Department of Transportation (Caltrans) sponsored this demonstration project.

FUNCTIONS OF COMPONENT TECHNOLOGIES

The DGD displays maps of the OUTREACH service area to OUTREACH

telephone schedulers (who book trips on-line) on computer screens. It also provides a means to display the position of vehicles determined by the AVL equipment.

The ATSS takes individual client trip requests and assigns them to available vehicles, by maximizing shared rides and minimizing vehicle circuity and deadheading. It then prepares the itineraries for each vehicle for each day.

The AVL equipment determines the position of the vehicle on a continuous basis, which is then transmitted to a base station. Messages are also transmitted from the base station to the vehicle, and are displayed on a vehicle unit. The messages between the base station and the vehicle are stored at the base station and displayed by OUTREACH. The position and vehicle status information is used by the ATSS software.

Concurrent with the demonstration project, OUTREACH also instituted several policy and operational changes; for example: expansion of the service area from seven to 15 cities; gradual elimination of the trip limit allowed per person; and changes in the fare structure and rate. In addition, OUTREACH also requires the vendors to provide vehicles to serve OUTREACH's clients exclusively (i.e., "dedicated" vehicles) after the ATSS became operational.

STUDY OBJECTIVES

The objectives of this evaluation study are to: evaluate the impacts of the advanced paratransit system on OUTREACH's

paratransit operation; assemble a knowledge base to serve as a bridge between an operational test and the understanding of its impacts and effectiveness for other locales; develop insight into how such systems may contribute to the national advanced public transportation systems (APTS) objectives.

PRINCIPAL FINDINGS

Cost and Productivity Impacts of ATSS

(a) It would have been very difficult for OUTREACH to accommodate rapid increases in the paratransit demand, which began in 1993, without this advanced paratransit system, as the old manual scheduling system had already reached its operating capacity.

(b) The capital cost of the ATSS was $310,105. The annualized capital cost of the ATSS was $0.03 per passenger mile (assuming seven years of service life and a discount rate of 5%).

(c) There were estimated annual savings in the total cost of $488,325 to OUTREACH during the first year of ATSS operation (compared with if the ATSS had not been deployed). This represents estimated savings of $1.53 per passenger trip, or $0.27 per passenger mile. OUTREACH was able to achieve this benefit without degrading the customer service quality.

(d) OUTREACH achieved substantially higher percent shared rides during the first year of the ATSS use than during the period before the ATSS use.

(e) On a per passenger mile basis, total OUTREACH personnel

salaries decreased by 28% during the first year of ATSS operation (compared with a period prior to the ATSS). However, OUTREACH had to reorganize its personnel resources because the new system required a higher level of technical skills, eliminated many functions and added many new ones.

(f) There was a 13% increase in vehicle deadheading per passenger mile for taxis during the first year of ATSS operation, relative to a period prior to the ATSS.

Costs and Benefits of AVL

(g) The capital costs of the AVL system was $473,805, which included components installed inside 40 vans, at OUTREACH, and at the three van vendors' sites.

(h) The benefits of the AVL system during the first two months of operation include:

- The AVL reduces the need for OUTREACH's personnel to telephone the van vendors about any changes on the day of service. It also enables OUTREACH personnel to deal with clients' queries more easily and speedily.
- Real-time AVL data support and enhance OUTREACH's day-to-day operation and management functions.
- AVL data enable OUTREACH to more easily and accurately monitor vehicle on-time performance than before.

(i) In the longer term, more substantial benefits of the AVL system than those seen during the initial 2-3 months of operation are possible, when OUTREACH and the vendors develop and implement

action plans to utilize the real-time information from the AVL system to its full potential; for example:

- Real-time vehicle status and location information can be used to schedule open-return trips in real-time.
- OUTREACH can utilize real-time information from the AVL system to create a multi-modal, timed-transfer transit service, in which some paratransit clients who travel long distances could connect with the light rail system as well as fixed-route buses.
- OUTREACH could implement action plans to improve vehicle schedule adherence in real-time.

Users' Perceptions

Surveys of OUTREACH clients indicate that:

(j) Clients, on average, perceived improvement in the following service attributes in the after-ATSS period relative to the before-ATSS period: vehicle on-time performance, in-vehicle ride comfort, and ease of trip booking. This was despite the fact that the survey in the after-ATSS period occurred at the time when the ATSS was still undergoing numerous modifications, and that the vendors were still adjusting to new ways of providing service to OUTREACH's clients. Such client perceptions in the after-ATSS period were likely to be influenced by the ATSS use as well as several other policy and operational changes instituted by OUTREACH. Although it was not possible to separate the effect of one from the others, it is clear that the ATSS has enabled OUTREACH

to achieve productivity gains without clients perceiving degradation in service quality.

Problems Encountered and Lessons Learned

(k) Emulation of proven software on a different platform, and integrating it with existing in-house software, could be difficult and costly for a paratransit agency.

(1) In implementing advanced paratransit systems, the agency needs to have flexibility in reallocating capital expenditures among component technologies as necessary, while staying within the overall budget.

(m) The ATSS software purchased by OUTREACH from the manufacturers lacks flexibility for inexpensive software modifications, due to the current manufacture and product specific design. This led to substantial additional costs for OUTREACH every time the software needed modification.

(n) Unforeseen expenses could occur during the installation, testing, and initial operation of the new system. Budgets for implementing advanced paratransit systems should include adequate funds for project management and technical staff.

(o) The level of technical skills required is far more than any one technical person could ever handle. There needs to be adequate budget to assemble a team of technical persons with appropriate expertise to work on the project. The team leader should have good technical background with some management skills in order to coordinate team members' work.

(p) The transit agency needs to have adequate expertise and manpower to develop critical check-lists at the outset to: assure smooth operation of the new system; anticipate problems that might occur during implementation; and evaluate other alternative system options.

(q) Transit agencies should select hardware with higher capacity than the required minimum, to assure satisfactory system performance and speed under real-world conditions.

(r) The AVL vehicle unit must be shielded from intense sunlight to avoid equipment malfunctions.

Perceptions of Participants

(s) The SCVTA believed that the ATSS is the cornerstone of the advanced paratransit system, and that the ATSS was a worthwhile investment. OUTREACH considered the demonstration project to have achieved most of its goals, and that automation of paratransit planning and scheduling functions is criticalto accommodating both the trip-volume increase and operations in the new cities. OUTREACH is happy with the reliability of the products.

Caltrans considered this project to be a successful demonstration of untried APTS technologies. Caltrans believed that the partnership between the state, local government, transit operators, and the private sector is essential in initiating, planning, implementing, and operating this and other APTSs.

The van vendors like the ATSS because it makes their task of providing rides to OUTREACH's clients easier, reduces dispatcher-

hours, and improves driver efficiency. The taxi vendors stated that they prefer operation under the old system to that under the ATSS. They felt that the ATSS plus the dedicated vehicle requirement have resulted in loss of income for taxi drivers.

Implications to National APTS Objectives

(t) Full automation of vehicle scheduling and trip reservation functions that utilizes technologies such as the ATSS can help paratransit agencies to increase the percent shared rides and achieve efficient utilization of vehicle and driver resources. This contribution of ATSSs is particularly important for large and medium-sized paratransit operations that are undergoing rapid growth in paratransit demand and ridership. The benefits may vary from agency to agency, depending on other policies that the agency concurrently implement with an ATSS. Guidelines or "road maps" should be developed to help paratransit agencies to maximize the potential benefits of the ATSS technology.

(u) ATSSs can be configured to meet the needs of any paratransit agencies regardless of the ride volume and size of the coverage area. Therefore, the technology holds promise for facilitating coordination and consolidation of paratransit services, among various cities within the same county as well as among counties.

(v) Large-scale use of ATSSs is likely to depend on a number of factors, including: availability of complete and user-friendly ATSSs; technical assistance to install and operate such systems;

and funding. The Federal and state governments should encourage and provide incentives for demonstration projects of the ATSS technology in various locales and under differing conditions. This would help to accelerate the development of next-generation, user-friendly ATSSs, as well as to advance the ATSS use toward a critical mass. Further, more demonstration projects are needed to derive reliable estimates of the benefits of the ATSS technology under differing conditions.

(w) The ATSS technology is likely to be the cornerstone of advanced paratransit systems. Automatic vehicle location (AVL) technology, when used together with the ATSS technology, have the potential to further enhance the ATSS performance and the productivity of paratransit operations,

CHAPTER ONE

INTRODUCTION

The Santa Clara Valley Transportation Authority (SCVTA) is responsible for providing door-to-door paratransit service to disabled persons within the county since 1992. The SCVTA plans to comply with 21 requirements (Table 1.1) of the 1990 Americans with Disabilities Act (ADA) by 1997. Essentially, the ADA requires the agency to make available paratransit service to eligible disabled persons for an unrestricted number of rides per month, and during the same hours as the fixed-route transit systems.

The SCVTA has selected OUTREACH Inc. (a private non-profit organization) as its paratransit service broker. OUTREACH is responsible for the following functions: conducting eligibility screening; contracting with taxi and van companies to provide rides; taking ride requests and reservations; administering passenger accounts and collecting fares; dispatching ride requests to contractors; and monitoring service quality. OUTREACH has contracted with several taxi and van companies (termed vendors) within the county to provide door-to-door transportation service to clients. OUTREACH pays the vendors for service rendered, and SCVTA in turn reimburses OUTREACH for these and other related expenditures.

TABLE 1.1 TIMETABLE FOR OUTREACH'S COMPLIANCE WITH ADA REQUIREMENTS

ADA REQUIREMENT	DATE COMPLIED
CLIENT ELIGIBILITY PROCESS	
1. OUTREACH accepts and processes clients' requests for eligibility certification	January 1994
2. Companions and personal care attendants can accompany OUTREACH clients	July 1993
3. Visitors to the area can obtain temporary access to paratransit service	July 1993
SERVICE AREA	
4. OUTREACH provides service to all origins and destinations within defined service area	July 1996
5. OUTREACH coordinates service with adjacent counties	January 1997*
RESPONSE TIME CRITERIA	
6. OUTREACH accepts trip requests during normal business hours, on "next day" basis	December 1993
7. OUTREACH accepts trip requests on weekends and holidays	December 1993
8. OUTREACH accepts trip requests at least 14 days in advance	December 1993
9. OUTREACH schedules trips within one hour of requested time	December 1993
FARE CRITERIA	
10. Client fare no more than twice the fixed-route fare	July 1994
11. Companion fare no more than twice the fixed-route fare	July 1994
12. Personal attendant is charged no fare	July 1994
DAYS AND HOURS OF SERVICE	
13. Paratransit provided during all days and hours when fixed route is in operation	July 1996
TRIP PURPOSES CRITERIA	
14. No restrictions on types of trip purposes	January 1997*
15. No prioritization by trip purpose when scheduling trip requests	January 1997*

TABLE 1.1 **TIMETABLE FOR OUTREACH'S COMPLIANCE WITH ADA REQUIREMENTS (continued)**

ADA REQUIREMENT	DATE COMPLIED
CAPACITY CONSTRAINT CRITERIA	
16. No restrictions on the number of trips an individual is provided	January 1997*
17. No waiting lists for eligibility or trip scheduling	July 1993
18. No substantial numbers of significantly untimely pickups for initial or return trips	July 1993
19. No substantial number of trip denials or missed trips	July 1993
20. No substantial number of trips with excessive trip lengths	July 1993
21. When capacity is unavailable, subscription trips are less than 50 percent	July 1993

Note: * Projected date of compliance, as per 1996 ADA Paratransit Plan Update.

Taxi vendors use regular taxi vehicles (without wheelchair lifts) to provide service exclusively for ambulatory users, or wheelchair users who are able to transfer to a car seat. The van vendors use vehicles that can carry wheelchairs, and include:

Accessible Van Service. This uses large vehicles, capable of carrying 2 to 4 wheelchairs. Most wheelchair-bound clients were transported by accessible vans up to August 1995. Accessible van service is generally more expensive than taxi service because it uses more specialized vehicles, and van drivers provide more help to passengers (e.g. operating wheelchair lifts).

Group Van Service. This uses similar vehicles as accessible van service, but is operated under contract with social agencies to transport groups of clients, who may be ambulatory or wheelchair users. The use of bigger vehicles also makes the group van service more expensive than taxis.

Mixed Van Service. This was introduced in August 1995, and by March 1996 has replaced the accessible van service. This service utilizes the same wheelchair accessible vehicles for transporting both ambulatory and wheelchair passengers, but most of the vehicles are minivans instead of full-sized vans. At the present time, more than half of OUTREACH's total rides are by minivans.

SERVICE EXPANSION

To comply with the ADA requirements, the SCVTA had to expand its paratransit service very significantly since 1993. This

included expansion of both the service area and service hours, reduction of reservation lead time from 48 hours to previous day, and gradual removal of the limit in the number of trips that eligible persons are allowed per month. Such expansion has led to sharp increases in the paratransitdemand and ridership, as evident by increases in the number of active users, frequency of use, and length of trips. Of the estimated 56,000 ADA eligible riders in the county, OUTREACH served about 3,000 in 1993. Projected riders is expected to increase to 10,000 by 1997, and the number of annual trips from 300,000 in 1993 to 890,000 by 1997.

ADVANCED PARATRANSIT SYSTEM DEMONSTRATION PROJECT

Both the SCVTA and OUTREACH had, at the outset, anticipated rapid ridership growth as a result of the ADA's requirements. To position itself to meet this anticipated growth in time of declining transit operating budgets, and to assure smooth operation in the new service area, OUTREACH began to formulate a plan to implement a "smart" or advanced paratransit system in 1993. This system would automate various day-to-day functions of the paratransit operation, particularly the assignment of passenger trips to vehicles to maximize shared rides, vehicle scheduling, monitoring of service quality, and accounting and reporting tasks. During the initial planning stage, OUTREACH stated that the primary goals for implementing an advanced paratransit system were to:

1. *Maximize shared rides and optimize efficient route selection.*

2. *Automate vehicle resource* allocation *to accommodate special needs (e.g., placing a certain style wheelchair on the vehicle type that will accommodate it) for efficient route planning.*
3. *Reduce route processing* time, *from tasks requiring eight hours of staff time to* tasks *accomplished by automation in minutes.*
4. *Make real-time* changes *to vehicle routes to accommodate schedule revisions either additions or deletions, which would result in more efficient use of driver/vehicle time, improved client service, and reduced costs.*
5. *Integrate fixed-route public transit system with paratransit trips, the goal of which is to provide 10-20% of total trips as inter-modal.*
6. *Reduce 48-hour response time to "next day" response time.*
7. *Accurately account for miles traveled by vehicles.*
8. *Reduce vehicle deadhead of van and taxi operations, as well as through integrated use of inter-modal connections.*
9. *Improve on-time rides and customer ratings of satisfaction with the service.*

The OUTREACH's advanced paratransit system consists of three related advanced technologies: a digital geographical database (DGD) automated trip scheduling system (ATSS), and automated vehicle location (AVL) equipment. The demonstration project was implemented in an incremental manner, with capital assistance from

the California Department of Transportation (Caltrans). First, the DGD and the ATSS were installed and became operational in February 1995. Then, the AVL equipment was installed on 40 accessible vans and became operational in June 1996. In this report, the installations of the DGD and ATSS are referred to as Phase 1, and that of the AVL equipment as Phase 2. Please note that OUTREACH's own documentation refers to each installation of the DGD, ATSS, and AVL equipment as Phases 1, 2, and 3, respectively.

The actual implementation of these technologies differed slightly from the above original goals of OUTREACH. In 1995, OUTREACH sought and received approval from Caltrans not to install AVL equipment on a small number of fixed-route buses as originally proposed. Further, after the AVL installation on about 40 vans was completed in June 1996, OUTREACH was not ready to implement inter-modal trips (i.e., linking paratransit trips to the fixed-route system) during this evaluation period. Therefore, the above original goal #5 was not applicable to this evaluation study.

MILESTONES

About the time when the advanced paratransit system demonstration project was under way, the SCVTA and OUTREACH instituted several policy changes, most of which were aimed to facilitate full ADA compliance by 1997. These policy changes are described below. The milestones for these policy changes as well as the demonstration project activities are shown in Figure 1.1.

FIGURE 1.1 TIMETLINE OF OUTREACH POLICY CHANGES AND APTS IMPLENTATION MILESTONES, 1993-1996

1993	August	- OUTREACH designated as SCCTD's ADA paratransit broker
	December	• Previous day reservation available to all users
1994	April	• OUTREACH stopped providing same-day service
	May	• Before-ATSS period user interviews conducted
	July	• North County cities added to OUTREACH's service area • Fare changed from distance-based to flat $1.50 fare
	September	• OUTREACH installed new telephone system
	October	- Allowable vehicle response time for open returns changed from 30 to 60 minutes
	December	- INSTALLATION OF DIGITAL GEOGRAPHIC DATABASE
1995	February	• OUTREACH hired 5 additional telephone schedulers . DEPLOYMENT OF AUTOMATED TRIP SCHEDULING SYSTEM
	April	• Trip limits increased from 16/24, to 24 trips per month for all users
	June	• After-ATSS period user interviews conducted
	July	• Three more cities added to OUTREACH's service area • Fare increased to $2.20 flat fare; companions charged the same fare • OUTREACH required all vendors to serve OUTREACH clients with dedicated vehicles
1996	June	- INSTALLATION OF AUTOMATED VEHICLE LOCATION SYSTEM COMPLETED

Service Area Expansion

In July 1994 (about seven months before the implementation of the ATSS), five new cities in Northern Santa Clara County were added to the original seven cities -- Sunnyvale, Palo Alto, Mountain View, Los Altos, and Los Altos Hills. In July 1995 (about four months after the implementation of the ATSS), three more cities (Los Gatos, Saratoga, Monte Sereno) were added. These 15 cities currently served by OUTREACH are shown in Table 1.2, together with the population within each.

Fare Changes

In July 1994, OUTREACH changed the paratransit fare structure from a distance-based to a flat fare. Prior to this date, users paid between $1.50 and $3.00 per trip depending on the distance travelled. The flat fare after July 1994 was $1.50 per trip. This made the out-of-pocket costs of making longer trips lower, and those for shorter trips essentially unchanged.

In July 1995, the flat fare was raised from $1.50 to $2.20 per one-way trip. Further, companions who travel with OUTREACH clients are also charged the same fare (these individuals traveled free in the past).

Relaxing Limits on Number of Trips

Prior to April 1995, clients could choose one of two service categories. Category A allowed each client 24 one-way trips per month for medical purposes. Category B allowed a client 16 one-way

TABLE 1.2 CITIES SERVED BY OUTREACH PARATRANSIT SYSTEM

CITY	DATE INCORPORATED INTO OUTREACH SERVICE AREA	1990 POPULATION (Source: 1990 Census)
San Jose	**December 1993**	782,248
Santa Clara	**December 1993**	93,613
Cupertino	**December 1993**	40,263
Campbell	**December 1993**	36,048
Milpitas	**December 1993**	50,686
Gilroy	**December 1993**	31,487
Morgan Hill	**December 1993**	23,928
Mountain View	July 1994	67,460
Los Altos	July 1994	26,303
Los Altos Hills	July 1994	7,514
Palo Alto	July 1994	55,900
Sunnyvale	July 1994	117,229
Los Gatos	July 1995	27,357
Monte Sereno	July 1995	3,287
Saratoga	July 1995	28,061
TOTAL SANTA CLARA COUNTY POPULATION		**1,391,384**

trips for other purposes. As of April 1995, these categories were eliminated and each client is allowed 24 trips per month, regardless of the trip purpose. A full compliance with the ADA will require OUTREACH to drop all restrictions on the number of trips an individual is allowed by 1997.

Same-Day Service

Until April 1994, OUTREACH provided same-day service, and same-day trips accounted for about 10% of OUTREACH's trip volume. Since then, same-day service has been virtually eliminated, and clients now have to book rides at least one day before. This includes open return trips (trips to return home where pick-up times are not specified in advance).

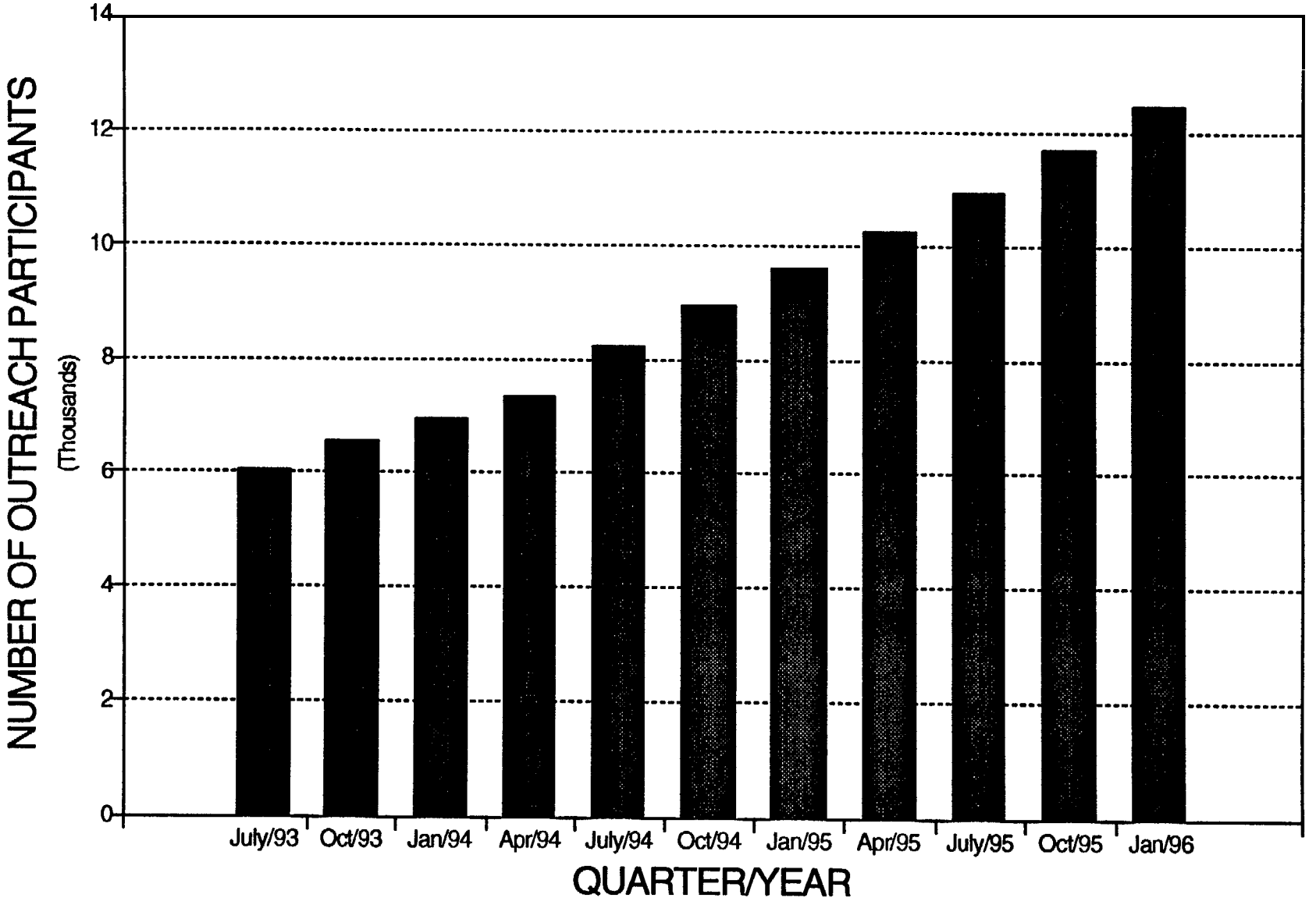
RIDERSHIP PROFILES

The number of OUTREACH passenger trips and passenger miles have steadily and substantially increased since 1993. So have the number of people registering for OUTREACH service, frequency of use of service, and distance travelled by the average client. These are elaborated below.

Number of Registered Clients

Figure 1.2 shows the number of clients registered for OUTREACH service per quarter. The figure indicates that the number of registered clients increased steadily over time. Between July 1993 and March 1996, the number of registered clients doubled from 6,000

FIGURE 1.2
REGISTERED OUTREACH PARTICIPANTS



to more than 12,000 clients. This was due to the expansion of the service area, plus the relaxation of the limit on the number of trips clients can make per month.

Number of Active Clients

Active clients are defined as those who actually take a ride on OUTREACH's system within a particular month. The numbers of monthly active clients for the van and taxi modes, from March 1994 through March 1996, are shown in Figure 1.3. The figure indicates that the total number of active clients increased sharply over time. In July 1994, the number of active clients for the taxi mode increased due to a growth in ambulatory taxi users, brought about by the expansion of the OUTREACH's service area. The growth in active users for the van mode since 1995 was due to OUTREACH's decision to serve most users in the North County service area using "mixed mode" mini vans (instead of taxis). Even though many of these users were ambulatory, they were included under the van mode.

Total Passenger Trips and Passenger Miles

The number of passenger trips and passenger miles per month is shown in Figure 1.4. The number of passenger trips is the number of one-way trips taken by clients per month (excluding trips by care attendants or companions). Passenger miles are the shortest distance between origins and destinations, regardless of the actual route travelled. The figure indicates that both passenger trips and passenger miles increased very substantially over time, as a

FIGURE 1.3
ACTIVE CLIENTS

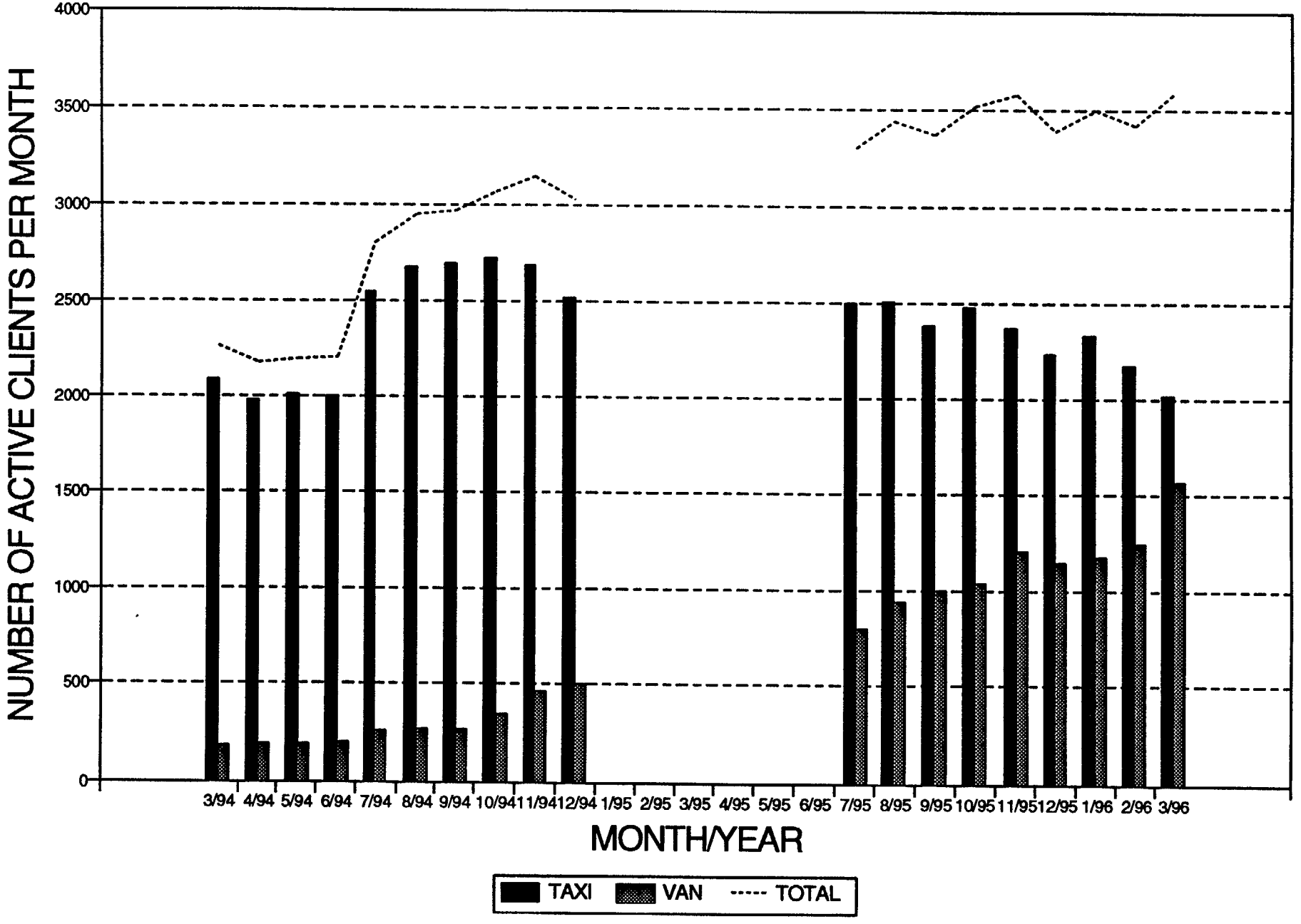
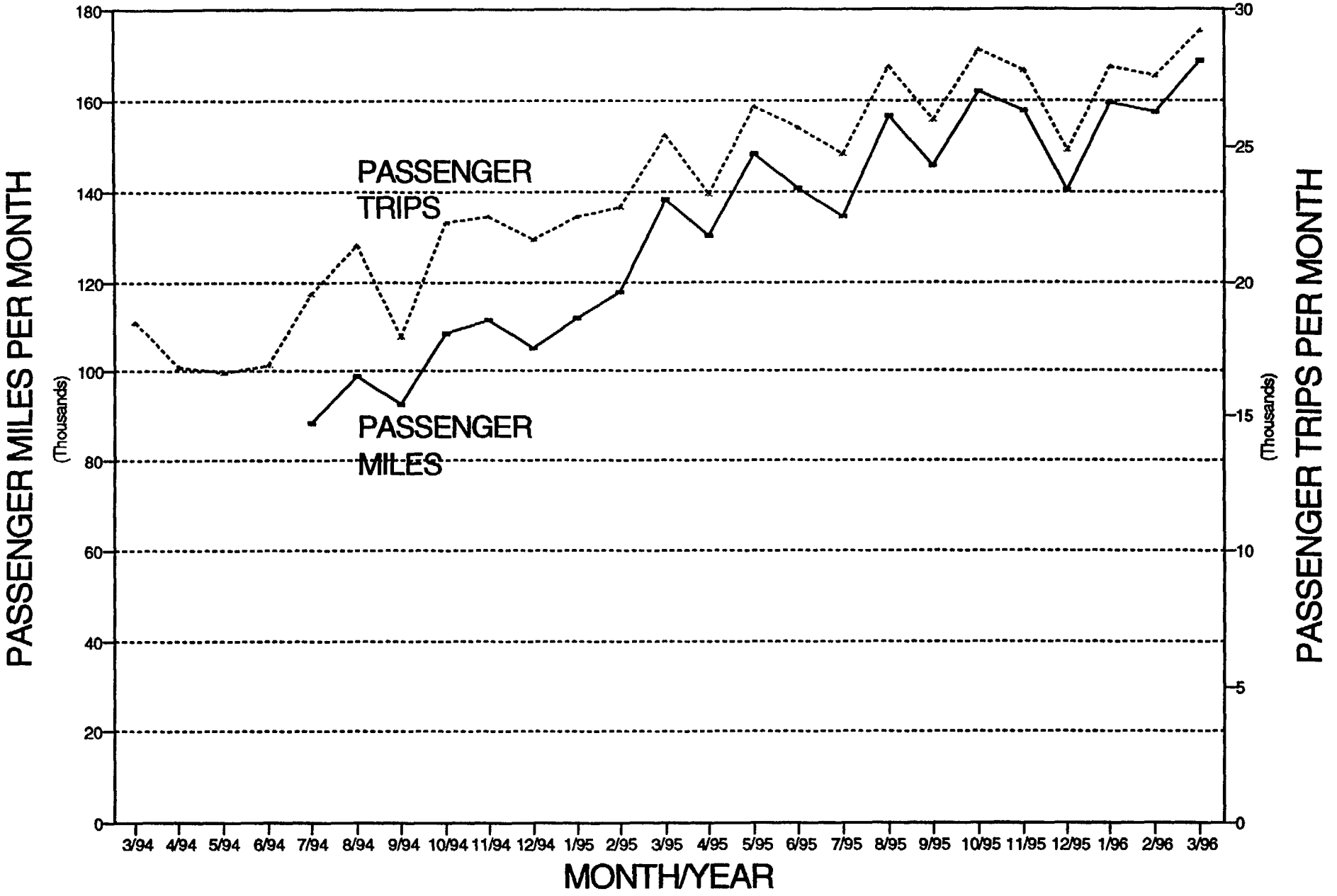


FIGURE 1.4
PASSENGER VOLUME SERVED BY OUTREACH



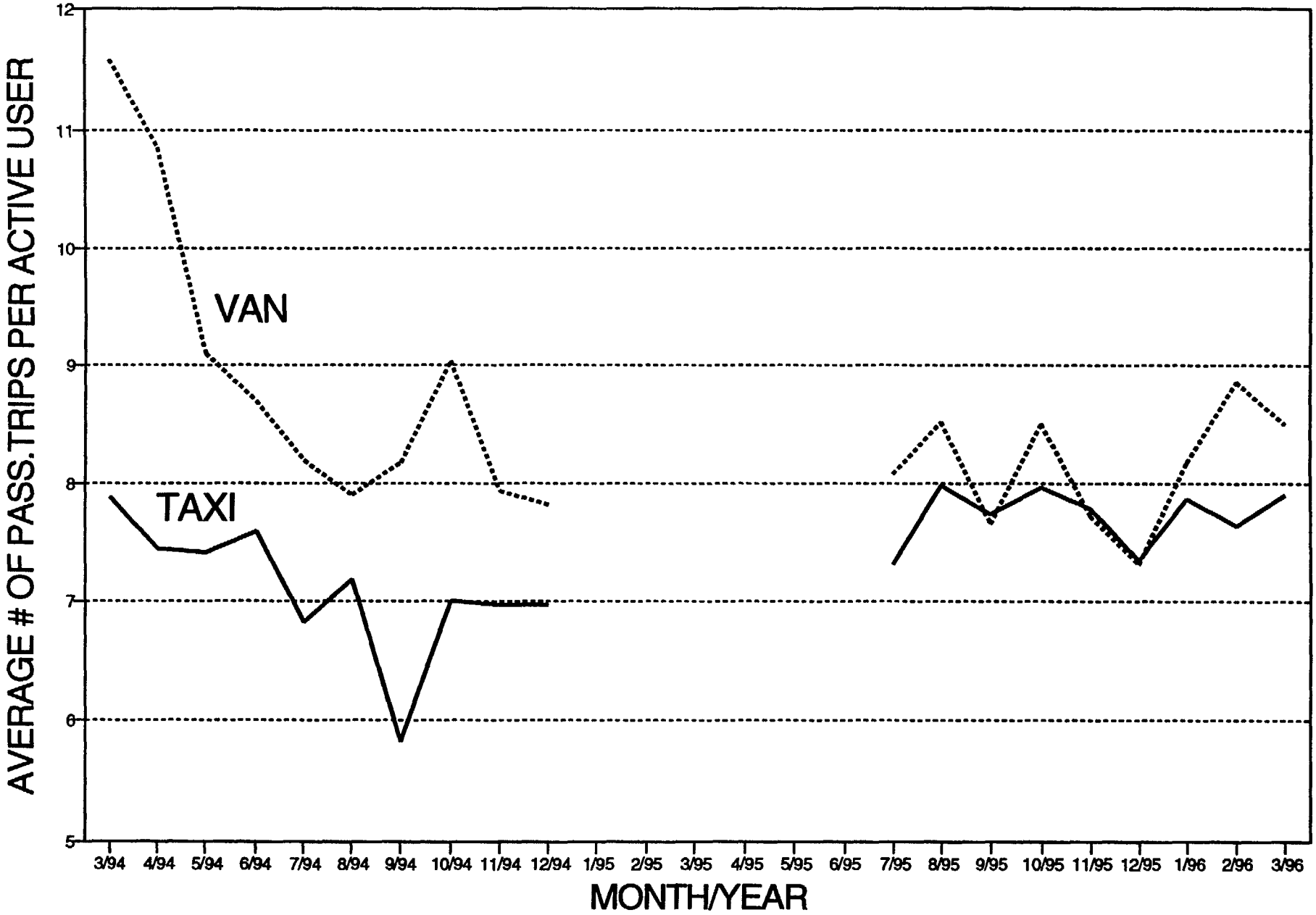
result of changes in the following OUTREACH policies:

- The addition of eight more cities into the OUTREACH service area (in July 1994 and July 1995).
- A reduction in the fare in July 1994, which could have encouraged clients to make more trips than before.
- Relaxing of the limit on the number of trips that clients could make in April 1995.

Trip Rate Per Client

Figure 1.5 shows average monthly trip rates per active client for the taxi and van modes, before and after OUTREACH started relaxing the limit on the number of trips that clients were allowed in April 1995. As expected, average monthly trip rates for taxi users were higher after April 1995 than a period before. The figure also shows that trip rates for taxi and van users after April 1995 were much more similar than those in a period before April 1995. Prior to April 1995, van users represented a relatively small group of clients who took more trips per month than taxi users. At that time, van users included many wheelchair clients whose medical needs required intensive use of the paratransit system (e.g. in order to travel to/from dialysis treatment three times a week). After April 1995, van users became more similar to taxi users. Ambulatory clients in the North County service area became van users, with similar trip rates to the remaining taxi users.

FIGURE 1.5
AVERAGE TRIPRATES OF OUTREACH CLIENTS



Passenger Trip Lengths

Monthly average passenger trip lengths (i.e., total passenger miles divided by total passenger trips) are available from OUTREACH between July 1994 and March 1996 (Figure 1.6). The figure indicates that passenger trip lengths over time for the taxi and van modes exhibit similar trends. The average trip length for all users increased from about 4.6 miles in July 1994 to 5.8 miles in March 1996, probably due to two policy changes -- the adoption of a flat fare in July 1994 (which decreased the out-of-pocket cost of longer passenger trips relative to shorter trips); and the expansion of the service area. Trips with only the origin or destination in the new service area were not possible before, but became possible after the expansion of the service area.

Increased passenger trip lengths imply higher consumption of the paratransit system output. Therefore, total passenger miles are a more appropriate measure than passenger trips in the analysis of the impacts of the OUTREACH's advanced paratransit system in subsequent chapters.

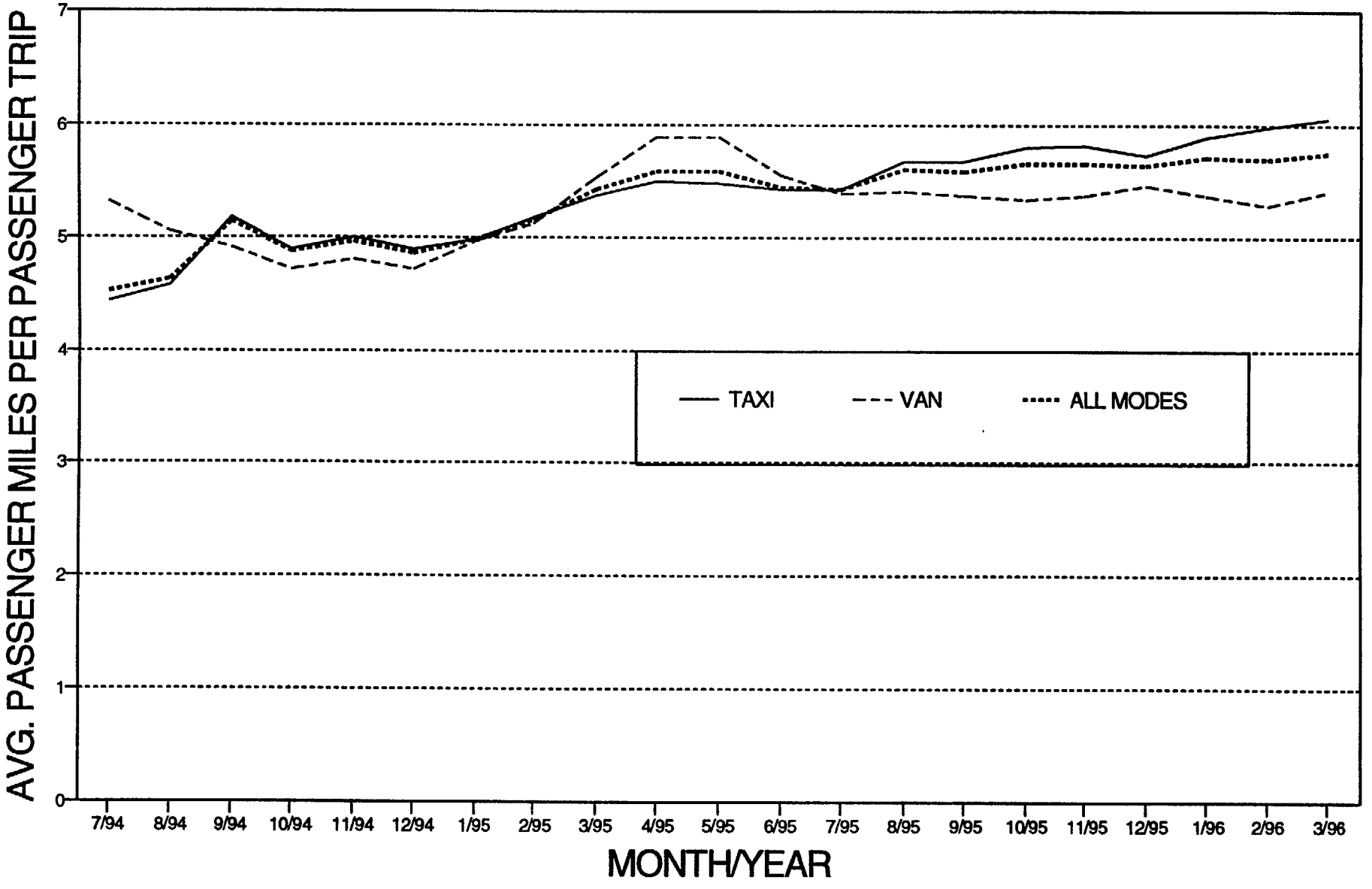
Trip Request Denials

Client trip requests may be denied by OUTREACH for the following reasons:

- Clients request same day service.
- Clients request more trips than are allowed per month.

The number of denied requests is related to OUTREACH's trip policies, and how well clients are aware of these policies. Trip

FIGURE 1.6
AVERAGE PASSENGER TRIP LENGTHS



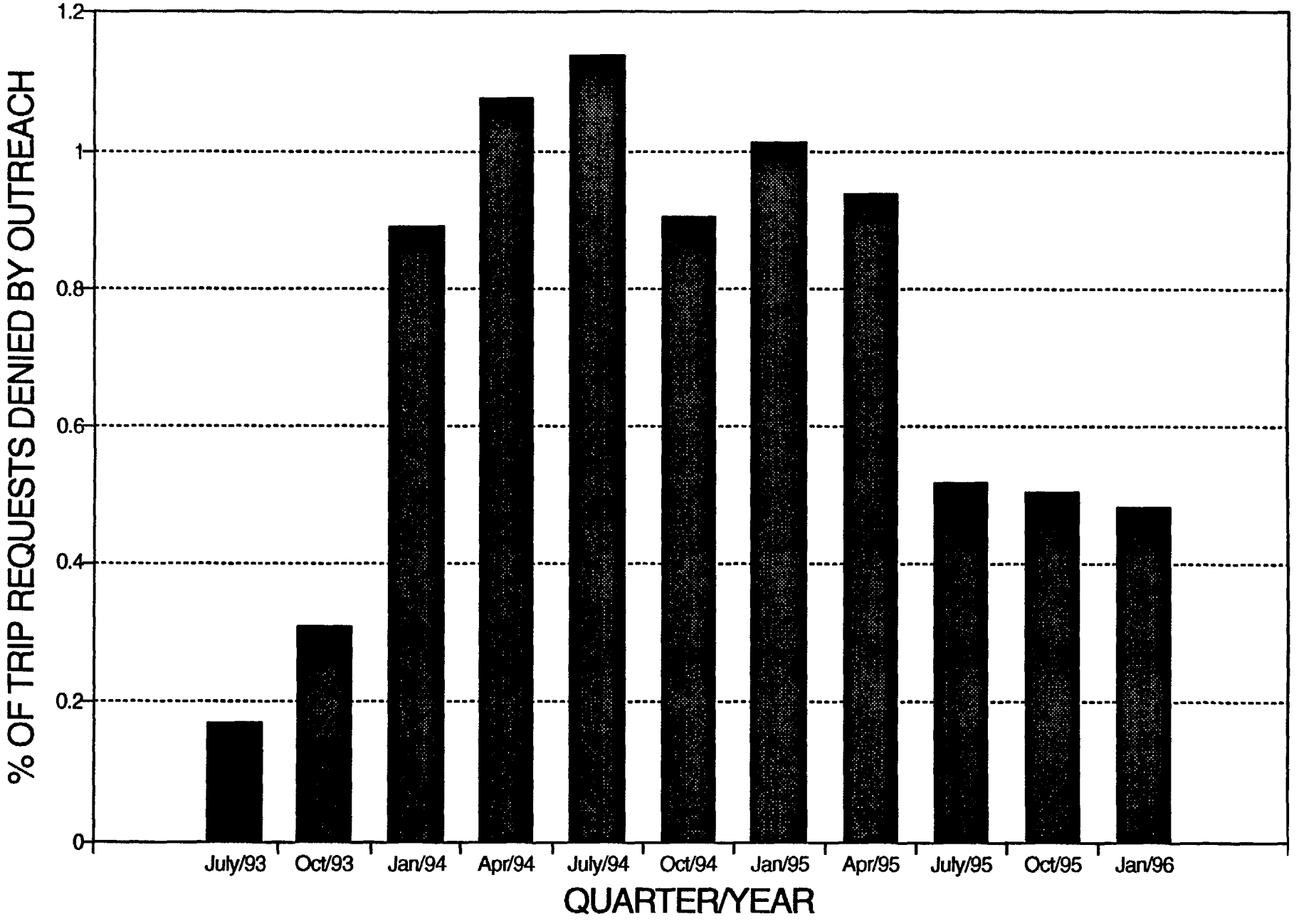
requests have never been denied because of a lack of vehicle capacity. The number of trip denials, expressed as the percent of passenger trips served per quarter, is shown in Figure 1.7. The figure indicates that a very small fraction of requests were denied. A sharp increase in trip denials in the first half of 1994 coincided with OUTREACH's decision to stop providing same-day trips. Trip denials decreased slightly in the last three quarters, corresponding to the raising of the allowed number of trips in April 1995. The trends in trip denials followed OUTREACH policy changes, of which relaxation of the trip limit was probably the most important.

OBJECTIVE OF THIS STUDY

Advanced paratransit systems similar to the one OUTREACH implemented have not been widely implemented; neither is there documentation to guide their implementations or knowledge of their impacts. At Caltrans's request, the University of California at Berkeley conducted this evaluation study aimed to:

- Determine the impacts of the advanced paratransit system on the transit agency and user.
- Assemble a knowledge base to serve as a bridge between an operational test in Santa Clara County and the understanding of its impacts and effectiveness for other locales, as well as to provide an insight into how such systems may contribute to the national advanced public transportation systems (APTS) objectives.

FIGURE 1.7
PERCENT TRIP REQUESTS DENIED



ORGANIZATION OF THIS REPORT

This report is organized into six chapters as follows. Chapter Two presents the implementation process and functionality analysis of the advanced paratransit system. Chapter Three presents the analysis of cost and productivity impacts of the ATSS. Chapter Four presents the user perceptions of service quality based on client surveys. Chapter Five discusses the benefits of the AVL system. Finally, Chapter Six discusses institutional issues in the implementation of the advanced paratransit system, as well as the implications for the national APTS objectives.

CHAPTER TWO

TECHNOLOGY IMPLEMENTATION

This chapter describes the features and functional capabilities of the automated trip scheduling and automated vehicle location technologies implemented by OUTREACH during the demonstration project. It also discusses how these technology components are integrated into OUTREACH's paratransit operations and various issues that arose during their implementations.

The OUTREACH advanced paratransit demonstration project involves the deployment of three related technologies:

* A digital geographic database (DGD).
* An automated trip scheduling system (ATSS).
* Automated vehicle location (AVL) equipment.

The DGD allows maps of the OUTREACH service area to be displayed to OUTREACH telephone schedulers (who answer client calls and book trips on-line) on computer screens. It also provides additional functionality over paper maps (e.g., the ability to vary the display of information and to automate the process of calculating distances or travel times between specific points). The telephone scheduler can vary the scale of the displayed map (zoom in and out) and move the display (termed panning) to show

different parts of the service area. Different parts of the map can be displayed in different windows on the computer screen at the same time, and the scheduler can quickly move between the windows. The information on the digital map is stored in layers, which the user has the ability to display selectively to tailor the level of detail to the scale of the display.

In addition to display capabilities, the DGD supports the geocoding of addresses into position coordinates (latitude and longitude). This forms an essential step in the operation of the ATSS software. Finally, the DGD provides a means to display the position of vehicles determined by the AVL equipment.

The ATSS software takes individual client trip requests as they are received by the OUTREACH telephone schedulers and assigns them to available vehicles. This is accomplished by combining multiple riders into a single vehicle trip where practical while reducing circuity and deadheading as much as possible. This function, called building "multiples" (i.e., shared rides), replaces the manual process that was formerly in place prior to the demonstration project. The automation of this multiple building task is intended to improve the efficiency of forming shared rides, as well as to provide the system with the ability to react to changes in trip requests (e.g., canceled trips or late requests) and readjust the allocation of vehicles to clients in near real-time. The way in which these functions are performed is discussed in more detail below.

The AVL equipment is based upon the use of global positioning

system (GPS) receivers in each equipped vehicle. These receivers determine the position (latitude and longitude) of the vehicle on a continuous basis, using signals transmitted by satellites. The vehicle position is then transmitted to a base station by a data radio link. The data radio link also has the capability of transmitting messages from the base station to the vehicle, which can be displayed to the vehicle driver on a unit installed on the vehicle. The base station operator can select predefined messages to send to the vehicle or can type any desired text message. The driver can also send a number of predefined messages to the base station, including acknowledging the receipt of a message, but does not have the ability to send variable messages. The messages between the base station and each vehicle are stored at the base station and can be displayed by OUTREACH.

In addition to the ability to track the location of each equipped vehicle and display it on a digital map, the position and vehicle status information derived from the AVL and driver messages are stored in a database that is used by the ATSS software.

SYSTEM IMPLEMENTATION

The three technology components of the advanced paratransit system were implemented in two phases. During Phase 1, which was completed in February 1995, the DGD was installed on OUTREACH computers, the computer system was upgraded with additional equipment, and the ATSS software was implemented on this new

system.[1]

Phase 2 commenced in March 1996 and involved installing AVL equipment on 40 accessible vans used to provide OUTREACH services.[2] The AVL system became operational in June 1996. It allows the ATSS software to track the locations of the AVL equipped vehicles in real time, and update the vehicle trip plan displays as drivers complete each pick-up or drop-off.

Features and Functional Capabilities

The features and functional capabilities of the three technologies implemented under the two phases of the demonstration project are described below.

Digital Geographic Database (DGD)

The DGD provides a computer-generated map of the OUTREACH service area, with supporting data files that include the street address range for each street segment (block). This allows the geocoding of any address, by first locating the street segment on which it lies, and then estimating its geographical coordinates from the coordinates of the two ends of the segment and the address range of the segment. The geocoding algorithm assumes that the addresses in the segment are uniformly distributed between the

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[1] This first phase corresponds to Phases I and II of the Caltrans demonstration project contract.

[2] This phase corresponds to Phase III of the Caltrans demonstration project contract.

segment ends. While not usually correct in practice, the errors thereby introduced are not large (typically only a small percentage of the block length), and do not affect the routing of a vehicle (since it has to traverse the block to reach the address).

The DGD replaced the use of printed maps and offers several features that are not possible with printed maps. The capability of adjusting the scale of the computer-generated map display (zooming) allows the user to work at whatever scale is more appropriate for the issue at hand, whether showing an overview of the region or a detailed view of individual street segments. This is a lot more convenient than working with large-scale printed maps, which must either be physically very large, and thus awkward to handle, or spread over many pages, which makes finding any particular street cumbersome. Displaying the map directly on their computer screens saves the telephone schedulers having to work with a separate document (or stand-alone computer system), and facilitates the integration of map-related tasks into the work flow. Finally the geocoding capability allows the system to automatically locate addresses and display the relevant area of the map, thus greatly simplifying the task of locating pick-up and drop-off addresses.

The DGD is also used by schedule analysis staff to identify pick-up and drop-off locations on a vehicle itinerary or to calculate distances to determine vendor payments.

The DGD was donated by Navigation Technologies (NavTech) together with annual maintenance support. The NavTech database

contains city and street names, address ranges for each block, and traffic flow characteristics, such as capacity, speed limit, traffic signals and turn restrictions. It also includes information on major facilities, such as hospitals, government buildings, schools and transit terminals. Coordinates are stored to a precision of l/100,000 of a degree, or about 3.5 feet.

The database is based on the U.S. Geological Survey 7.5 minute quadrangle sheets, updated and extended with information from aerial photography, local base maps, data collected by the American Automobile Association, the U.S. Postal Service zip code tapes, state, county and municipal sources, and NavTech's own field work. The database is continually updated as new information becomes available. The DGD provided by NavTech covers Santa Clara County and the adjacent counties within the OUTREACH service area.

Automated Trip Scheduling System (ATSS)

The ATSS software takes each passenger trip request and identifies how this can be assigned to a specific vehicle in a way that uses the vehicles most efficiently, while maximizing the amount of ride-sharing. This process must also respect any constraints imposed by client requirements (e.g., the need to accommodate a wheel-chair or appointment times) and service standards defined by OUTREACH, such as the maximum amount of time that a client should spend on a vehicle for a trip of a given length. It must also reflect the time required to drive from location to location, and to load and unload passengers.

The result of this process is a list of vehicle itineraries, indicating pick-up and drop-off locations in sequence and associated times. The manual process formerly in place relied heavily on the ability of OUTREACH personnel to recognize potential trips that could be combined into multiples, as well as on their knowledge of the region and their ability to estimate vehicle travel times. Such a manual process was also time-consuming.

The development of computer algorithms to automate this process is a classical problem in operations research, and has been extensively studied. These algorithms use optimization routines to seek a near-optimal allocation of passenger trips to vehicles. Their ability to do this is limited only by the complexity of the problem and the time available to perform many required iterations.

In the current application, the problem is complicated by the need to advise OUTREACH clients of their pick-up times when they make their trip reservation. Thus the allocation of rides to vehicles is made as each trip request is received, without knowing anything about ride requests that are yet to be made. This is likely to result in a very different allocation of rides to vehicles than what would result from first recording all the trip requests for a given day, then grouping trips together into multiples, and then leaving it up to the vendors to allocate these rides to vehicles, as was done with the previous manual process.

For OUTREACH, the application of the ATSS was further complicated by the fact that the vehicles are provided by many different vendors who are responsible for dispatching their own

vehicles. During the initial months of ATSS deployment, OUTREACH provided the vehicle itineraries for each day to the vendors on computer print-outs the previous evening. By early 1996, a computer system and printer had been established at each vendor, and OUTREACH now transmits vehicle itinerary files by telephone modem to be printed at the vendor site.

System Hardware. Prior to the start of the advanced paratransit demonstration project, OUTREACH had made the decision to upgrade its computer system from an IBM System/36 to an IBM AS/400. The latter was acquired with another funding source, and was not part of the demonstration project. By the start of the demonstration project, conversion of the existing computer software (called the Integrated Paratransit Business System, IPBS) to the new AS/400 computer was well underway. The advanced paratransit demonstration project included some additional equipment and personnel resources to fully implement the IPBS and integrate the DGD and ATSS software.

The DGD was initially installed on the AS/400 computer. However, it was found to be difficult for the ATSS software to access the AS/400 in real time, so the DGD was also installed on the Novell file server (a Compaq Proliant 2000) supporting the Ethernet local area network. Thus beyond the system integration tasks already mentioned, this component of the system required no further hardware. The ATSS software, discussed in more detail below, operates under the DOS operating system, and was installed on a Hewlett Packard Pentium 60 personal computer operating as a

client server, connected to the rest of the OUTREACH system through an Ethernet local area network. The client/server architecture allows any of the workstations attached to the OUTREACH network to send requests to the ATSS server to perform trip assignment tasks. In turn, the ATSS server exchanges passenger trip and client information with the AS/400.

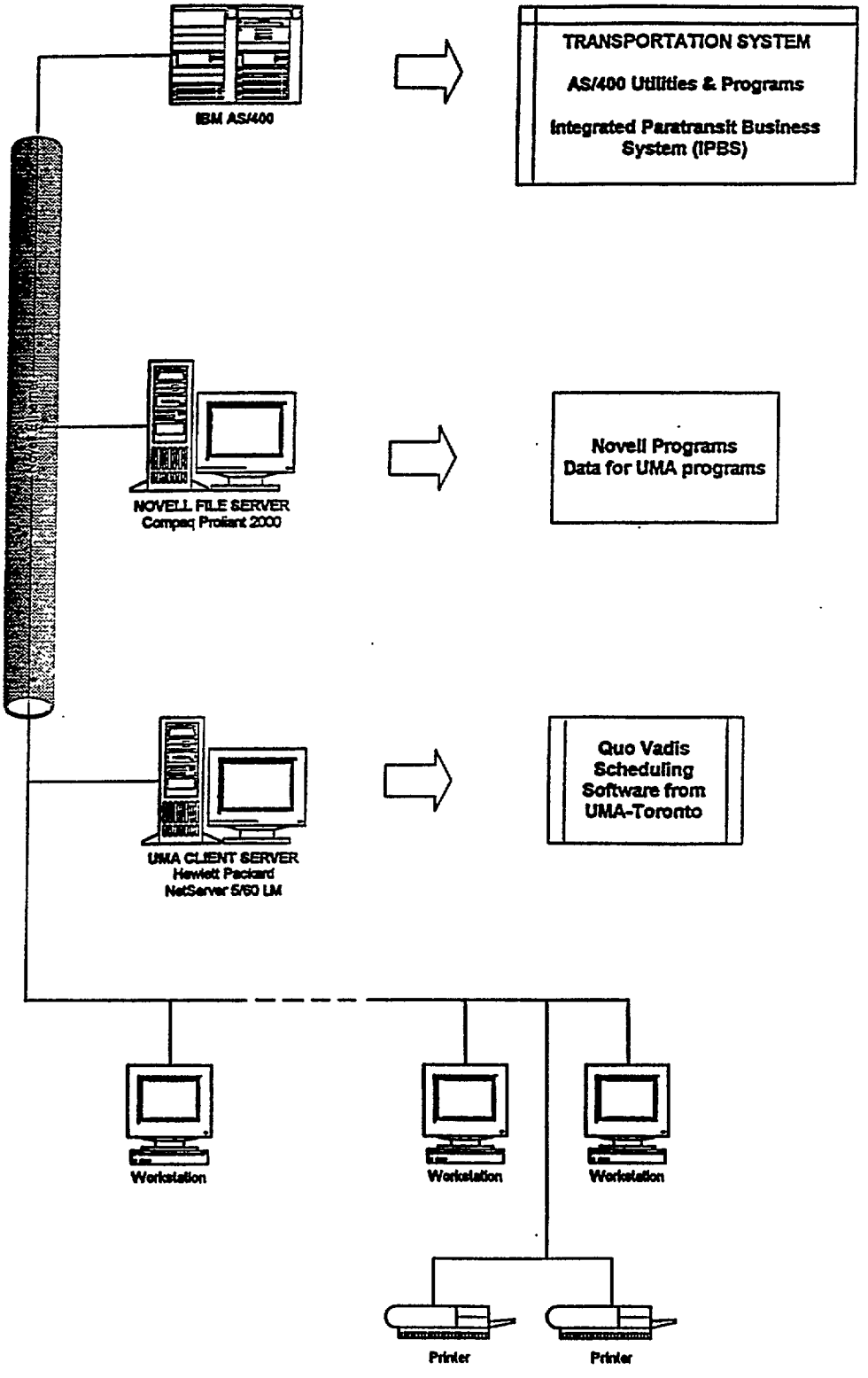
The overall system architecture at the end of Phase 1 of the demonstration project is shown in Figure 2.1.

Software. The ATSS software consisted of the Quo Vadis paratransit software modules from UMA Engineering (later renamed Trapeze Software), which perform both trip reservation and ride scheduling functions. The reservation function involves entering the client identification and the trip details -- date, times, pick-up and drop-off locations, and companion riders. The client database is checked for eligibility and any special requirements (e.g., whether the client uses a wheelchair or is blind).

The ride scheduling function then inserts these rides into a sequence of pick-ups and drop-offs for a given vehicle on a given day. Since drivers in the OUTREACH program are required to know the local street system, it is not necessary to provide actual driving directions from place to place. The ATSS software assigns clients to vehicles in a way that attempts to minimize the vehicle cost while generating acceptable client pick-up and drop-off times and respecting special client needs. This is achieved by assigning client trips to specific vehicles to maximize an objective function that reflects the trade-offs between the cost of providing service

Figure 2-1

Phase 1 System Configuration



SOURCE: OUTREACH

and the quality of the service provided, subject to constraints imposed by OUTREACH service standards (e.g., specified time windows around the scheduled pick-up time within which the pick-up will occur or the maximum time that a client will spend on a vehicle). The details of this process are described in the "Data Input and Output" section.

Information on client trips is maintained by the ATSS software, including the assignment to vehicles and the location coordinates that were computed using the DGD when the reservation was accepted. The software obtains travel times between locations from the DGD, using two different methods described in more detail below. At the end of each day, the client trip information is uploaded to the IPBS on the AS/400 for client record keeping and vendor accounting. The software can also produce standard reports of system performance to be used by OUTREACH management.

Automatic Vehicle Location (AVL)

The AVL system consists of a base station (located at OUTREACH) and the AVL equipment on each vehicle. Since the vehicle position is communicated to the base station by a digital radio link, this link can also be used to transmit messages between each vehicle and the base station. Thus the system is in fact both a vehicle location plus communication system.

Apart from the ability to track the location of each equipped vehicle and display it on a digital map, the position and vehicle status information derived from the AVL and driver messages can be

stored in a database that is used by the ATSS software.

Vehicle Equipment The equipment on each vehicle consists of a Trimble PSC-200 Intelligent Data Controller with a GPS receiver. This is linked to a Motorola Maxtrac digital radio. The controller can also receive inputs from vehicle sensors, such as the ignition, and communicates with a Trimble Echo XL mobile data terminal (MDT). The MDT can display free-form messages of up to 230 characters transmitted from the dispatch center and allows the driver to send up to eight predefined status messages or fifteen pre-programmed messages by pressing keys on the unit. Each key is located near the screen, which displays the title of that status key.

The MDT is programmed to store up to eight messages providing the data for the next client pick-up or drop-off events. These messages are stored in time order and the driver can scroll through the messages. In the normal course of operations only six event messages are sent to the MDT at any one time. This allows two additional messages for new trips that need to be inserted into the sequence to be sent to the vehicle without overwriting existing messages and then needing to resend them.

Base Station Equipment The base station equipment provides the communication link with the vehicles and comprises a Trimble PSC-200 Intelligent Data Controller, linked to Trimble NCManager network communications management software running on a 486-class computer and a Motorola Maxtrac control station radio. The network communications management software manages the message, AVL polling, and network control functions. The base station radio is

linked by a directional antenna with a Motorola Quantar repeater located at the transmission tower. The NCManager is linked to a differential GPS server running on a separate 486-class computer. This receives position signals from a GPS receiver located at the base station, compares those positions with the actual location, and generates GPS position corrections which are broadcast to all the vehicles.

The communication system between the base station and vehicles is illustrated in Figure 2.2.

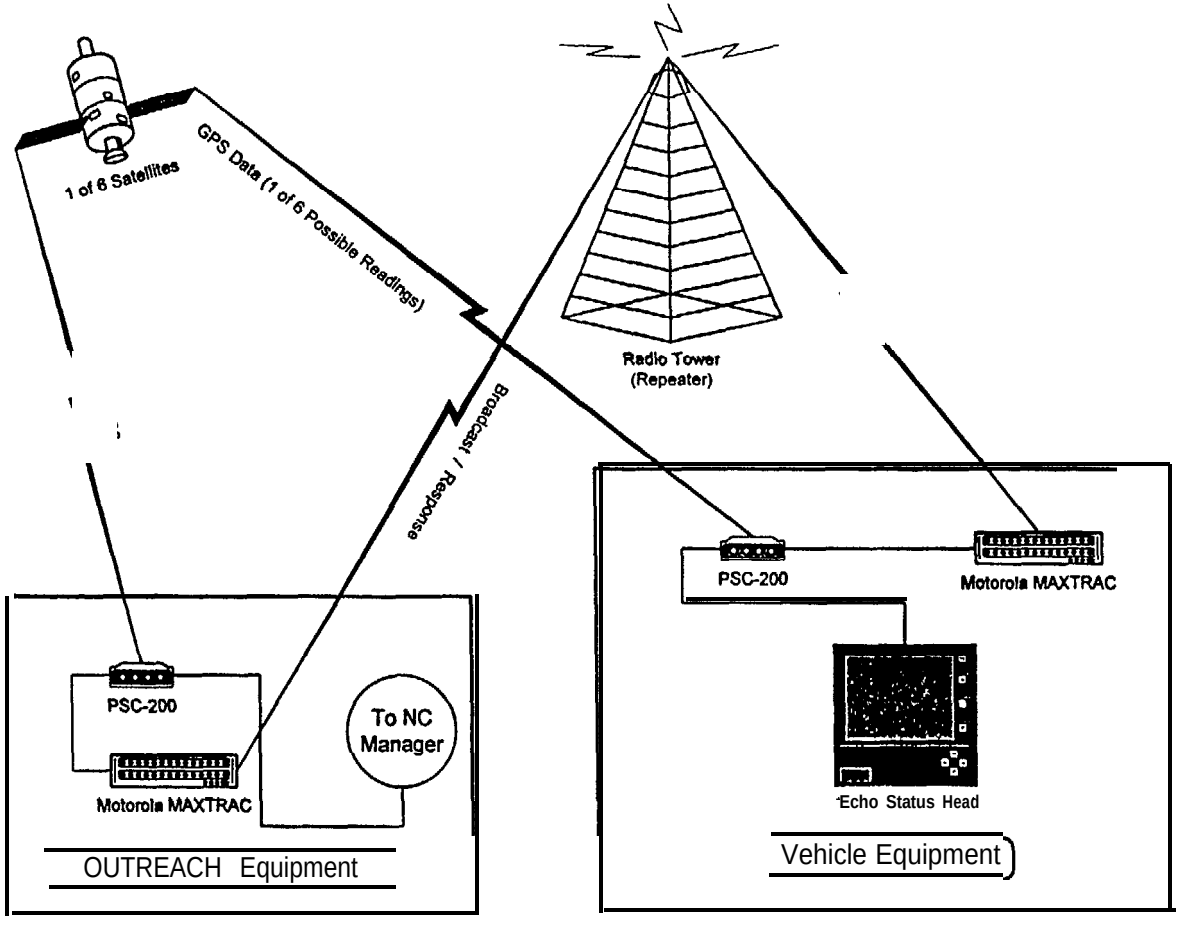
Dispatch Center Equipment The OUTREACH dispatch center comprises Trimble AVLManager system management software running on a 486-class computer, together with Trimble StarView real-time map display software running on a Sun Sparcstation 5 workstation. The system management software serves as the data interface to the vehicles and supplies vehicle locations and display commands to the map display system.

The current system configuration can support up to five terminals displaying vehicle location and status in text format, although only three are currently installed. The software could support a further eight terminals, with expansion of the hardware to provide more serial ports.

The StarView map display software shows the location of each vehicle on a digital map, using user-selectable icons. The system can display the identity of each vehicle as well as its status by changing the icon color. In addition, text information for each vehicle can be displayed in a pop-up window. The software also has

Figure 2-2

Communication System between OUTREACH and AVL Equipped Vehicles



SOURCE: OUTREACH

the capability to display vehicle locations on other map display systems (such as the OUTREACH client scheduling system) by means of commands transmitted over an Ethernet link. However, this capability is not yet implemented at OUTREACH.

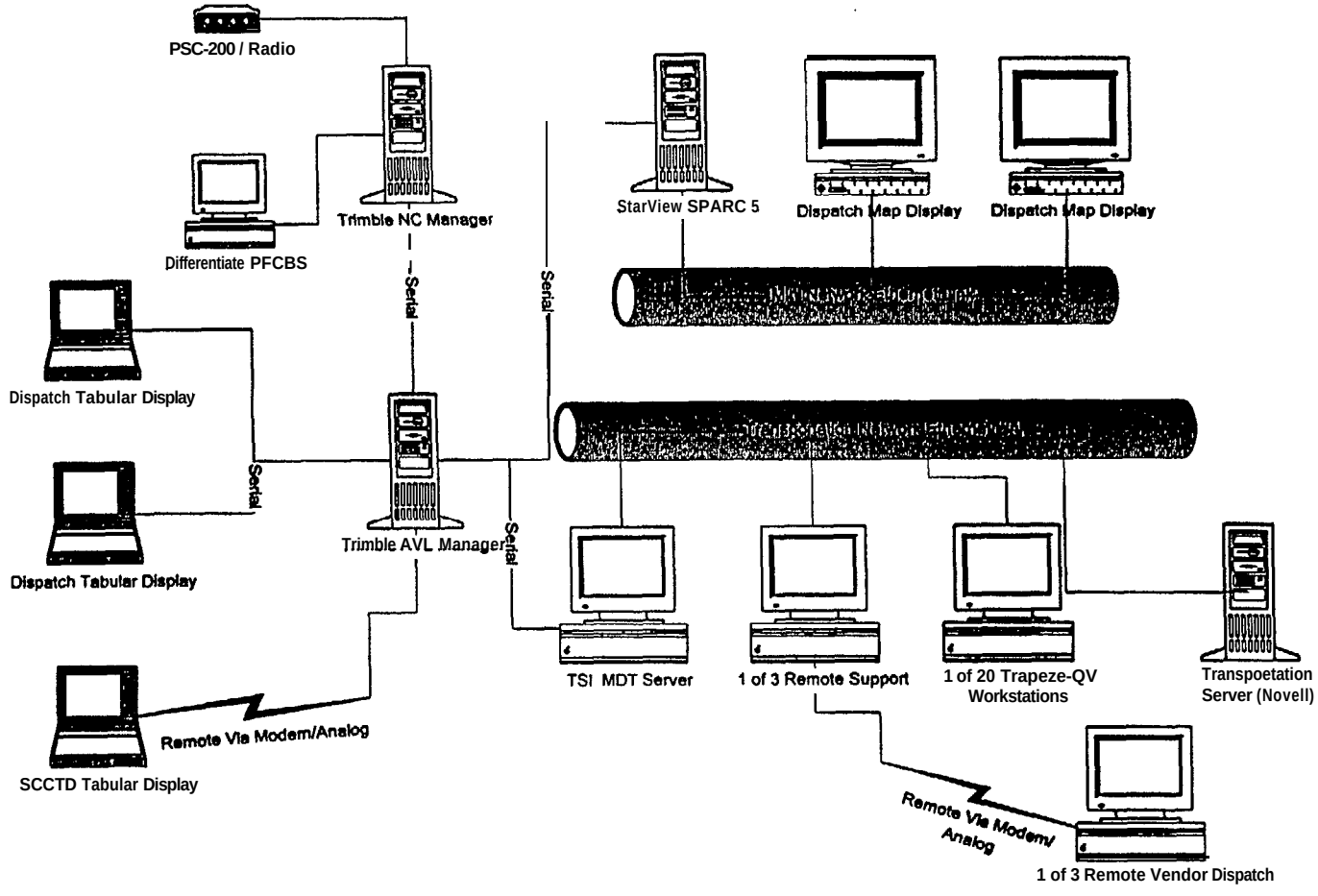
Instead, the AVLManager software is linked by a serial cable to a Pentium P90 computer running custom software, and termed the MDT server. This communicates with the ATSS software over the Ethernet link and utilizes the vehicle position and status reports to update the dispatch displays that show the sequence of client trips assigned to each vehicle with the times at which each trip is actually performed, and hence those trips that have been completed. This server also takes the information on the sequence of client trips for each vehicle from the ATSS and generates the messages to be transmitted to the MDT in the vehicle.

Dedicated workstations in the OUTREACH dispatch center run the dispatch display for each of the three vendors with AVL equipped vehicles.

Remote Dispatching Equipment Terminals are installed in the dispatch office of each of the three van vendors. Each terminal echoes the dispatch display for that vendor, via modem and regular telephone lines. Thus both the OUTREACH and vendor dispatchers can view the same display simultaneously while conferring by telephone, and either can manipulate the display from their keyboard.

The overall system architecture at the end of the Phase 2 (which implemented the AVL system) is shown in Figure 2.3.

Figure 2-3
Phase 2 System Configuration



SOURCE: OUTREACH

Data Input and Output

In order to understand how the ATSS fits into the overall provision of OUTREACH services, this section describes the input data entered into the ATSS and the output generated by the system.

At the highest level, the input consists of a series of requests for service that specify the location at which the client wishes to be picked up, the location to which they wish to be taken, and either the time at which they wish to be picked up or the time by which they need to be at their destination, together with any other restrictions (such as mobility limitations). The output of the process consists of a list of vehicle trips that identify for each trip the locations and times at which clients have to be picked up and dropped off.

Client Ride Requests

When a client calls OUTREACH to book a trip, the OUTREACH telephone scheduler enters the trip information into the trip database: the client's identification, locations of pick-up and destination, and requested time (either for the pick-up or destination). The system checks the client's eligibility, the ability to meet the requested time, and computes the fare that the vendor will be paid for the ride.

Ride requests for non-recurring trips (termed *casual rides)* take place during the 14 day period prior to the day of travel. Some trips may be scheduled on a regular basis (for example medical appointments may take place at the same time each week), and

requests for these trips (termed *subscription rides)* are made more than 15 days in advance of the first trip. Generally, clients will make a reservation for an outbound and return trip. However, in some cases they will not know the time of the return trip (which may depend on factors beyond their control, such as the wait to obtain medical treatment), so this will be left as an open return. When they are ready to be picked up, they will call OUTREACH and request a pick-up.

The distribution of how far in advance trip requests occur is shown in Table 2.1, based on an analysis of OUTREACH telephone data for selected days. The effect of weekends on the pattern of trip requests can be seen from the data in the table, with a large proportion of trip requests for a given day occurring on the last two or three weekdays prior to the day of travel and very few requests on a weekend, except for trips on the following monday.

The locations for the pick-up and destination may be given as street addresses or named locations (such as a specific hospital). Each client's home address will already be entered in the client database. These addresses (or locations) are then geocoded to a latitude and longitude position for use in the trip scheduling software. This process also serves to check that the scheduler has entered a valid address or location. At this point, the ATSS assigns the trip to a vehicle (as described in the next section) and the client is advised of the pick-up time. This ensures that a viable plan exists to serve the requested trips, given the available vehicles and travel times involved.

Table 2-1
Booking Pattern for Casual Trips

Days Before	Ride Date 8/07/95 Trips	(%)	9/14/95 Trips	(%)
14	9	1.8		
13	4	0.8	19	2.7
12	11	2.2	2	0.3
11	8	1.6	3	0.4
10	10	2.0		
9			27	3.8
8	1	0.2	23	3.2
7	21	4.2	37	5.2
6	33	6.6	36	5.0
5	39	7.8	12	1.7
4	88	17.5	20	2.8
3	147	29.2	132	18.5
2	57	11.3	149	20.8
1	67	13.3	251	35.1
same	8	1.6	4	0.6
	503	100.0	715	100.0

NOTE: Weekend days shown in italics. September 4 (10 days before travel day) was the Labor Day holiday.

SOURCE: Analysis of OUTREACH trip reservation data.

Vehicle Trip Plan

As client requests are accepted and assigned to vehicles, a trip plan evolves for each vehicle. These trip plans comprise sequences of single and multiple passenger trips, organized to provide each vehicle with a reasonable sequence of pick-ups and destinations.

Fifteen days ahead of the day of travel, the subscription trips are assigned to vehicles by the ATSS software. As regular reservations come in over the next 14 days, the ATSS assigns each trip to a vehicle. The trip scheduling algorithm that assigns trips to vehicles has two modes of operation. The first takes a set of unscheduled trips and optimally assigns them to vehicles. The second mode of operation inserts a single trip into a set of scheduled trips by assigning it to a vehicle. The algorithm uses an objective function that comprises a series of parameters and associated weights, that reflect the relative importance of various measures of system performance, such as the time clients spend on the vehicle or the vehicle-miles travelled. The user can vary the way trips are scheduled by changing the weights for each parameter.

The algorithm schedules trips by examining the effect on the objective function of assigning the trip to each vehicle in turn. Time windows are defined around requested pick-up and drop-off times, and pick-up and drop-off times can be rescheduled within the window to allow insertion of another trip. The current parameters used in the objective function and their relative weights are shown in Table 2.2.

Table 2-2

Trip Assignment Algorithm Parameters

Parameter	unit	Weight
Vehicle distance	miles	4
Vehicle travel time	minutes	0.5
Passenger travel time	minutes	0.1

This process requires an estimate of travel times between any two points. While this can be done by performing a shortest-path analysis on the street network database, this takes too long for real-time analysis (such as taking a client booking). Therefore the ATSS software provides three faster alternatives. The first simply calculates the straight-line distance between the points and uses an average speed. The second provides a somewhat improved estimate by calculating the distance along the two perpendicular sides of a right angled triangle, the hypotenuse of which joins the two points. The orientation of the two perpendicular sides with respect to north can be varied to match the predominant orientation of the street grid. The third alternative is based on dividing the region into equally sized zones and estimating the travel time from the number of zones between the two points.

The user can specify which alternative travel time calculation is used by the scheduling algorithm. OUTREACH has selected the triangulation approach, with the assumed speed varying by time of day. However, the street network approach is used later to determine the true street distance to calculate fares and ride distance.

Two situations arise that cannot be handled by the foregoing procedure. Obviously, will-call (i.e., open return) trips cannot be assigned to vehicles at the time of booking, since it is not known when they will occur. The second situation arises when there are insufficient vehicles assigned to OUTREACH operations to accept a trip without violating service constraints (such as the maximum

time that a client can be on the vehicle). In practice, additional vehicles will usually be assigned by the vendor to cover these OUTREACH operations. Therefore extra trips that cannot be assigned to a specific vehicle are assigned to a "virtual vehicle" (designated as vehicle zero for each vendor).

Toward the end of each day, OUTREACH reviews the number of shifts required for the following day with the vendors and most of the virtual vehicle rides are assigned to additional vehicles. However, the vendors like to keep a few rides on the virtual vehicle, so that they can make up for any cancellations on the day of service.

The trip scheduling software then prepares reports listing the vehicle trip plan for the next day. Three different reports are generated: a list of pick-ups and drop-offs in time sequence for each vehicle, a list of pick-ups and drop-offs for all vehicles in time sequence, and a list of will-call trips that have not been assigned to a vehicle. These reports were originally printed for each vendor and picked up by a vendor's representative for use by their dispatchers the next day. As noted above, they are now transmitted to the vendors electronically and printed at the vendors' dispatch offices.

Vehicle Dispatching

If the client requests contained in the vehicle trip plan for a given day did not change, if no problems were encountered by the vehicle drivers, and if the vehicles performed no other duties, the

drivers could simply be given the trip plan for their vehicle for that day and left to perform the trips. However, none of these conditions are typically true. Details of client trips change (most commonly the pick-up times for return trips), new trips may need to be added and some canceled, vehicles may encounter unexpected traffic delays or the time to load and unload passengers may take longer then expected, or vehicles may experience mechanical problems. In addition, the vendors providing the transportation services also serve other clients, and thus may need to fit those trips into the schedule of trips being performed for OUTREACH. Therefore the assignment of vehicles to specific passenger trips may need to be changed as the day proceeds to respond to these concerns. This is the function of the vendor dispatchers.

With the advent of the AVL system and the provision of remote access to the dispatch software in the van vendor dispatch offices, there is a significant difference between the way in which van and taxi vendors dispatch vehicles. The van vendors are now operating fully dedicated fleets, while the taxi vendors serve both OUTREACH and other clients with the same vehicles. However, the van vendors are currently allowed to use vehicles dedicated to OUTREACH to serve other clients if there is a window of 45 minutes or more in the OUTREACH schedule.

At the start of each day, the taxi dispatchers take the vehicle trip plan generated by OUTREACH and assign it to specific vehicles and drivers. They may also identify changes that better

suit their other commitments, as well as driver preferences, vehicle availability, and their judgement as to the efficiency of particular multiple trips. For example, they may decide to combine passenger trips that the trip scheduling software suggested should be served by separate vehicle trips or split a multiple trip into two or more separate trips. However, OUTREACH is supposed to agree with such changes before a modified plan is given to the drivers.

As the day proceeds and problems or changes occur, the dispatchers reallocate the trips between vehicles, communicating with the drivers by voice radio. It should be noted that these dispatching decisions do not generally involve OUTREACH personnel. When clients notify OUTREACH of a change in their trips (cancellation, revised time or new trip), OUTREACH communicates these changes to the vendor's dispatcher.

Output

The Phase 1 system generated two distinct outputs. The first was the availability of a digital map display to OUTREACH telephone schedulers while they were arranging a trip reservation with a client, and the geocoding of addresses into map coordinates (latitude and longitude) for later use by the routing and scheduling software. The second was the assignment of client trips to vehicles and the development of a sequence of pick-ups and drop-offs for each vehicle.

In the case of casual rides, the assignment of the client trip to a vehicle is performed during the trip request telephone call,

and thus pick-up and drop-off times can be given to the client at the time based on a viable assignment of trips to available vehicles.

The geocoded pick-up and drop-off locations are automatically inserted into the trip record. The digital map display allows the telephone schedulers to determine the coordinates of locations that cannot be automatically geocoded from the address or description. Its distance calculation function can also be used to check distances between locations when auditing vendor fare reports or adjusting calculated fares for operational changes (such as the cancellation of part of a multiple trip).

The output of the ATSS software replaced the trip assignment reports previously generated manually, and followed a similar format, as shown in Figures 2.4 and 2.5. Thus the two principal effects on the system performance would be any change in the number of multiple rides as a result of the new assignment procedure, and the elimination of the need for OUTREACH personnel to perform a manual assignment of client trips into shared rides.

Phase 2 system output consists of three elements. The first is the display of client ride information on the Echo XL MDT in each of the equipped vans. Typically the next six events (pick-ups or drop-offs) are presented in time order. As each is completed, it is removed from the display and the details of the next event to be added to the list, including the client name, location address, scheduled event time and other information, is sent to the display.

Figure 2-4
Typical Vehicle Ride Log

Date: 2/07/95 RIDE LOG FOR UNITED CAB COMPANY (Taxi) vehicle Number: 800 shift Page 190

Ride # / Multi# / Fare	Time / Seq	client Name / Adress / unit city / Location Name / Remarks	ID# Sponsor / Telephone / Mobility Codes	transportation Details	Time / Seq	Address / Unit City / Location Name / Remarks
123407	PickU 08:30	HILMAR ST SANTA CLARA	134533 (408)	GO TO THE DOOR/HELP CANE/QUAD CANE WALKER	drop0 08:34	22 WASHINGTON ST SANTA CLARA
	1		P C AWST 1		2	HIROLOS BEAUTY/22 WA
$ 3.00		RESIDENCE				22 WASHINGTON ST 2412578
• == DIVER						
122806	pickU 08:55	CRESCENT AVE SUNNYVALE	131594 (408)	BLIND/VISUALLY IMPAIRED WHITE CANE	Drop 09:40	795 Willow RD B3318 Menlo PARK
	3		P C AWST 1		4	VA HOSP/795 WILLOW
$ 20.63		PU IN LOBBY				795.WILLOW/BLD 331 BINS
*** DRIVER						
122215	pickU 08:59	SLOAT CT SANTA CLARA	112601 (408)	TAKE CLIENT INSIDE CO TO THE DOOR/HELP	DropQ 09:45	300 PASTEUR DR PALO ALTO
	5		P C AWST 1 I		6	STANFORD HOSPITAL
$ 30.26		2964682				300 PASTEUR DR/ENTR BY F O
*** DRIVER						
123237	PIckU 09:38	N SAN TOMAS AQUINO RO CAMPBELL	120283 (408)	SPEECH DEFECT GO TO THE DOOR/HELP	DropQ 09:50	751 S BASCOM AVE SAN JOSE
	7		P C AWST 1		8	VHC HOSPITAL/751 S
$ a.29		PU OUTSIDE NEAR DRIVEWAY				751 S BASCOM AVE/OLD MAIN
*** DRIVER						
123121	pickU 10:00	WINCHESTER BLVD CAMPBELL	115399 (408)	WHEELCHAIR	DropQ 10:13	225 N BASCOM AVE SAN JOSE
	9		P C AWST 1		10	
$ 7.26						BISCHOFFS /MEDICAL SUPPLIES
*** DRIVER						
123448	pickU 10:15	S BASCOM AVE CAMPBELL	127,073 (408)	GO TO THE DOOR/HELP MAXIMUM ASSIST CANE/QUAD CANE WHEELCHAIR	DropQ 10:23	3333 s BASCOM AVE SAN JOSE
	11		P C AWST 1		12	
S 3.36						THERAPY/3698080
• ** DRIVER						

P = Personal Care Attendant, C = Companion A = Ambulatory, W = Wheelchair, S = Scooter, T = Transferable

Figure 2-5

Typical Vendor Ride Log for All Vehicles

Date: 7/19/95 UNITED CAB COMPANY LOG IN PICKUP SEQUENCE Page: 94

Ride# / Veh# / Multi# / Fare	Client Name / Address / Unit City / Location Name / Remarks	ID# / Telephone / Mobility Codes	Sponsor	Transportation Details	P/U Time	P/U Address	D/O Time	D/O Address
12137 801 719204 2	[redacted], [redacted] [redacted] ESTELLA DR SANTA CLARA NEW ADDRESS^^^	134273 (408) [redacted] P C A W S T 1		BLIND/VISUALLY IMPAI CANE/QUAD CANE GO TO THE DOOR/HELP	08:15		08:28 4	2725 EL CAMINO REAL SANTA CLARA 2725 EL CAMINO REAL 29686
*** DRIVER								
12170 802 $ 8.59	[redacted], [redacted] [redacted] TASMAN DR SP459 SUNNYVALE ADOBE WELLS MHP	132366 (408) [redacted] P C A W S T 1		GO TO THE DOOR/HELP	07:41		07:56	820 W MC KINLEY AVE SUNNYVALE SUNN SR CTR 7307360
*** DRIVER								
12040 800 $ 23.16	[redacted], [redacted]. [redacted] LAFAYETTE WAY SANTA CLARA	107939 (408) [redacted] P C A W S T 1			08:15		09:07	6830 VIA DEL ORO 100 SAN JOSE DR DEVINE 2246991
*** DRIVER 14								
12164 803 719210 1 $ 39.77	[redacted], [redacted] [redacted] RUSTIC DR SANTA CLARA	104177 (408) [redacted] P C A W S T 1		BLIND/VISUALLY IMPAI CANE/QUAD CANE	08:17		08:46 3	2760 HOMESTEAD RD SANTA CLARA 2760 HOMESTEAD RD
*** DRIVER								
11084 803 719210 2	[redacted], [redacted]. [redacted] LU ANNE DR CAMPBELL	121580 (408) [redacted] P C A W S T 1		GO TO THE DOOR/HELP MAXIMUM ASSIST DEAF/HEARING IMPAIRE	08:33		09:30 7	3952 TWILIGHT DR SAN JOSE COMM CENTER HOGUE PARK
*** DRIVER 19								
11778 803 719210 4	[redacted], [redacted] [redacted] BOWERS AVE SANTA CLARA	119376 T (408) [redacted] P C A W S T 1		BLIND/VISUALLY IMPAI CANE/QUAD CANE SPANISH SPEAKING	08:53		09:12 6	101 N BASCOM AVE SAN JOSE 101 N BASCOM AVE 2954016
*** DRIVER								

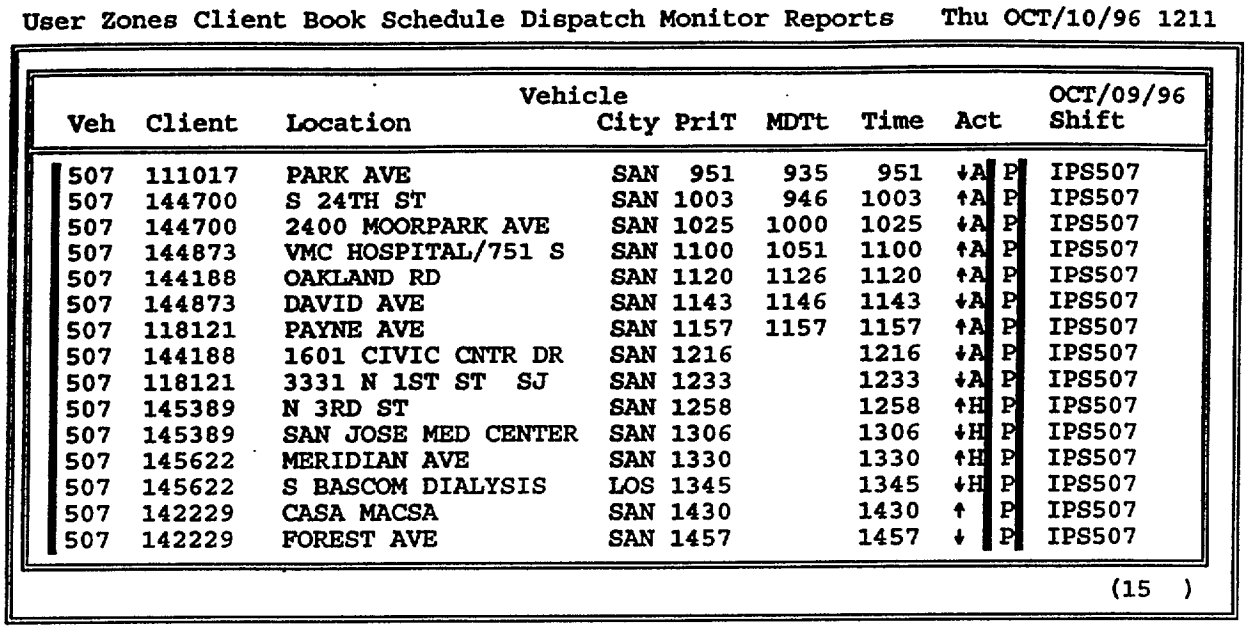
The second element is the dispatch display showing the current status of the client trips for a specific vehicle. As the driver indicates that each event has been completed, by clearing the event information from the MDT display, this time is recorded by the AVL system and added to the dispatch display, as shown in Figure 2.6. This provides the dispatchers with a continuously updated report on the progress of each vehicle. Since the dispatch display is simply one screen on the ATSS display options, the vendor dispatchers have access to the full trip booking data, as shown in Figure 2.7.

The third element is the StarView display, showing the current location of each equipped vehicle on a map of the region. Unlike the dispatch display, which only shows the last event, the StarView display shows the location of the vehicle at the last AVL polling cycle, typically within the last minute.

The information on pick-up and drop-off arrival and completion times obtained from the AVL system when the driver presses the relevant button on the MDT is added to the vehicle trip database. These times are subsequently used to generate Vehicle Schedule Adherence reports, as shown in Figure 2.8. These reports show the scheduled sequence of events for a specific vehicle shift and the actual times these events were performed. The number of events that were more than 15 minutes late and those more than 45 minutes late are noted. These reports are used by OUTREACH to monitor driver performance and schedule adherence, as well as vendor compliance with the requirements for dedicated vehicles. They are also useful when investigating client complaints.

Figure 2-6

ATSS Dispatch Screen Showing Event Completion Times



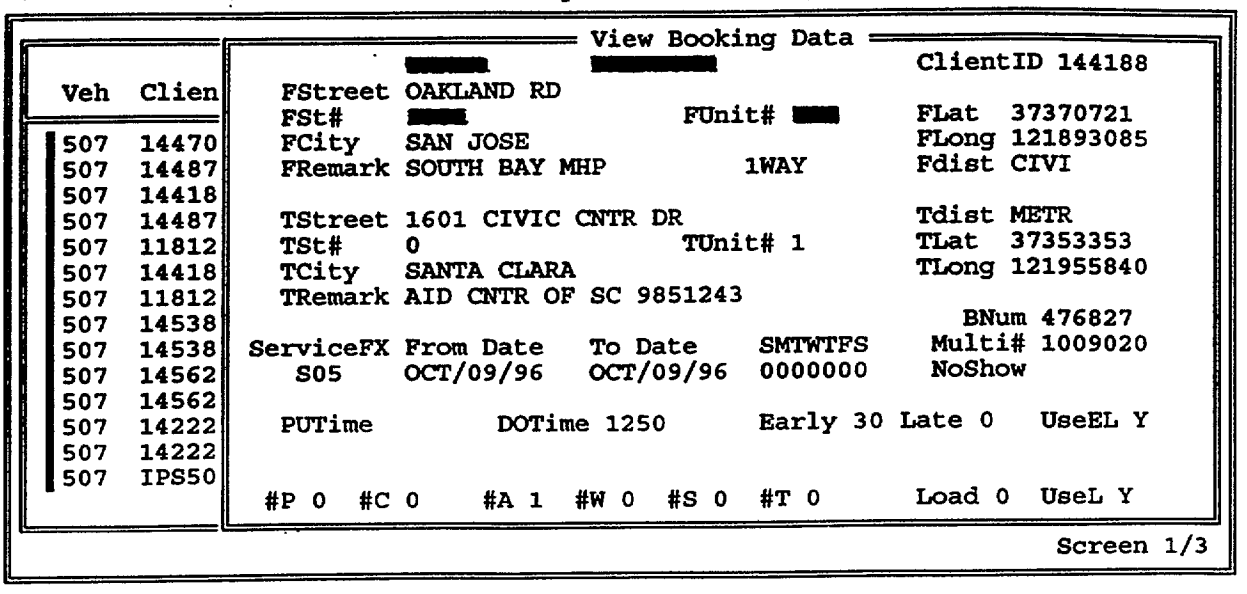
User Zones Client Book Schedule Dispatch Monitor Reports Thu OCT/10/96 1211

Veh	Client	Location	Vehicle City	PriT	MDTt	Time	Act	OCT/09/96 Shift
507	111017	PARK AVE	SAN	951	935	951	↓A	P IPS507
507	144700	S 24TH ST	SAN	1003	946	1003	↑A	P IPS507
507	144700	2400 MOORPARK AVE	SAN	1025	1000	1025	↓A	P IPS507
507	144873	VMC HOSPITAL/751 S	SAN	1100	1051	1100	↑A	P IPS507
507	144188	OAKLAND RD	SAN	1120	1126	1120	↑A	P IPS507
507	144873	DAVID AVE	SAN	1143	1146	1143	↓A	P IPS507
507	118121	PAYNE AVE	SAN	1157	1157	1157	↑A	P IPS507
507	144188	1601 CIVIC CNTR DR	SAN	1216		1216	↓A	P IPS507
507	118121	3331 N 1ST ST SJ	SAN	1233		1233	↓A	P IPS507
507	145389	N 3RD ST	SAN	1258		1258	↑H	P IPS507
507	145389	SAN JOSE MED CENTER	SAN	1306		1306	↓H	P IPS507
507	145622	MERIDIAN AVE	SAN	1330		1330	↑H	P IPS507
507	145622	S BASCOM DIALYSIS	LOS	1345		1345	↓H	P IPS507
507	142229	CASA MACSA	SAN	1430		1430	↑	P IPS507
507	142229	FOREST AVE	SAN	1457		1457	↓	P IPS507

(15)

Figure 2-7

Typical Client Trip Data Available from Dispatch Screen



User Zones Client Book Schedule Dispatch Monitor Reports Wed OCT/09/96 1434

Veh	Clien
507	14470
507	14487
507	14418
507	14487
507	11812
507	14418
507	11812
507	14538
507	14538
507	14562
507	14562
507	14222
507	14222
507	IPS50

View Booking Data

[redacted] [redacted] ClientID 144188

FStreet OAKLAND RD

FSt# [redacted] FUnit# [redacted] FLat 37370721

FCity SAN JOSE FLong 121893085

FRemark SOUTH BAY MHP 1WAY Fdist CIVI

TStreet 1601 CIVIC CNTR DR Tdist METR

TSt# 0 TUnit# 1 TLat 37353353

TCity SANTA CLARA TLong 121955840

TRemark AID CNTR OF SC 9851243 BNum 476827

ServiceFX	From Date	To Date	SMTWTFS	Multi# 1009020
S05	OCT/09/96	OCT/09/96	0000000	NoShow

PUTime DOTime 1250 Early 30 Late 0 UseEL Y

#P 0 #C 0 #A 1 #W 0 #S 0 #T 0 Load 0 UseL Y

Screen 1/3

Figure 2-8
Typical Vehicle Schedule Adherence Report

Vehicle Schedule Adherence for Vehicle: 202 on: 961 028 ShiftMW2015A

ClientID	Street Address/Location	Sched	Arrive	Complete		
MW20l5A	MV Transportation	6:11				
120509	3286 MARTEN AVE	6:30	6:27	6:31	P	
120509	VA HOSP/795 WILLOW	7:10	7:09	7:15	D	
113793.	2940 RUSTIC DR	8:42	8:24	8:32	P	
132813	792 LOS PADRES BLVD	9:15	9:07	9:18	P	
113793	LIVE OAK/PAYNE AVE	9:31	9:33	9:42	D	
132813	LIVE OAKPAYNE AVE	9:33	9:34	9:43	D	
107209	400 W RINCON AVE	10:18	9:59	10:12	P	
107209	VALLEY HEALTH/750 S	10:30	10:34	10:36	D	
122193	4621 MIA CIR	11:00	11;07	11:11	P	N/S
143035	1711 MERIDIAN AVE	11:21	11:27	11:32	P	
122193	25 N 14TH ST	11:34		11:11	D	N/S
143035	2982 MARY CAROLINE CT	11:45	11:53	11:55	D	
122367	220 N WHITE RD	12:19	12:07	12:13	P	
122367	EAST VALLEY CLINIC	12:30	12:23	12:25	D	
118568	1489 LITTLE ORCHARD ST	13:07	12:59	13:13.	P	
134221	549 LELAND AVE	13:23	13:24	l3:28	P	
118568	VMC HOSPITAL/751 S	13:30	13:35	13:38	D	
134221	2221 ENBORG LN	13:37	13:42	13:43	D	
MW2015A	MV Transportation	14:00				

Total number of events : 18
Total nymber /w actual times : 18
Total number of lates (triple) : 0 (0)

Percent Late : 0.0

The overall vendor performance for a given day is summarized in a Vendor On-time Performance report, as shown in Figure 2.9. Similar reports are also prepared on a monthly basis.

ATSS FUNCTIONALITY ANALYSIS

This section examines how well the implementation of the DGD and ATSS has met the functional goals of the demonstration project. These goals include enabling OUTREACH to handle a steadily increasing volume of rides, while improving the efficiency with which these trips are assigned to vehicles.

System Performance Measures

The performance of the ATSS and supporting DGD can be measured in a number of ways that reflect the project's goals; for example: reduction in the cost of service provision; and improvement in the service provided to OUTREACH clients.

One measure of the first goal is the number of shared rides. However, the cost savings from increasing the percent of shared rides will depend on the additional vehicle travel involved in combining trips. This in turn will depend on how well the trip multiples are put together. Furthermore, the reduction in the number of vehicle-trips can conceivably result in increases in the time that some clients spend on board the vehicle.

Thus the extent to which the ATSS has improved the assignment of trips to vehicles must consider the service provided to the clients, as well as the effect on the costs paid by OUTREACH. It

Figure 2-9
Typical Vendor On-Time Performance Report

Vendor On Time Performance for MVT on 961028

Shift ID	# Events	# With Actual Times	# Lates	# Triple Lates	Percent Late
MW2015A	18	18	0	0	0.0
MW2016A	21	20	1	0	5.0
MW2022A	17	15	1	0	6.7
MW2023A	16	16	0	0	0.0
MW2294A	18	17	0	0	0.0
MW2301A	22	21	1	0	4.8
Total	112	107	3	0	2.8

should also consider the impact on the vehicle vendors, in terms of vehicle utilization and deadheading. While OUTREACH does not directly compensate the vendors for these costs, in the long run they can affect what the vendors are willing to bid to provide service to OUTREACH.

These issues are examined in more detail in the cost and productivity analysis (chapter three). Other performance measures, such as equipment reliability and ease of use, reflect both the cost of OUTREACH operations and the quality of the service provided to its clients. Equipment failure involves repair costs and may degrade the service experienced by clients. It may also require additional staff time to fix the problem and restore lost data. Ease of use affects staff productivity and training requirements.

This section examines the following performance measures: system reliability; ease of use; effectiveness of the trip assignment algorithm; and support staff requirements. The third measure deserves some discussion. Since developing a reasonable vehicle trip plan from a given set of trip requests involves making trade-offs between the costs of providing the service and the quality of the service provided, it is not possible to define an "optimal" plan against which others can be compared. Rather it is necessary to compare any particular plan with other viable plans that could be generated to serve the same trip requests, on the basis of the range of relevant criteria.

While the ATSS eliminated the need to manually assign trips, and may have improved the productivity of OUTREACH telephone

schedulers and other staff, the introduction of a sophisticated automated system created a need for additional technical support staff.

System Reliability

With the implementation of the ATSS, OUTREACH is totally dependent on the system to manage the client ride requests and generate the vehicle trip plans. Therefore system reliability is essential to allow OUTREACH to function effectively.

System Hardware

No particular problems have been experienced to date with the various computers supporting the ATSS. The primary file server has been designed with a redundant file system with multiple disk drives that can be replaced without shutting down the system.

The client-server architecture puts relatively small demand on the Ethernet network, and routine tests have shown that it is far from saturation, even at busy periods. The principal bottleneck is the ATSS server, which has to analyze each new trip to determine where it can best be inserted. By the summer of 1996 OUTREACH technical staff believed that they were approaching the limit on the single server, with system response starting to slow when ride requests approached 1,500 per day. They felt that this problem can be solved fairly easily by adding more servers, and have recently acquired a second server. The workload can be easily divided between the servers by using each to handle different days.

Software

Significant problems were encountered integrating the ATSS software into the existing computer systems. The system as purchased needed to be customized to integrate with the IPBS running on the AS/400 and add features required by OUTREACH. Not all these features had been fully tested by the time the system became operational, and the first few weeks were spent fixing problems as they surfaced.

Particular difficulties were experienced with address geocoding on the AS/400 system and transferring data between the AS/400 and ATSS software. Some of this can be attributed to errors by the telephone schedulers, but there were also software bugs in linking the ATSS to the existing systems. In turn, incorrect or missing coordinates resulted in problems with building multiples.

Other difficulties with forming multiples resulted from the need to establish parameter weights for the trip assignment objective function. These were adjusted by trial and error until they gave reasonable results. However, this process contributed to vendor frustration with the initial results.

Ease of Use

The introduction of the DGD changed the way the telephone schedulers entered geographical information into client trip requests. Before the DGD, addresses were coded into a half-mile grid system, that was used to compute trip lengths. While grid references for client home addresses and common destinations were

indexed in the system, schedulers had to look up the grid reference to less common destinations in a code book or from a map and enter them during the telephone call. With the DGD, most addresses are automatically geocoded, either by selecting a common destination from a menu or entering the address. Where it is necessary to identify a location on the map, the OUTREACH telephone scheduler can open a map window on the terminal and manipulate the map display.

Map display functions include positioning and sizing a zoom box on the display, and then changing the display (zooming) to that area of the map. The area displayed may also be shifted laterally and vertically (panning). The mouse may be used to pin-point streets or intersections on the map. A list of street names can be displayed, a particular street selected and then highlighted on the map. The map functions also allow a system of rectangular zones to be defined and displayed, including a street level detail of a selected zone. Speeds can be assigned to each zone by time of day. A calculation function determines the distance between two selected points, using the above-mentioned distance calculation methods.

Operation of the ATSS software involves no particular ease of use issues. This contrasts with the previous semi-automatic system, which involved a great deal of knowledge of the region and judgement on the part of the personnel building the multiples.

Learning Curve

As with any new system, it could be expected that the initial

performance would increase over time, as the implementation problems were worked out and the staff became familiar with the system. An analysis was performed of several performance indicators for the period following the implementation of the ATSS.

For the two weeks before the ATSS deployment, trip requests were entered into both the existing and new systems, in case of major problems or failures. However, the disruption caused by the additional work involved in this duplication was so great that it was discontinued after a few days' experience with the new system.

Most of the performance indicators showed significant improvement during the first week, and had reached a reasonably stable level by early March 1995. The frequency of missing information in the vehicle trip logs reduced as software errors were fixed, the number of poor trip multiples that had to be corrected by hand dropped as the geocoding problems were solved and the scheduling parameters adjusted, and the frequency of problems with the calculated fares declined as software changes were made and the multiples improved.

Interviews with OUTREACH's telephone schedulers revealed that full proficiency with the ATSS was achieved within six months, by which time the ATSS was reportedly as easy to use as the previous scheduling system.

Trip Assignment

The assignment algorithm parameter weights given in Table 2.2 imply that a client trip will be inserted into an existing vehicle

trip, rather than served with a new vehicle trip, if the deadheading involved in a new vehicle trip (single ride) is greater than the disturbance to the existing trip. This disturbance is measured as the additional weighted distance and travel time of the vehicle, plus the additional weighted travel time of the passengers already on board. Passenger time is weighted at one fifth of the vehicle time, while at an average speed of 20 mph (the speed assumed for most of the day) distance is weighted one third greater than the actual driving time. Both vehicle and passenger travel time include time spent loading and unloading.

This implies that the marginal value of passenger time is about one tenth the value of vehicle time. Of course, the benefits of reduced passenger travel time do not accrue to OUTREACH, while the costs of additional vehicle trips may ultimately do.

There appears to be no theoretical basis for selecting particular parameter values, and OUTREACH relied initially on the advice of the ATSS software vendor, based on values that had worked well elsewhere. These values were then modified several times on the basis of the experience with the resulting trip assignments.

AVL FUNCTIONALITY ANALYSIS

The implementation of the AVL equipment on the accessible van fleet has significantly improved the ability of OUTREACH to monitor the operation of these vehicles and enhanced the coordination between the OUTREACH and vendor dispatchers. By providing OUTREACH with a database of actual arrival and completion times for every

event in the vehicle trip plan for each day, the system allows OUTREACH to review the accuracy of travel time assumptions and time allowances for pick-ups and drop-offs, as well as monitor vendors and their drivers for conformance to the trip plan and service standards. This database also provides a basis for investigating client complaints.

System Reliability

The accuracy of the differential GPS is much greater than strictly necessary to track the location of each van, which really only needs to be known to the nearest street segment. Communication between a vehicle and the base station is sometimes lost temporarily when the vehicle is in a radio shadow from the repeater tower. Therefore each message is sent twice on successive polling cycles.

While the time at which the drivers indicate that they have arrived at a location or completed an event are accurately recorded by the system, there is of course no assurance that they push the relevant button at the time in question. Observations of actual van operations showed that, particularly when drivers are behind schedule, they will sometimes become so busy loading and unloading clients that they forget to indicate their arrival or completion of the event. Later they will realize this and then send the event complete message in order to download the next event to be added to the list, resulting in an erroneous event time. It would be possible to program the system to record the actual time at each

event location, based on the GPS position, but this is not currently done.

A related problem arises when there are several clients on a vehicle for pick-up or drop-off at the same location (e.g. a senior center). Each of these client pick-ups or drop-offs is a separate event. However, the driver has to indicate the previous event has been completed and clear it from the MDT list before the arrival message for the next event can be sent. Thus typically what will happen is that the arrival message for the first event will be sent upon arrival, then the completion message for that event and the arrival and completion messages for the other events at that location will be sent in quick succession after all the clients have been boarded or unloaded. This gives misleading data on the time to load or unload each client, as well as the travel times involved. Again, it would be possible to program the system to recognize multiple events at the same location and adjust the times accordingly, but this is not currently done.

Both problems are usually fairly obvious in the Vehicle Schedule Adherence reports, and can be corrected by anyone analyzing these data.

Ease of Use

The system is fully automatic apart from the actions required by the drivers to indicate arrival and completion times. Upon starting their shift the drivers sign on using a button on the MDT. This causes the first six event messages to be downloaded. After

acknowledging that they have received each one, they can start their trip. The MDT warm-up and initial download of client data takes about 90 seconds, although this usually takes place during other van preparation procedures. Adjustment of the computer screen, acknowledging receipt of data for each event, and comparing the information with the hard copy run sheet takes about 5 minutes on average.

The vendors still require the drivers to record odometer readings and actual time of arrival on the hard copy run sheets. Some vendor dispatchers require the drivers to radio base for the official arrival time, while others accept the times generated by the AVL system. In fact the AVL time is likely to be more accurate, as radio calls can be delayed by other radio traffic.

The hard copy run sheets provide the drivers with an overview of their entire shift, whereas the MDT provides the pick-up and drop-off information six events at a time. Seeing the entire shift makes it easier to identify difficult or illogical sequences of events, allowing the driver an opportunity to request a modified sequence. It also provides a way to record changes in the plan, such as adding an unscheduled pick-up or the transfer of a client to another vehicle. In general, it is difficult or impossible to incorporate this type of change into the MDT list once the event information has been downloaded.

Accuracy of Vehicle Location Display

The current system provides three methods for displaying the

location of a given vehicle. The most precise is the StarView display, which shows the location of each vehicle at the most recent AVL polling cycle as an icon superimposed on a map of the region. The location information is accurate to a reported 2 to 5 meters, and each vehicle is polled two to three times per minute. At the next level of detail, the tabular dispatch displays give the position of each vehicle in terms of their distance and direction from street intersections or other landmarks. The least precise is the ATSS dispatch display, which shows the time at which the most recent event was completed, and thus by inference the approximate position of the vehicle (between the location of the last event and next).

Currently only OUTREACH has a StarView display, while OUTREACH and the Santa Clara County Transit District have tabular dispatch display terminals. The vendors only have terminals showing the ATSS dispatch display. OUTREACH is working with the ATSS software vendor to develop a modification that would allow the latest position of each AVL equipped vehicle to be shown on the ATSS map display. This would allow the vendor dispatchers direct access to this information without the need for any further communication or display equipment at the vendor dispatch offices.

SUPPORT STAFF REQUIREMENTS

The operation of a technically sophisticated vehicle tracking and trip scheduling system, involving multiple computers and ancillary equipment communicating with each other on a real-time

basis, creates a need for appropriately experienced support staff. One cannot expect to simply set up the equipment, turn it on, walk away, and have it continue to operate smoothly month after month. In the case of OUTREACH, this was further complicated by the need to integrate the ATSS with pre-existing reservation and accounting systems. Also, the architecture of the entire ATSS/AVL system evolved progressively over a period of almost two years. The design of the AVL system evolved even after the ATSS had reached full functionality, in order to take advantage of newer equipment offered by the AVL suppliers.

OUTREACH was fortunate to be able to hire a system development engineer who had worked for the supplier of the ATSS software, and thus was both familiar with the software and its integration into other systems. Additional technical support was also donated by the suppliers of the AVL and communications systems. In a situation where these functions are provided by the system suppliers as part of a turn-key contract, it is important to make provision for training support staff who will maintain the system once it is operational. If the support staff are also provided by contract, and are not routinely on site, the design of the system needs to preserve as much functionality as possible if individual components fail, so that some level of service can be provided to clients and vendors while waiting for problems to be fixed.

CHAPTER THREE

COST AND PRODUCTIVITY IMPACTS OF ATSS

This chapter describes the evaluation of the impacts of the ATSS on the productivity of OUTREACH's paratransit operation during the first year of ATSS operation. A period before the ATSS deployment, termed the before-ATSS period, covered 18 months. A period after the ATSS deployment, termed the after-ATSS period, covered 12 months.

This chapter proceeds as follows: The next section presents the evaluation framework. This is followed by the impacts of the ATSS on: OUTREACH's workforce productivity, costs, vehicle productivity, and customer service quality.

EVALUATION FRAMEWORK

The productivity of a paratransit system is usually measured by relationships between the outputs and inputs of a system (system efficiency), as well as relationships between system outputs and consumption of the outputs (system effectiveness).

System Input and Output

Three kinds of input were examined. The first is the monetary resource (the costs of providing the paratransit service), which is

reimbursed to OUTREACH by the SCVTA, cities in Santa Clara County, and other sponsoring organizations. The second type of input is OUTREACH staff resources needed to perform various functions of the paratransit operation. The third type of input is the vehicle resources (supplied by the vendors under contract with OUTREACH).

System outputs examined include vehicle revenue miles and vehicle deadheading miles.

Consumption of Outputs

Consumption of system outputs examined includes the number of passenger trips (the number of one-way trips) and passenger miles.

Productivity Measures

Productivity measures include: cost-effectiveness (the ratio between monetary inputs and consumption), work force productivity (the ratio between OUTREACH staff resources and outputs or consumption), and vehicle productivity (the ratio of vehicle inputs and outputs or consumption).

Customer Service Quality

The inputs, outputs, consumption, and productivity measures described above do not adequately account for the quality of service. Many trade-offs between productivity and service quality frequently affect the level of productivity actually achieved by paratransit systems. Service quality attributes examined include: vehicle on-time performance, client in-vehicle travel times, and

the ease of clients making trip reservations.

Data Sources

Data for the evaluation were obtained from three primary sources. The first was the OUTREACH's operational database, where cost and performance data were available quarterly or monthly. Second, we collected data not available from OUTREACH's database using an observer on-board a sample of vehicles to record information such as: vehicle deadheading, vehicle occupancy, and passenger travel times. Third, we interviewed OUTREACH's staff as well as the personnel of the taxi and van companies.

As previously mentioned in Chapter One, the ATSS implementation occurred amidst a period of sharp ridership growth. Passenger trips, passenger miles, and passenger trip lengths all increased substantially since 1993 and through the after-ATSS period. For example, the number of passenger trips increased by almost 50% between July 1993 and March 1996. This raises several important questions about the impacts of the ATSS on OUTREACH's operation; for example:

- Whether the ATSS was the critical factor that has enabled OUTREACH to accommodate the sharp growth in the paratransit demand.
- Whether the ATSS allowed OUTREACH to serve the increased demand more cost-effectively.

The evaluation results are presented below. A glossary of the terms used in this chapter is shown in Table 3.1.

TABLE 3.1 GLOSSARY OF TERMS USED

ACTIVE CLIENTS - Registered OUTREACH clients who have taken rides on OUTREACH's paratransit system within a certain period of time (e.g. one month).

ADMINISTRATIVE COSTS - OUTREACH's costs of providing on-going administrative support for their paratransit operation. Includes telephone, administrative equipment, and office supplies costs.

AUTOMATED TRIP SCHEDULING SYSTEM (ATSS) - Refers to the hardware, software, and functional capabilities of the advanced trip reservation and optimization system implemented by OUTREACH under the Smart Paratransit Demonstration Program. Except when stated otherwise, 'ATSS' includes the Digital Geographic Database.

COMPUTER MAINTENANCE COSTS - On-going costs of maintaining OUTREACH'S computer systems. Includes regular servicing by outside contractors.

DIGITAL GEOGRAPHIC DATABASE (DGD) - Digital map file containing street and geographic information of Santa Clara County.

INTEGRATED PARATRANSIT BUSINESS SYSTEM (IPBS) - Computerized business system installed by OUTREACH for internal record keeping and management use. Also referred to as Management Information System (MIS).

ON-BOARD OBSERVATIONS - Data collection technique where a sample of vehicle trips were observed by an on-board observer. Vehicle itineraries, vehicle occupancies, and passenger travel times were recorded.

PASSENGERS - All registered (ADA eligible) clients using the transportation services of OUTREACH. Passengers do not include companions and personal care attendants accompanying OUTREACH clients, except where stated otherwise.

PASSENGER MILES - The number of one-way miles travelled by passengers on board OUTREACH vehicles. Passenger miles are estimated based on the shortest path distance between the origin and destination of a trip, regardless of the actual route followed by a vehicle when the trip is made. Passenger miles does not include circuity added by making intermediate stops when ridesharing occurs. (Subsequent to the current analysis OUTREACH's operational definition of 'Passenger Miles' was changed to reflect trip distances following the vehicle path).

TABLE 3.1 GLOSSARY OF TERMS USED (continue)

PASSENGER TRIPS - The number of one-way trips made by OUTREACH clients on-board OUTREACH vendors' vehicles.

REGISTERED CLIENTS - Clients who are registered as eligible for ADA paratransit service and have successfully completed the application process for OUTREACH service.

SHARED RIDE - If at any time during a person's trip, another person (i.e. other clients, companions or personal attendants) is also on the vehicle, the trip is counted as a shared ride. The trip of a companion and of a care attendant is always counted as a shared ride.

TRANPORTATION OPERATING COSTS - Direct costs of providing transportation to OUTREACH clients. Consists mainly of payments made to vendors for transportation services provided. Also includes vehicle operations and maintenance costs for the period July through October 1993.

TRIP LENGTH - The average distance of trips requested to be taken by OUTREACH clients. It does not reflect the actual number of miles travelled on-board a vehicle, but the direct origin-destination distance. Average trip lengths are computed as the ratio of passenger miles to passenger trips.

TRIP RATE - The average number of passenger trips taken by active OUTREACH clients on OUTREACH paratransit vehicles, over a period of time. Calculated as the ratio of passenger trips to active clients.

VEHICLE OPERATIONS AND MAINTENANCE COSTS - Operating costs incurred by OUTREACH when they were operating their own van fleet (through October 1993). Includes fuel, lubrication and vehicle maintenance. This cost is included in transportation operating costs for this analysis.

VEHICLE DEADHEADING - Distance travelled by paratransit vehicles while serving OUTREACH clients, but with no OUTREACH passengers on board, for instance travelling empty from a drop-off to the next pickup location.

VEHICLE REVENUE MILES - Distancetravelled by paratransit vehicles with one or more OUTREACH clients on board.

TABLE 3.1 GLOSSARY OF TERMS USED (continue)

VEHICLE TRIP - A vehicle trip starts when an empty vehicle starts moving towards a passenger's pickup location (in deadheading), and ends when the vehicle is empty again after delivering that passenger and all other passengers picked up.

VENDOR PAYMENTS - Payments made by OUTREACH to transportation vendors, for transportation provided for OUTREACH's clients.

IMPACTS OF ATSS ON OUTREACH'S WORKFORCE

The analysis of the ATSS's impacts on OUTREACH's workforce used data from the interviews and logs of telephone scheduling activity. Interviews were conducted about four months before the ATSS implementation, during the ATSS implementation, and up to 18 months after the ATSS implementation.

Change in OUTREACH's Workforce

Interviews with OUTREACH personnel before the ATSS implementation revealed that OUTREACH telephone schedulers, in particular, were operating at (or near) capacity. The number of available telephone schedulers had been perceived by the OUTREACH's management to be the critical capacity-constraint factor. In order for OUTREACH to accommodate a 50% increase in the number of passenger trips in the after-ATSS period without changes to any of its operational procedures, it would have had to increase the number of employees very substantially.

As it turned out, the size of OUTREACH's workforce increased from 22 in the before-ATSS period to 25.5 full-time positions in the after-ATSS period. The availability of operating funds was a major control factor of the size of OUTREACH's workforce. OUTREACH faced funding constraints throughout the advanced paratransit system demonstration period, with little funds available for hiring additional employees.

The ATSS implementation has enabled OUTREACH to accommodate sharp increases in trip volumes with little change to the size of

its workforce, and thus its salary expenses. However, the ATSS deployment did require a significant change in the specific skills required by OUTREACH. OUTREACH employees can be classified according to the type of task performed: telephone schedulers, customer service staff, hardware operators, management information system (MIS) support services, software engineers, and managers. The numbers of employees in each category during the before ATSS and after ATSS periods are shown in Table 3.2. The ATSS's impacts on these personnel categories are as follows:

OUTREACH Telephone Schedulers

Ride-Booking Procedure Before ATSS

In the before-ATSS period, OUTREACH telephone schedulers performed the following tasks in booking rides:

(a) After answering a call, the telephone scheduler asked for the client identification number or name of the client and entered it into the computer. This brought up the client's personal file.

(b) The telephone scheduler asked the client for the trip date, the desired pickup time and location, and the time of the client's appointment. Additional information such as accompanying passengers or mobility limitations were also obtained.

(c) The telephone scheduler entered the date into the computer. The computer then checked whether the client was eligible to make the desired trip, as well as checking the number of trips requested during the preceding month. If the client's trip limits would be exceeded, the telephone scheduler was informed

TABLE 3.2 CHANGES IN OUTREACH'S WORK FORCE BEFORE AND AFTER ATSS IMPLEMENTATION

JOB DESCRIPTION	NUMBER OF EMPLOYEES	
	BEFORE ATSS	AFTER ATSS
Telephone Scheduling	10	14.5
Customer Service	3	3
Iardware Operations	1	2
MIS Support Services	4	3
Paratransit Software Engineer	0	1
Managerial	4	2
TOTAL	22	25.5

and the trip denied.

(d) The telephone scheduler entered the pickup and drop-off addresses into the computer. The computer assigned a grid number to each address, based on its location on a half-mile grid covering the service area. If the computer did not recognize the address (i.e. if it had not been entered into the list of common origins/destinations maintained in the computer database), the telephone scheduler had to look up the grid number on a wall map and type it in. The computer calculated the trip distance and fare and displayed the information to the telephone scheduler.

(e) The telephone scheduler calculated the pickup time, using a simple trip-distance formula as follows: if the trip length was more than six miles, the pickup time was set at 60 minutes before the time of the client's appointment. If the trip was shorter than six miles, the pickup time was set at 45 minutes before the client's appointment time. The telephone scheduler entered the pickup time into the computer and conveyed it to the client.

(f) The telephone scheduler asked the client if a return trip was also desired. If the client requested a scheduled return trip, steps (b) through (e) were repeated for the return trip. If the client requested an open return trip (i.e. with an unspecified pickup time), a pickup time was not entered at the time when the telephone scheduler booked the ride.

In addition, telephone schedulers also occasionally performed the following tasks in the before-ATSS period:

Subscription trips. Subscription trips (trips that occur

regularly the same time every week; for example: medical treatment every monday) were booked manually by telephone schedulers. Once every month all subscription trips for the following month had to be entered into the booking system by a telephone scheduler. This task was estimated to take up two to four person-days per month.

Same-day changes. Telephone schedulers also received calls from clients wanting to change or cancel their scheduled ride requests. If the ride was scheduled for that day, then the change (cancellation, or change in time/location) was recorded on a slip of paper and passed to the person at the returns desk.

Returns desk. The telephone scheduler at the returns desk (also called OUTREACH's dispatcher) was responsible for telephoning the vendors about all changes on that day's schedules. Information with cancellations or time/location changes was received from the other schedulers, and the returns desk scheduler telephoned the vendor with the updated information. Clients who were taking open return trips and were ready to be picked up also called the returns desk. This information was also conveyed to the appropriate taxi or van vendor by telephone.

Ride Booking Procedure in AFTER-ATSS Period

The ATSS implementation has resulted in significant changes in the procedures used by the telephone schedulers to book rides. They include:

Geocoding of addresses. With the ATSS, the telephone

scheduler no longer has to look up the grid number of addresses on a wall map, if it can not be located by the computer. The locations of addresses are now identified by exact latitude and longitude coordinates automatically calculated by the computer via the DGD. When particular coordinates cannot be found, the telephone scheduler can access several help screens to locate the address on an on-screen map or on a list of street names. New clients' home addresses are geocoded in advance (i.e., before they start taking any trips) and the coordinates stored in client files. In the majority of cases, geocoding is completed in a very short amount of time. On rare occasions, more time and effort are needed for geocoding problematic addresses. All telephone schedulers are trained to handle difficult geocodes.

Computing travel time. After the geocodes are found and the scheduler inputs a desired pick-up or arrival time, the ATSS computes the expected travel time, and then suggests a pickup time to the telephone scheduler. Therefore, the telephone scheduler does not estimate a pick-up time with the simple trip-distance formula as in the before-ATSS period.

Assigning trips to vehicles. In the before-ATSS period, passenger trips were booked but not assigned by OUTREACH to specific vehicles. With the ATSS, a trip is booked and simultaneously assigned to a specific vehicle. The ATSS chooses the vehicle for the trip by means of an optimization algorithm, considering other trips that have already been assigned. Then, the ATSS provides a pick-up time to the telephone scheduler, who

conveys it to the client on the phone. The times assigned by the ATSS may not be exactly the times requested by the client. The client may negotiate a different time. This may result in the telephone scheduler asking the ATSS to identify another pick-up time that is acceptable to the client. This negotiation between the telephone scheduler and the client did not exist in the before-ATSS period.

Same-day changes. As in the before-ATSS period, clients call telephone schedulers with same-day changes to their trips (e.g., cancellations, open returns, or changes in pick-up times and locations). However, instead of taking this information down on a slip of paper and passing the information on to the returns desk, the telephone scheduler simply inputs the change into the computer, which is automatically passed on to the returns desk via the local computer network.

Subscription trips. Unlike the before-ATSS period, subscription trips no longer need to be entered by the telephone scheduler every month. The ATSS maintains a subscription master file, from which subscription trips are automatically booked in advance. Therefore, the ATSS frees up the time that telephone schedulers previously spent on this task.

To summarize, the ATSS has significant impacts on the procedures followed by telephone schedulers in trip booking. Streamlining of trip booking was achieved by automating the booking of subscription trips and by automating the transfer of information on same-day changes. The geocoding of addresses is automated and

more useful than the previous grid location system. However, some new tasks were created that probably require more skill, judgment, and the ATSS knowledge on the part of telephone schedulers than before. They include: negotiation of pick-up and drop-off times with clients; and geocoding of exact address locations using the DGD.

Change in Number of Telephone Schedulers

The number of telephone schedulers employed by OUTREACH has increased from 10 in the before-ATSS period to 14.5 in the after-ATSS period (Table 3.2); there is one part-time position. After the ATSS became operational in February 1995, OUTREACH received additional funding from the SCVTA to hire five additional telephone schedulers to cope with sharp increases in the number of trips that it was experiencing.

OUTREACH Customer Service Personnel

Customer service personnel handle client registration, queries, and problems. The ATSS provides these personnel with clients' ride histories as well as future rides when addressing clients' queries or problems. These personnel also advise and "educate" clients about how the new system performs trip scheduling (compared with the old system), so that clients would understand and be able to take these new features into consideration when requesting rides. The number of customer service personnel was the same in both the before-ATSS and after-ATSS periods.

OUTREACH Hardware Operators

OUTREACH hardware operators include staff involved in day-to-day operation of the OUTREACH's computer systems. Their responsibilities include trouble shooting, regular archiving of historical data, and overseeing the printing or downloading of the daily trip logs that are used by vendors. In the before-ATSS period, one full-time employee was needed for hardware operation. An additional hardware operator was hired in the after-ATSS period, partly as a result of the ATSS implementation. The computing facilities used by OUTREACH expanded significantly in the after-ATSS period, due to the installation of new servers, work stations and peripherals needed to support the ATSS. This has called for an additional hardware operator who has a higher level of technical skills on computer hardware operation.

There was another factor not related to the ATSS that might have also contributed to OUTREACH hiring the additional hardware operator in the after-ATSS period. Since 1993, OUTREACH has expanded its service to seven days a week. This requires the scheduling system to operate on weekends, as well as seven-day-a week oversight of the computers. The second hardware operator has made it possible to accommodate all of these.

Paratransit Software Engineer

OUTREACH created a position of software engineer (or programmer) specifically as a result of the ATSS implementation. The software engineer performs the following tasks:

* Integration of the DGD and ATSS with OUTREACH's existing business management system on the AS/400 platform; this required familiarity of the ATSS software and knowledge of computer systems.
* Fine-tuning of the ATSS after it became operational to make it compatible with OUTREACH's operations. The software engineer specified appropriate weightings of vehicle distance, vehicle travel time, and passenger travel time for use in the ATSS's optimization algorithm. He also developed vehicle scheduling for subscription trips, taking into consideration driver shifts of varying lengths.

Employing a skilled software engineer proved to be the key to the demonstration project. Installing the ATSS required major efforts from this software engineer to integrate the ATSS with OUTREACH's existing AS/400 computer system.

Management Information System (MIS) Support Services

MIS support services include personnel providing services to support day-to-day operation of the paratransit system. Support services include administrative and accounting tasks. The number of personnel in this category decreased from four in the before-ATSS period to three in the after-ATSS period. This reduction was directly related to the ATSS deployment. By automating scheduling and vehicle assignment tasks using the ATSS, OUTREACH was able to eliminate the need for an employee who had performed such tasks

semi-manually before the ATSS deployment. This resulted in reorganization of the responsibilities of other employees providing MIS support services. In particular, the following tasks performed in the before-ATSS period were no longer needed after the ATSS became operational:

Manual building of shared rides. In the before-ATSS period, one full-time employee grouped passenger trips with similar origin and destination pairs together to form shared rides (termed multiples). This task required a person with good knowledge of the service area and its road network. Once multiples were so constructed, they were reentered into the computer to be included in vehicle trip logs for the next day. It took an average of about 5 minutes (for an experienced staff member, with knowledge of the service area) to build each multiple. Therefore, an average of 96 multiples could be built in an S-hour day.

With the ATSS, multiples are now built automatically by the ATSS software. Therefore, the OUTREACH employee who built multiples manually was no longer needed, and the position was eliminated. Because of the expansion of the service area (during and after the time that the ATSS became operational), it would have been impossible for OUTREACH to continue building multiples manually. This is because the trip volume sharply increased, and the person responsible for this task in the before-ATSS period could not be expected to have good enough knowledge of the newly added service areas for multiple building purposes.

Accounting tasks on the MIS business system. In the before-

ATSS period, one full-time employee was needed to do accounting tasks. These involved programming on the RS6000 business system that preceded the AS/400 business system, to generate client statements and bills for sponsoring agencies (SCVTA and Caltrans). This position was phased out when the business system transitioned from the RS6000 to the AS/400 platform, and the ATSS now allows OUTREACH to automate these accounting functions. MIS service staff calculate and revise vendor fares within the ATSS software, making use of its capability to display historical trip data. This is a new function provided by the ATSS which was customized for OUTREACH. Therefore, the ATSS partly resulted in the elimination of this position.

The ATSS also created new tasks that were not performed in the before period. These new tasks, divided between the remaining MIS support staff and one new employee, include:

Geocoding of addresses. The ATSS requires addresses of trip origins and destinations to be coded in terms of latitude and longitude coordinates before the trips can be scheduled in the ATSS scheduling system (i.e., geocoding of addresses). During the DGD and ATSS installations, a geocode specialist was hired to geocode problematic addresses. This geocode specialist was not required shortly after the ATSS became operational.

Auditing of vehicle assignments. OUTREACH created one part-time position to audit vehicle routes built by the ATSS (termed "schedule analysis" by OUTREACH). Because the old system did not build explicit vehicle routes, this task did not exist in the

before-ATSS period. The task involves checking vehicle assignments for the next day, and making corrections where the auditor thinks vehicle routes can be made more efficient.

Overall, the number of employees in the category of MIS support staff decreased from four to three, and many tasks are now automated by the ATSS. OUTREACH managers stated that the staff now face heavy work loads, and that additional staff are needed in the future to help with auditing vehicle assignments, and to process an increased number of client accounts.

OUTREACH managers

The number of OUTREACH managers decreased from four in the before-ATSS period to two in the after-ATSS period, primarily as a result of the budget constraint during the after-ATSS period. The ATSS helped OUTREACH to soften the blow of having two fewer managers. The tasks performed by an assistant manager in the before-ATSS period included the generation of daily and weekly operating reports (including summaries of the number and types of trips served, the number of late vehicles, and any incidents reported). The ATSS automates many of these report generation functions. We estimated that the managerial staff time replaced by the ATSS was about one-quarter of a full-time manager position. The remainder of the managerial tasks performed by the two managers who left OUTREACH, were redistributed between the two remaining managers.

To summarize the impacts of the ATSS on the OUTREACH's

workforce, the ATSS helps to streamline the tasks of booking trips (particularly subscription trips). The ATSS significantly affected the skill requirements of OUTREACH's personnel. A highly skilled software engineer, with the aid of an extra hardware operator, was the key to the ATSS operation. The ATSS automates many tasks previously performed by MIS support staff (e.g., building shared rides), but also created new tasks that did not exist before (e.g., geocoding of addresses).

On balance, the ATSS has helped OUTREACH to cope with sharp increases in the trip volume without having to appreciably increase the size of its total employees.

ATSS IMPACTS ON COSTS

An analysis of the impacts of the ATSS on the costs of OUTREACH's paratransit operation involves comparing the costs between the before-ATSS and after-ATSS periods. Cost data were obtained from several sources: OUTREACH's database; OUTREACH's documents and reports (e.g., monthly reports on operating statistics, quarterly cost reports prepared for the Metropolitan Transportation Commission, and summaries of the capital expenses for the advanced paratransit demonstration project); and interviews with OUTREACH managers.

Components of Costs

The ATSS costs consist of capital and operating costs (Figure 3.1). The capital cost includes one-time expenditures associated

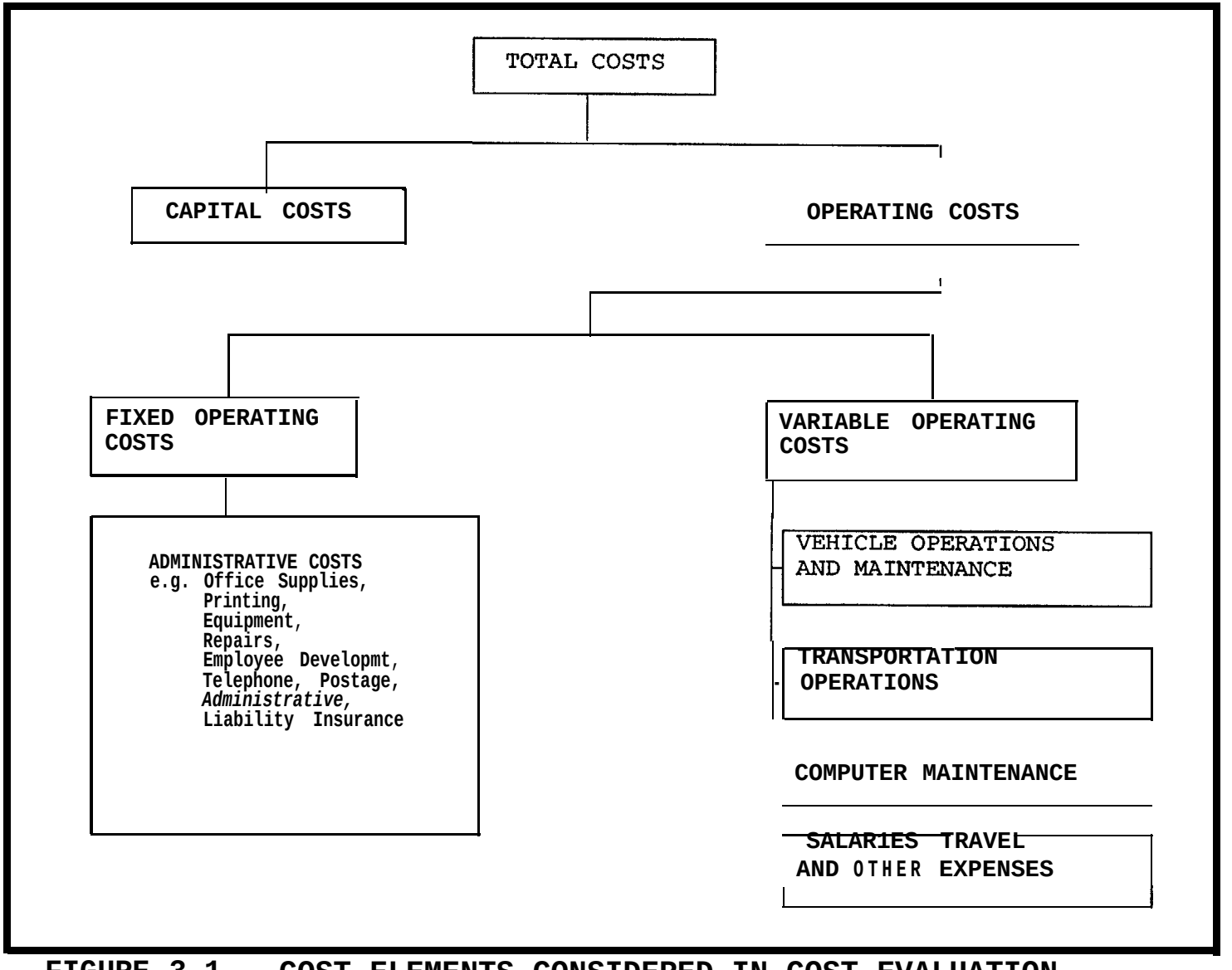


FIGURE 3.1 COST ELEMENTS CONSIDERED IN COST EVALUATION

with the acquisition, integration, and implementation of the ATSS and DGD. Operating costs are the ongoing costs, which may be fixed or variable. Fixed operating costs are independent of the level of output produced and consumed (e.g., passenger trips, passenger miles). It includes administrative expenditures such as those detailed in Figure 3.1. Variable operating costs are usually sensitive to the level of output produced or consumed. Variable operating costs include: vehicle operations and maintenance, transportation operations, computer costs, salaries, travel and other expenditures.

Corrections of Costs Due to Inflation

Data on capital costs, administrative expenses, and computer expenses were corrected for inflation using the Producer Price Indices published for 1993-1994. Therefore, all costs in this chapter are based on 1993 costs. Inflation rates of 0.7% and 1.4% were used for computer and administrative expenses respectively. Salary expenditures were not corrected for inflation because the average salary per employee did not change over the course of the evaluation period.

Capital Costs

The capital cost of the ATSS consists of the DGD, the ATSS hardware/software, integration of the software, and project management (Table 3.3).

TABLE 3.3 SUMMARY OF CAPITAL COSTS OF ATSS

YEAR	ESTIMATED COSTS NOT INCLUDED IN ATSS CAPITAL COSTS *		ATSS CAPITAL COSTS	
	1992-1993	1994-1995	1994	1995
S/400 Acquisition & Implementation	$174,656	$23,552		
Hardware	$87,000	$22,250		
Software	$31,500	$1,302		
Outreach Staff	$56,156			
Digital Geographic Database **		$4,000		
Automated Trip Scheduling System			$148,754	$17,134
Hardware & PC Software			$62.651	$7.567
UMA Software			$86,103	$9,567
Software Integration			$27,051	$76,734
Budgeted Costs			$27,051	$42,564
Cost not included in budget				$34,170
Project Management			$9,747	$33,743
Budgeted Costs			$9,747	$11,393
Cost not included in budget				$22,350
OTAL CAPITAL EXPENDITURES	$174,656	$27,552	$185,552	$127,611
OTAL COSTS (1993 Dollars) **			$184,262	$125,843
OTAL ATSS CAPITAL COST (1993 Dollars)			$310,105	

Notes:

* Relevant figures include 8.25% sales tax.

** Digital Geographic Database was donated; estimated value is given.

*** Total annual costs are adjusted using an average 0.7% inflation rate.

Digital Geographic Database (DGD)

The DGD was installed on the ATSS file server and required no extra hardware. Because the DGD was donated to the demonstration project by Navigation Technologies (NavTech), it was not included in the ATSS's capital cost. Its estimated value is about $4,000.

Paratransit Business System

OUTREACH operates the Integrated Paratransit Business System (IPBS) to assist in the paratransit operation management. The IPBS contains the client information database as well as computer programs used for accounting and reporting. The functional relationship between the IPBS and OUTREACH's other hardware components is shown in Figure 3.2.

Prior to the start of the ATSS deployment, OUTREACH had upgraded the IPBS hardware from an IBM System/36 to an IBM AS/400. Because the purchase of the AS/400 was made independent of the ATSS deployment, its purchase price was not included in the capital cost of the ATSS. However, some conversion of data and programs was necessary. Funding for the upgrade was provided by the Metropolitan Transportation Commission (MTC), private foundations and Caltrans[3]. The upgrading was completed after the start of the ATSS demonstration program.

The cost of the IPBS upgrade to the AS/400 platform was $198,044 (1993 Dollars). This included the hardware and software

[3] Santa Clara County Transit District, Project Proposal, July 1993.

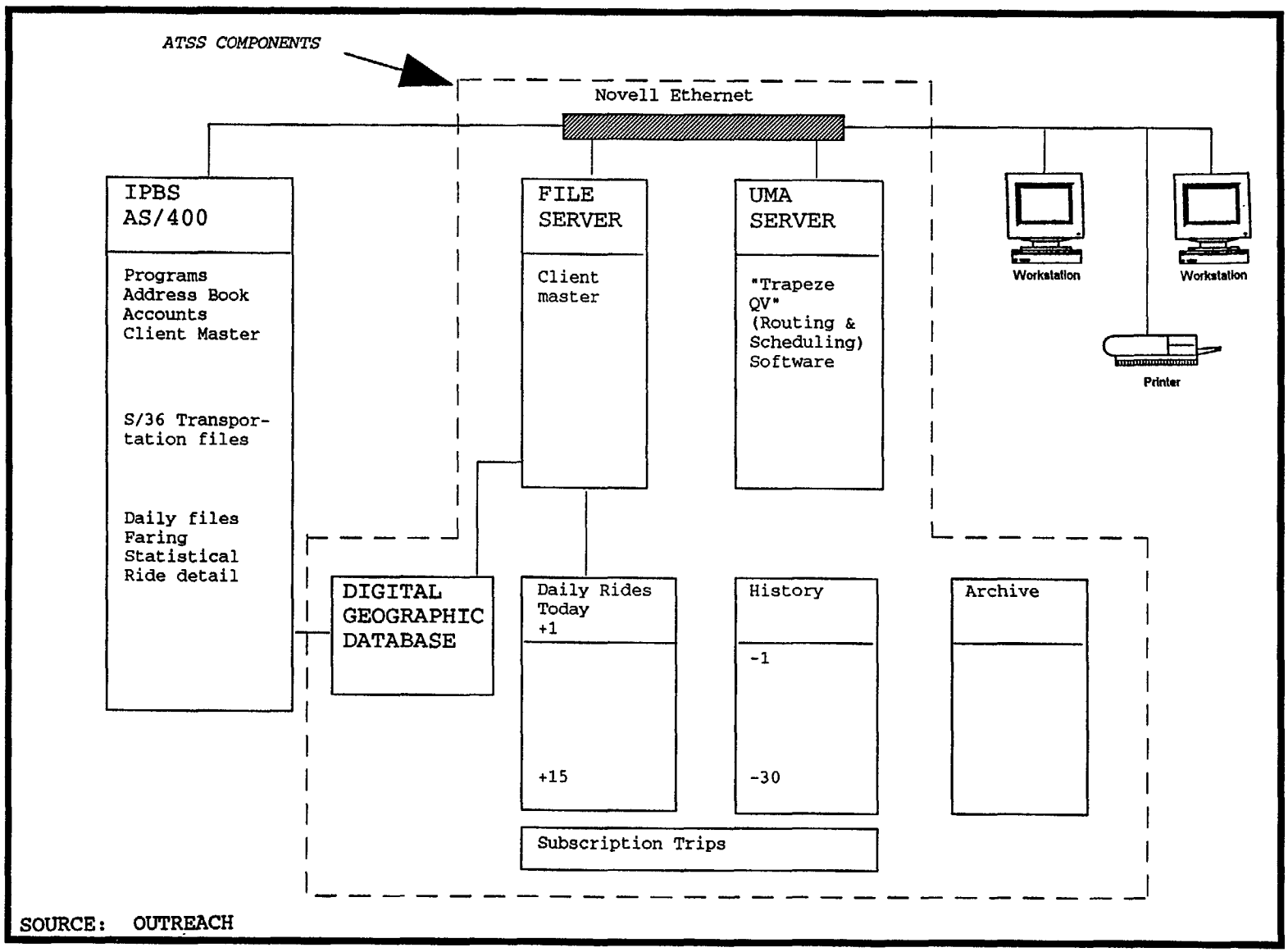


FIGURE 3.2 HARDWARE AND SOFTWARE COMPONENTS OF SCHEDULING SYSTEM

as well as estimated OUTREACH staff time (Table 3.3). The ATSS interfaces extensively with the IPBS, and extra equipment and personnel resources were needed for the integration of the IPBS with the ATSS and DGD.

Automated Trip Scheduling System (ATSS)

The ATSS consists of hardware and software components, shown in Figure 3.2. Hardware components include two new servers. The file server, installed on a Compaq Proliant 2000, maintains the client database and the trip records for the next fifteen days. The ATSS software, which was installed on a Hewlett Packard Pentium 60 personal computer, operates as a client server. The IPBS, file server and ATSS server are connected with each other via a Novell Ethernet local area network. The total cost for the two new servers and the connecting network was $69,678.

The ATSS software is a proprietary product developed by UMA Engineering of Toronto, Canada, and marketed under the product name Trapeze QV. The software performs trip booking, schedule optimization, real-time inquiry into vehicle and client schedules, and reporting functions. The software was purchased and installed at a cost of $94,939. The combined hardware and software costs of the ATSS totalled $164,617, or about 53% of the total capital cost of the demonstration project.

Software Integration

Extensive programming was needed to integrate the ATSS's

hardware and software with OUTREACH's existing computer systems. OUTREACH's existing IPBS contains various utilities and programs used for fare calculations, updating client accounts and other accounting functions. Since these functions do not exist within the proprietary ATSS software, they needed to be accessed by the ATSS software via the Ethernet network. The DGD also had to be integrated with the AS/400 computer. Software integration tasks were performed by private consultants hired by OUTREACH between May 1994 and May 1995. The total cost of software integration was *$102,533* (or 33% of the total capital costs of the demonstration project). It is noted that the final cost of the software integration was about one-third higher than an initial estimate.

Project Management

The project management cost, which included consultancy fees and in-house management, totalled $42,955. This included a cost overrun of $22,040 over budget. The outside consultants had to remain on site longer than initially anticipated, mostly to solve the problems encountered with the AS/400 and ATSS interface during the ATSS start-up.

Annualized Capital Cost

As shown in Table 3.3, the total capital cost for the ATSS was $310,105 (1993 Dollars). The annualized amount of this cost is $53,592, assuming a useful life of 7 years (which was based on the estimated useful life of OUTREACH's computer equipment) and a 5%

discount rate. For the first year of ATSS operation (1995-1996), the annualized capital cost of the ATSS was estimated to be $0.17 per passenger trip, or $0.03 per passenger mile.

Fixed Operating Expenditures

Figure 3.3a shows fixed, variable, and total operating expenditures by quarter from July 1993 through March 1996. Total fixed operating costs remain essentially unchanged between the before-ATSS and after-ATSS periods. Fixed operating expenditures include all administrative expenditures (e.g., office equipment, telephone and postage), and liability insurance. Expenditures related to the operation of the ATSS and salaries of administrative personnel are considered as variable operating expenditures. The fixed operating expenditure as the percent of the total operating expenditure decreases from 18% in July 1993 to 5% in January 1996, as the latter increased.

On a per-passenger mile basis, administrative costs decreased from $0.30 in the before-ATSS period to $0.20 in the after-ATSS period.

Variable Operating Expenditures

OUTREACH's variable operating expenditures (shown in Figure 3.3b) consist of computer expenses, salary expenses, and transportation operating expenditures (or payments OUTREACH makes to transportation vendors for the services they provide). The figure indicates steady increases of variable operating costs

FIGURE 3.3(a)
FIXED AND VARIABLE OPERATING COSTS

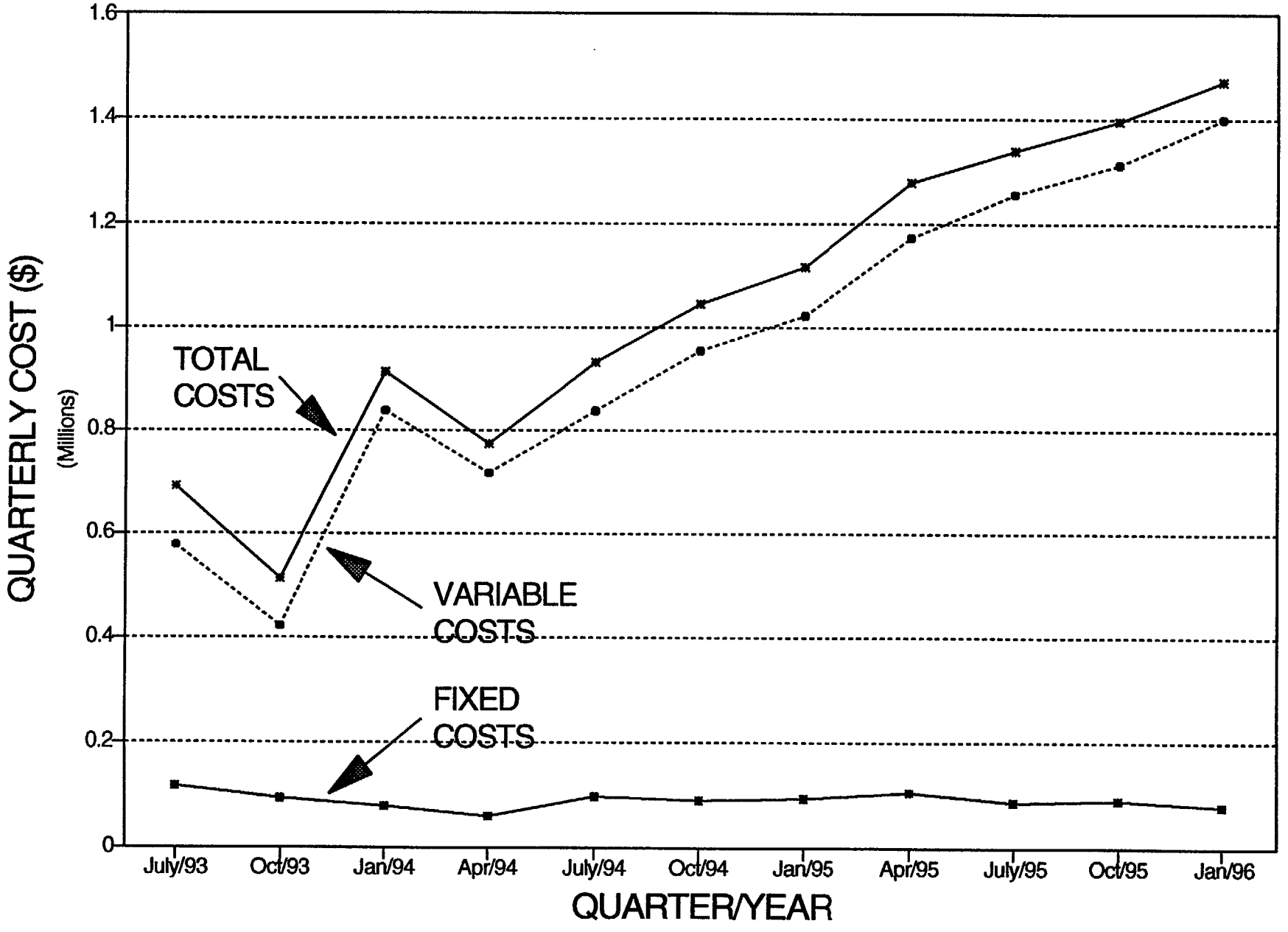
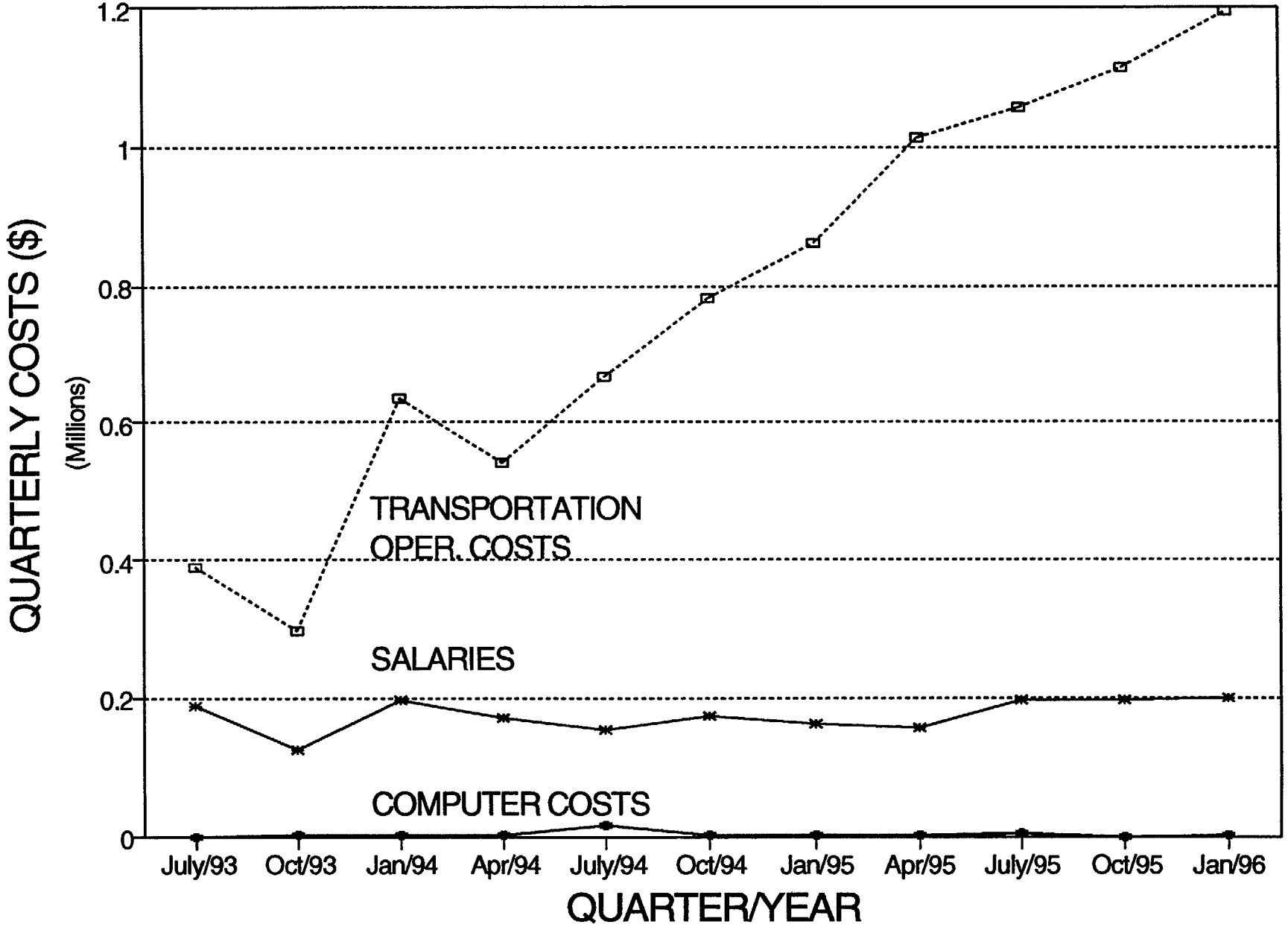


FIGURE 3.3(b)
VARIABLE OPERATING COSTS



during both the before-ATSS and after-ATSS periods, primarily as a result of the growth in the number of passenger trips and passenger miles.

The increase in variable operating expenditures is attributable to an increased transportation operating cost. Annual salaries, computer expenses, and transportation operating expenditures for the before-ATSS and after-ATSS periods are shown in Table 3.4.

The impacts of the ATSS on each variable cost component are examined below.

Salary Expenses

Salaries are mostly OUTREACH employees' salaries and benefits. OUTREACH's annual salary expenses increased from $672,334 in the before-ATSS period to $735,776 in the after-ATSS period, primarily due to the hiring of five additional telephone schedulers to accommodate increased demand for the service. On a per-passenger mile basis, salary expenditures decreased from $0.59 in the before-ATSS period to $0.42 in the after-ATSS period.

Table 3.5 shows the number of OUTREACH employees in each job category as a result of the ATSS implementation. The table indicates that the ATSS deployment led to a decrease of one employee in the after-ATSS period relative to the before-ATSS period. This position was an employee who built multiples manually in the before-ATSS period. The salary expense saved by this position is about $30,600 per year. The ATSS deployment made it

TABLE 3.4 OPERATING COSTS IN BEFORE AND AFTER ATSS PERIODS

COST CATEGORY	ANNUAL EXPENDITURE		% CHANGE
	BEFORE ATSS	AFTER ATSS	
NON-TRANSPORTATION COSTS			
Administrative	$346,275	$349,636	+0.9%
Computer Maintenance	$15,803	$7,384	-53.3%
Salaries & Other	$672,334	$735,776	+9.4%
Total non-transportation costs	$1,034,412	$1,092,796	+5.6%
Annual Passenger Miles	1,139,111	1,769,165	+55.3%
Annual Passenger Trips	240,975	315,972	131.1%
Non-transp. Cost per Passenger Mile	$0.91	$0.62	-31.9%
Non-transp. Cost per Passenger Trip	$4.29	$3.46	-19.4%
TRANSPORTATION COSTS			
Taxi vendor payments	$1,878,908	$2,159,404	+14.9%
Van vendor payments	$804,814	$1,939,816	+141.0%
Annual Passenger Miles: Taxi	974,320	1,247,316	+28.0%
Annual Passenger Miles: Van	164,791	521,849	+216.7%
Transp. Cost per Pass. Mile: Taxi	$1.93	$1.73	-10.2%
Transp. Cost per Pass. Mile: Van	$4.88	$3.72	-23.9%

TABLE 3.5 ESTIMATED IMPACTS OF ATSS ON OUTREACH'S SALARY EXPENSES

JOB CATEGORY	ADDITIONAL NUMBER OF EMPLOYEES REQUIRED	ADDITIONAL SALARY EXPENSES PER YEAR DUE TO ARSS
Telephone Schedulers	0	
Hardware Operators	0	
MIS Support Services	-1	-$30,600
Software Engineers	+1	+$45,600
Managers	0	
TOTAL	0	+$15,000

necessary for OUTREACH to employ one software engineer that would otherwise not have been needed. The software engineer's salary is about $45,600 per year.

OUTREACH hired an additional hardware operator in the after-ATSS period, but reduced the number of managers from four to two. As previously mentioned, these actions were not primarily related to the ATSS deployment, and the salary changes are therefore not attributed to the ATSS.

Table *3.5* shows that an increase of $15,000 per year in salary expenses can be attributed to the ATSS deployment. This represents about 2% of the total salary expenses in the before-ATSS period.

Computer Maintenance Costs

Computer maintenance costs include payments made to service providers for routine maintenance of OUTREACH's computer hardware and software. It does not include one-time payments for the installation of new equipment, as they are already included in the ATSS capital costs. Therefore, computer maintenance costs capture the costs associated with running the computer systems on a day-to-day basis. Table 3.4 shows that the computer maintenance cost in the first year of ATSS operation was significantly lower than that in the before-ATSS period. Annual maintenance costs decreased from *$15,803* to $7,384. This is because little maintenance was necessary for the newly installed systems. The long-term maintenance needs of the ATSS hardware and software are not known at this time. The contribution of this cost category to operating

expenses is very small (less than 1%).

Vehicle Operation and Maintenance Costs

OUTREACH incurred vehicle operation and maintenance costs up to October 1993 while operating its own van fleet. Since then, OUTREACH has contracted private van vendors to provide all wheelchair accessible transportation.

Vehicle operation and maintenance costs include operating expenditures such as fuel and routine maintenance. Costs in this category are not analyzed separately but are included with the payments made to vendors. In the following discussion, the transportation operation cost refers to the sum of vendor payments and vehicle operations and maintenance (where applicable).

Transportation Operating Cost

Among all operating-cost components, the transportation cost (or vendor payments) is the most substantial, accounting for up to 78% of the total operating cost. The magnitude of vendor payments grew substantially between the before-ATSS and after-ATSS periods. However, on a per-passenger mile basis, payments to taxi vendors decreased from $1.93 per passenger mile in the before-ATSS period to $1.73 in the after-ATSS period (a 10.4% decrease), and payments to van vendors decreased from $4.88 per passenger mile to $3.72 per passenger mile (a 23.9% decrease). These decreases in unit vendor payments in the after-ATSS period relative to the before-ATSS period could conceivably be affected by a number of factors:

- Increases in total passenger-miles as a result of higher trip volumes and longer average trip length in the after-ATSS period.
- Changes in the unit contract prices that OUTREACH renegotiated with vendors.
- The ATSS use.

In order to determine the impacts of the ATSS on vendor payment per passenger mile, the effects of the other two factors must be factored out. The results of this analysis are presented below, after a description of vendor-payment models that OUTREACH uses to calculate the payments due to each vendor.

Models for Calculating Vendor Payments

As previously mentioned, taxi vendors provide service exclusively for ambulatory users and wheelchair users who are able to transfer to a car seat. Taxi vendors are paid the standard taxi fare, minus a discount negotiated between OUTREACH and each vendor (which varies between 10% and 20% depending on the taxi company).

The van mode includes a diverse set of operations and vendors, and differs from the taxi mode in that it carries wheelchairs. The van mode includes accessible van service, group van service, and mixed van service. Most wheelchair-bound clients were transported by accessible vans up to August 1995. Accessible van service is generally more expensive than taxi service because it uses more specialized vehicles and van drivers provide more help to riders. Group van service uses similar vehicles as accessible van service,

but is operated under contract with certain agencies for transporting groups of clients who may be ambulatory or wheelchair users. Mixed van service, which replaced the accessible van service by March 1996, utilizes the same wheelchair accessible vehicles for transporting both ambulatory and wheelchair passengers, but most of the vehicles are minivans instead of full-sized vans. The cost of this type of service is somewhat lower than accessible van service.

OUTREACH calculates the monthly payment for each vendor using a standard formula, which is based on a fixed cost for every passenger or group of passengers (termed a flag drop) plus a cost per mile travelled by the vehicle with passenger(s) on board. Multiples receive only one flag drop.

The amount paid to vendor i for service rendered in a particular time period is calculated from the following formula:

$$\text{Payment}_i = c_{1i}*(\#\text{ of veh trips}), + C_{2i}*(\text{veh revenue miles})_i \quad \ldots \text{Eq.3.1}$$

where C_{1i} = Unit price per vehicle trip for vendor i

C_{2i} = Unit price per vehicle revenue mile, vendor i

OUTREACH defines a vehicle trip as a trip during which one or more OUTREACH passengers are transported, from the first pick-up until the vehicle is empty again. It defines vehicle revenue miles as the miles travelled with clients on-board, thus excluding deadheading miles.

Unit prices per vehicle trip and per vehicle revenue mile were specified in contracts between OUTREACH and the vendors. They varied among vendors and changed over the course of the study period. Further, OUTREACH generally imposes penalties on vendor payments in case of late vehicles. OUTREACH pays premiums to van vendors for pickups after 8 pm, and to taxi vendors if drivers have to handle wheelchairs. Examination of vendor payment records revealed that such premiums and penalties were approximately proportional to the number of vehicle trips, and that vendor premiums and penalties were relatively small (less than six percent of vendor payments) in both the before-ATSS and after-ATSS periods. Therefore, we incorporated vendor premiums and penalties in the C_{1i}' in the above equation (3.1).

Table 3.6 summarizes estimated average contract unit prices for taxis and vans, for the before-AT% and after-ATSS periods.

Estimated Unit Contract Price Per Vehicle Revenue Mile (c_2)

For each taxi and van mode, the average C_{2i} was calculated by weighting the known contract price for each vendor by the number of vehicle revenue miles. For taxis, average values for the before-ATSS period (c^b_{2T}) and the after-ATSS periods (c^b_{2T}) were both $1.47 per vehicle revenue mile. For van vendors, the average value in the before-ATSS period (c^b_{2V}) was $1.67 per vehicle revenue mile, and that in the after-ATSS period (c^a_{2V}) was $2.56 per vehicle revenue mile.

TABLE 3.6 AVERAGE CONTRACTED UNIT PRICES: TAXI AND VAN MODES

MODE	Per Flagdrop (c_1) (Source: {1})		Per Vehicle Revenue Mile (c_2) (Source: {2})	
	Before Period	After Period	Before Period	After Period
VAN MODE	c^b_{1V} =$18.61	c^a_{1V} = $0.00	c^b_{2V} = $1.67	c^a_{2V} = $2.56
TAXI MODE	c^b_{1T} = $2.84	c^a_{1T} = $2.46	c^b_{2T} = $1.47	c^a_{2T} = $1.47

Sources: **(1) Estimated by regression from vendor payment data**
{2} Weighted average of contract unit prices per vehicle revenue mile (weighted by vehicle revenue miles)

Estimated Unit Contract Price Per Vehicle Trip (c_1)

For the taxi mode, the estimated average value in the before-ATSS period (c^b_{lT}) was $2.84 per vehicle trip, and that in the after-ATSS period (c^a_{lT}) was $2.46 per vehicle trip. For the van mode, the value in the before period (c^b_{lV}) was $18.61 per vehicle trip, and that in the after period (c^a_{lV}) was zero. This is due to the fact that contracts with van vendors were renegotiated to decrease the contract unit prices per vehicle trip and to increase the contract prices per vehicle mile.

Savings in Vendor Payments in After-ATSS Period due to Renegotiated Contracts

The savings in payments to van vendors in the after-ATSS period due to renegotiated contract unit prices are estimated as follows:

$$\text{Savings} = (c^b_{lv} - c^a_{lv})(\text{veh trips}) + (c^b_{2v} - c^a_{2v})(\text{veh miles})$$
$$= \$246,357 \quad \text{per year.}$$

Similarly, the savings in payments to taxi vendors in the after period due to renegotiated contract unit prices was $72,783 per year. These translate into the savings of $0.47 per passenger mile for vans, and $0.06 per passenger mile for taxis.

Effects of Higher Passenger-Miles of Travel

Next, an analysis was performed to determine whether there was a significant effect of higher passenger-miles of travel on the

unit vendor payment in the after-ATSS period, after having adjusted for the effect of renegotiated contract unit prices. This involved calculating "adjusted" vendor payments in the after period by applying the before-period contract unit prices, c^b_1 and c^b_2, to vehicle trips and vehicle miles of the after period. These "adjusted" vendor payments in the after period represent what after-period payments would have been if unit contract prices had not been renegotiated. Before-period and adjusted after-period vendor payments for taxis and vans are shown in Figure 3.4.

A regression analysis was performed using monthly vendor payments per passenger mile in the before-ATSS period, adjusted vendor payments per passenger mile in the after-ATSS period, and passenger miles for taxi and van modes. The vendor payment per passenger mile was the dependent variable; passenger miles and the before/after period were candidate independent variables. The regression model and results are described in Appendix 3A. The estimated regression models are:

For the taxi:

$$Y = 1.93 - 0*14*(X)$$

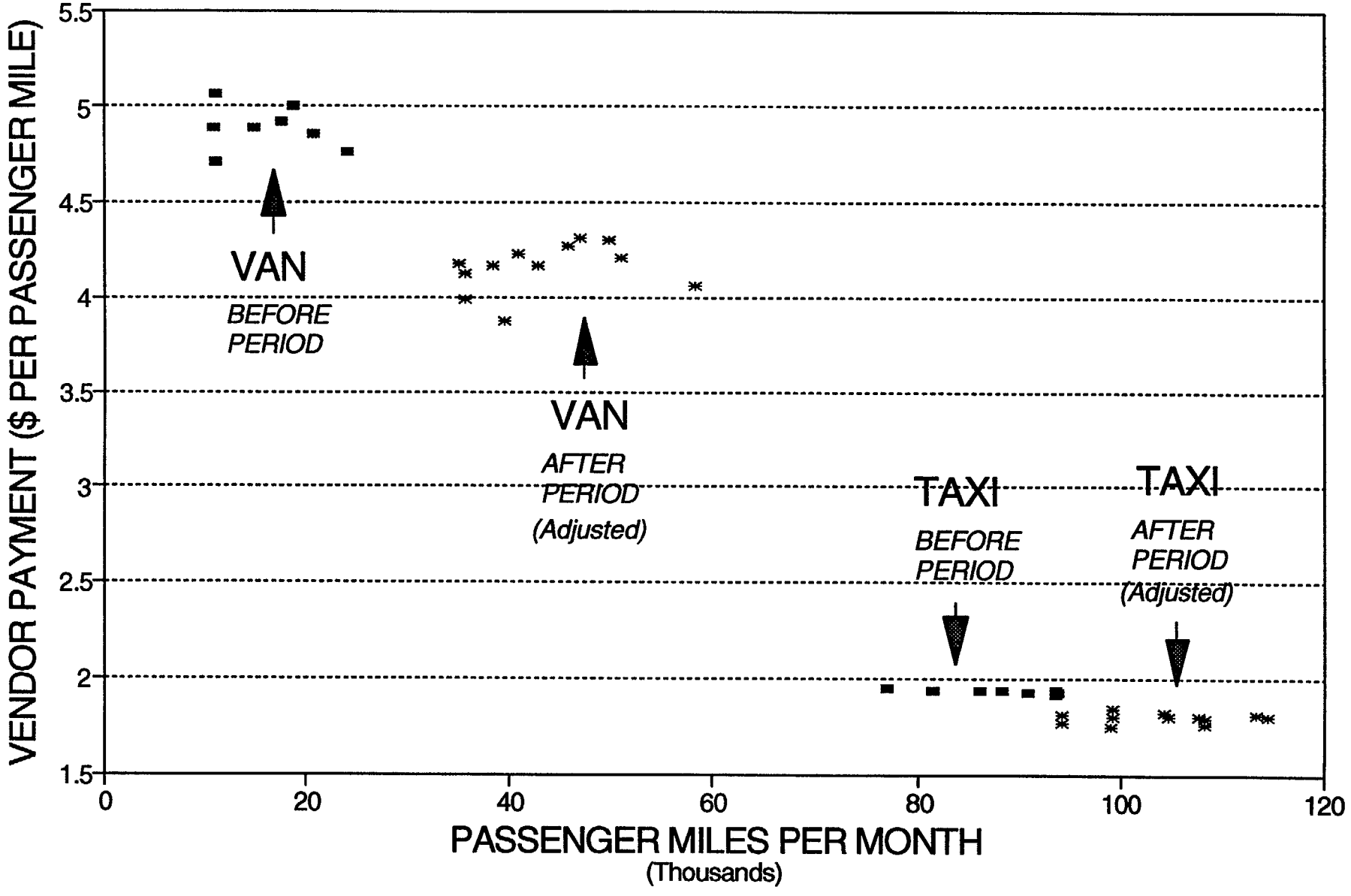
. ..Eq 3.2

For the van:

$$Y= 4.89 - 0.71*(X)$$

. ..Eq 3.3

FIGURE 3.4
VENDOR PAYMENTS PER PASSENGER MILE



where Y = vendor payment per passenger mile, and

x = 0 for before period; 1 for after period.

R^2 values were 0.92 and 0.89 for equations 3.2 and 3.3. The sample size was 20 for each regression. The estimated coefficient of X was significant in both equations at any reasonable value of a! (t-values of -13.9 and -12.9 for equations 3.2 and 3.3, respectively). On the other hand, the passenger-mile was found to be a non-significant variable for both the taxi and van modes. This implies that vendor payments per passenger mile (after having adjusted for the effect of renegotiated contract prices) was not affected by higher passenger miles served in the after-ATSS period.

The results from the above two analyses suggest that the renegotiated unit contract prices between OUTREACH and the vendors were possible, possibly in part due to expectations by the vendors of a larger scale operation. If so, the benefits due to the renegotiated unit contract prices implicitly include the portion of the economies-of-scale benefit that was passed through to OUTREACH.

Effects of ATSS

In the above regression models (equations 3.2 and 3.3), the before-ATSS period represents the absence of the ATSS, and the after-ATSS period represents the ATSS use. Equations (3.2) and (3.3) imply that the ATSS significantly affects the vendor payment per passenger mile, after accounting for the effect of renegotiated contract unit prices.

Savings in monthly vendor payments due to the ATSS are

indicated by the estimated coefficients of X in equations (3.2) and (3.3). The savings were $0.71 and $0.14 per passenger mile for the van and taxi modes, respectively. The savings in the taxi vendor payment per passenger mile due to the ATSS represent 7% of the before-period payment, and the savings for the van mode represent 14% of the before-period payment. Table 3.7 summarizes the savings in vendor payments (per passenger mile) due to renegotiated contract unit prices and the ATSS use.

At the after-period level of passenger miles of 147,430 per month, the savings in vendor payments attributed to the ATSS use were estimated to be $45,428 per month, or about 13% of total vendor payments.

How Did ATSS Help to Reduce Transportation Cost?

To illustrate the manner in which the ATSS helped to lower the transportation cost, further analysis of its effects on the number of vehicle trips and vehicle revenue miles (reported by OUTREACH) was performed as follows.

The number of vehicle trips and vehicle revenue miles per month are divided by passenger miles, to express the amount of vehicle resources needed to serve one passenger mile, for the before and after periods (Table 3.8). Both quantities, for both the taxi and van modes, decreased significantly in the after period (t-tests, a=0.05). A larger reduction occurred in the number of vehicle trips per passenger mile (about 20% for vans and 13% for taxis), probably reflecting higher percent shared rides achieved as

TABLE 3.7 SAVINGS IN AVERAGE VENDOR PAYMENT PER PASSENGER WHILE IN AFTER ATSS PERIOD

MODE	TOTAL SAVINGS	SAVINGS DUE TO CHANGES IN CONTRACTED UNIT PRICES	SAVINGS DUE TO ATSS
VAN	$1.18	$0.47	$0.71
(% of Before Period)	(24%)	(12%)	(14%)
TAXI	$0.20	$0.06	$0.14
(% of Before Period)	(10%)	(3%)	(7%)

TABLE 3.8 **CHANGES IN VEHICLE TRIPS AND VEHICLE MILES PER PASSENGER MILE**
(Source: OUTREACH operational records)

	BEFORE ATSS	AFTER ATSS	% CHANGE	t-value
VEHICLE TRIPS PER PASSENGER MILE				
VAN	0.173	0.139	-19.7%	15.8
TAXI	0.159	0.139	-12.6%	12.6
VEHICLE MILES PER PASSENGER MILE				
VAN	0.998	0.951	-4.7%	3.4
TAXI	1.004	0.949	-5.5%	8.8
Number of months observed	8	12		

well as greater average passenger trip length in the after-ATSS period.

Table 3.8 also indicates that vehicle revenue miles per passenger mile decreased by about 5% for both taxi and van modes in the after period relative to the before period. The ATSS might have accomplished this in two ways. First, the ATSS has enabled a higher efficiency for routing vehicles between pickups and drop-offs. Second, the ATSS measures vehicle revenue miles more accurately than the old system; and OUTREACH managers believed that the old system tended to overestimate vehicle revenue miles.

To summarize the impacts of the ATSS on OUTREACH's annual paratransit costs, these impacts (Table 3.9) are:

(a) The annual total capital cost of the ATSS was $53,592. On a unit cost basis, the capital cost of the ATSS added $0.17 to the average cost of providing one passenger trip in the first year, or $0.03 to the average cost of providing one passenger mile. Generally speaking, the capital costs of implementing similar systems would depend on the level of computerization that was already in existence within the transit agency.

(b) The ATSS use resulted in significant savings in the unit vendor payment (per passenger mile). After adjusting for various policy changes, it was found that the estimated annual reduction in vendor payments due to the ATSS was $545,137 during the first year of ATSS operation. This represents about 10% of the annual operating costs for the after-ATSS period.

TABLE 3.9 SUMMARY OF IMPACTS OF ATSS ON ANNUAL COSTS

COST CATEGORY	ANNUAL EXPENDITURE			ESTIMATED IMPACT OF ATSS IN AFTER PERIOD (3)-(2)	% CHANGE {(3)-(2)} / {2}
	(1) BEFORE ATSS	(2) AFTER WITHOUT ATSS (EXPECTED)	(3) AFTER WITH ATSS (OBSERVED)		
Administrative	$346,275	(a) $346,275	$349,636	+$3,361	+0.9%
Computer Maintenance	$15,803	(a) $15,803	$7,384	-$8,419	-53.3%
Salaries & Other	$672,334	(b) $720,776	$735,776	+$15,000	+2.1%
Transportation: Taxi	$1,878,908	(b) $2,334,028	$2,159,404	-$174,624	-7.5%
Transportation: Van	$804,814	(b) $2,310,329	$1'939,816	-$370,513	-16.0%
TOTAL OPERATING COSTS	$3,718,134	$5,727,211	$5,192,016	-$541,917	-9.5%
ATSS CAPITAL COSTS	-	-	$53,592	+$53,592	-
TOTAL ANNUAL COSTS	$3,718,134	$5,727,211	$5,245,608	-$488,325	-8.5%
Annual Passenger Miles	1,139,111	1,769,165	1,769,165	-	-
Annual Passenger Trips	240,975	315,972	315,972	-	-
TOTAL COST PER PASS. MILE	$3.26	$3.24	$2.97	-$0.27	-8.4%
TOTAL COST PER PASS. TRIP	$15.43	$18.13	$16.60	-$1.53	-8.4%

NOTES:

(a) Expected costs in after period are equal to before period costs

(b) Expected after period costs are calculated by offsetting observed costs of after period by the estimated impact of the ATSS in the after period.

(c) The ATSS achieved the reduction in vendor payments by decreasing both the number of vehicle trips and vehicle revenue miles needed to serve one passenger mile. The ATSS has achieved a more efficient assignment of passengers to vehicles, leading to more shared rides than before. Also, the DGD/ATSS has helped to improve the accuracy with which vehicle miles travelled are measured, because distance calculations are now based on exact street distances instead of the grid system used before.

(d) The ATSS helps to reduce the total cost of the OUTREACH's paratransit operation (i.e., capital costs, vendor payments, plus other fixed and variable operating costs). Table 3.9 indicates that during the first year of the ATSS operation, estimated annual total cost savings of $488,325 occurred (relative to the expected total costs had the ATSS not been deployed). This represents the savings of $0.27 per passenger mile, or $1.53 per passenger trip.

VEHICLE PRODUCTIVITY

In July 1995 (five months after the ATSS was deployed), OUTREACH instituted a new policy requiring vendors to provide vehicles dedicated to OUTREACH clients for any given day. This means that dedicated vehicles can serve only OUTREACH clients during the time of day for which they are so designated. OUTREACH requires dedicated vehicles because the ATSS assigns passenger trips to specific vehicles to produce an explicit itinerary (i.e., sequences of pickups and drop-offs) for each vehicle. In the before-ATSS period, OUTREACH did not require vendors to provide

such dedicated vehicles, and the same vehicles usually served both OUTREACH and non-OUTREACH clients in any one day.

Measures of vehicle productivity examined include: the percent shared rides, vehicle revenue miles, vehicle deadheading miles, and average vehicle occupancies. OUTREACH provided data on the overall number of shared rides (or multiples), and monthly numbers of passenger trips taken by clients and companions. These data were used to evaluate the percent shared rides achieved in the before-ATSS and after-ATSS periods. Shared ride data provided by OUTREACH is referred to as OUTREACH's "aggregate" data.

In addition, we also conducted observations onboard a sample of taxis and vans in the before-ATSS period (for two weeks in July 1994) and the after-ATSS period (for two weeks in July 1995, plus another three weeks in July 1996). Information collected through on-board observations (referred to as "onboard sample" data) included the amount of miles travelled by vehicles in deadheading and in revenue service, and the number of clients served on each vehicle trip. On each observation day, the vehicle itinerary was recorded by an observer traveling on-board the vehicle. Sample sizes were 66 vehicle trips[4] in the before-ATSS period (26 for vans and 40 for taxis), and 146 vehicle trips in the after-ATSS period (33 for vans and 113 for taxis).

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[4] A vehicle trip is measured from when an empty vehicle starts travelling (in deadhead) towards the next pickup, and ends as soon as the vehicle is empty again after all passengers have been dropped off.

Compliance to Dedicated Vehicle Policy

Table 3.10 shows the average daily number of miles travelled by taxis and vans while serving all clients (OUTREACH plus non-OUTREACH clients), and while serving OUTREACH clients exclusively, for the before-ATSS and after-ATSS periods. The table was derived from data collected during onboard observations. The total vehicle miles include vehicle deadheading miles while in revenue service. The average percentage of miles travelled in dedicated OUTREACH service increased from 86% in the before-ATSS period to 97% in the after-ATSS period for the taxi vendor, and increased from 67% in the before-ATSS period to 77% in the after-ATSS period for the van vendor. The increase in the percentage of dedicated miles is statistically significant (at a 0.05 significance level) for the taxi vendor but not for the van vendor.

These results suggest that taxi vendors appear to have essentially complied with OUTREACH's dedicated-vehicle policy, and that van vendors might have provided a lower level of dedicated vehicles for OUTREACH clients than taxi vendors during the first year of ATSS operation.

Vehicle Revenue Miles

Vehicle revenue miles are vehicle miles travelled with OUTREACH clients on-board. Vehicle revenue miles from on-board observations are shown in Table 3.11. Vehicle revenue miles per passenger trip were calculated by dividing vehicle revenue miles for each vehicle trip by the number of OUTREACH clients carried

TABLE 3.10 USE OF VEHICLES DEDICATED TO OUTREACH SERVICE
(Source: Sample data, On-board Observations)

	DAILY AVERAGE PER VEHICLE			
	ALL MILES TRAVELLED	DEDICATED VEHICLE MILES	AVG % OF MILES DEDICATED	
TAXI VENDOR				
BEFORE ATSS	117.4	101.0	86%	t-value = -2.2'
AFTER ATSS	146.0	142.0	97%	
VAN VENDOR				
BEFORE ATSS	129.6	87.6	67%	t-value = -1.1'
AFTER ATSS	127.8	99.0	77%	

TABLE 3.11 VEHICLE REVENUE MILES
(Source: Sample Data, On-board Observations)

	REVENUE MILES PER PASSENGER TRIP				
	VAN BEFORE	VAN AFTER	TAXI-A BEFORE	TAXI-A AFTER	TAXI-B AFTER
AVERAGE	5.565	5.234	4.350	5.513	5.654
STANDARD DEVIATION	3.867	3.146	2.759	3.985	4.263
NO OF VEHICLE TRIPS OBSERVED	26	33	40	52	61
FREQUENCY DISTRIBUTION					
< 2	11.5%	21.2%	27.5%	23.1%	19.7%
2-4	26.9%	18.2%	32.5%	26.9%	26.2%
4-6	26.9%	21.2%	17.5%	17.3%	23.0%
> 6	34.6%	39.4%	22.5%	32.7%	31.1%
TOTAL	100%	100%	100%	100%	100%

during that vehicle trip. The table indicates that average vehicle revenue miles per passenger trip (observed during onboard observations) decreased slightly from 5.57 to 5.23 for the vans, but increased slightly from 4.35 to 5.51 for the taxis. Neither of these changes are statistically significant at the 0.05 significance level. Average vehicle revenue miles per passenger mile for sampled vehicles observed during onboard observation cannot be estimated because it was difficult to measure passenger miles during onboard observations that would correspond to the definition of "passenger miles" used by OUTREACH (see Table 3.1). Please note that the previously presented vehicle revenue miles per passenger mile (which were based on data obtained from OUTREACH's database) decreased by 5% in the after-ATSS period relative to the before-ATSS period. Vehicle revenue miles per passenger mile is likely to be a better measure of vehicle productivity because of longer average passenger trip length in the after-ATSS period due to the expansion of the OUTREACH service area after the ATSS implementation.

Vehicle Deadheading

Vehicle deadheading refers to vehicle miles of travel without OUTREACH clients onboard, and represents the amount of vehicle resources that vendors are not explicitly compensated for by OUTREACH. Changes in vehicle deadheading between the after-ATSS and before-ATSS periods can conceivably be influenced by at least two factors: (a) OUTREACH's expansion of the service area in the

after period, which was likely to increase both average vehicle and passenger trip lengths; and (b) the ATSS's scheduling algorithm coupled with OUTREACH's dedicated vehicle requirement.

Possible impacts of the ATSS on vehicle deadheading was assessed using sample data collected in the onboard observations. Vehicle deadheading miles per passenger trip was measured (i.e., vehicle deadheading miles for each vehicle trip divided by the number of passengers served by that vehicle trip). The miles travelled in deadheading toward a pick-up is attributed to that vehicle trip.

Table 3.12 shows observed vehicle deadheading miles per passenger trip for vans and taxis observed for the before-ATSS and after-ATSS periods. The table indicates that average deadheading miles per passenger trip was lower for taxis than for vans in both periods. This is likely due to the fact that, compared with taxi clients, there were fewer van clients spreading over a larger service area. For taxis, there was a 42% increase in average vehicle deadheading per passenger trip in the after-ATSS period relative to the before-ATSS period (which is statistically significant at a 0.05 significance level). On the other hand, vehicle deadheading miles per passenger trip for vans decreased by about 18% in the after ATSS period relative to the before period (but this change is not statistically significant at a 0.05 significance level).

A dedicated taxi fleet that follows the ATSS's vehicle assignments exclusively leaves vendors with less flexibility to use

TABLE 3.12 VEHICLE DEADHEADING MILES PER PASSENGER TRIP
(Source: On-board Observations)

DEADHEADING MILES PER PASSENGER TRIP				
	VAN BEFORE	VAN AFTER	TAXI BEFORE	TAXI AFTER
Average	8.913	7.315	4.105	5.846
STANDARD AVERAGE	6.413	8.063	2.811	4.655
NO OF VEHICLE TRIPS OBSERVED	21	31	35	47
FREQUENCY DISTRIBUTION				
<5	33.3%	48.4%		
5-10	28.6%	25.8%		
10-15	19.0%	16.1%		
>15	19.0%	9.7%		
TOTAL	100%	100%		
<2.5			34.3%	23.4%
2.5-5.0			34.3%	34.0%
5.0-7.5			17.1%	12.8%
>7.5			14.3%	29.8%
TOTAL			100.0%	100.0%

their own experience and judgment to reduce vehicle deadheading. Further, a larger service area tends to induce longer average passenger trips, which could increase vehicle deadheading. Table 3.12 shows that the largest increase in taxi deadheading miles per passenger trip was associated with trips longer than 7.5 miles. The observed increase in taxi deadheading miles per passenger trip in the after-ATSS period is consistent with what the taxi vendors stated in interviews. The taxi vendors believed that the ATSS use plus the dedicated-vehicle policy, together with the service area expansion in the after ATSS period, resulted in deadheading trips between different service areas.

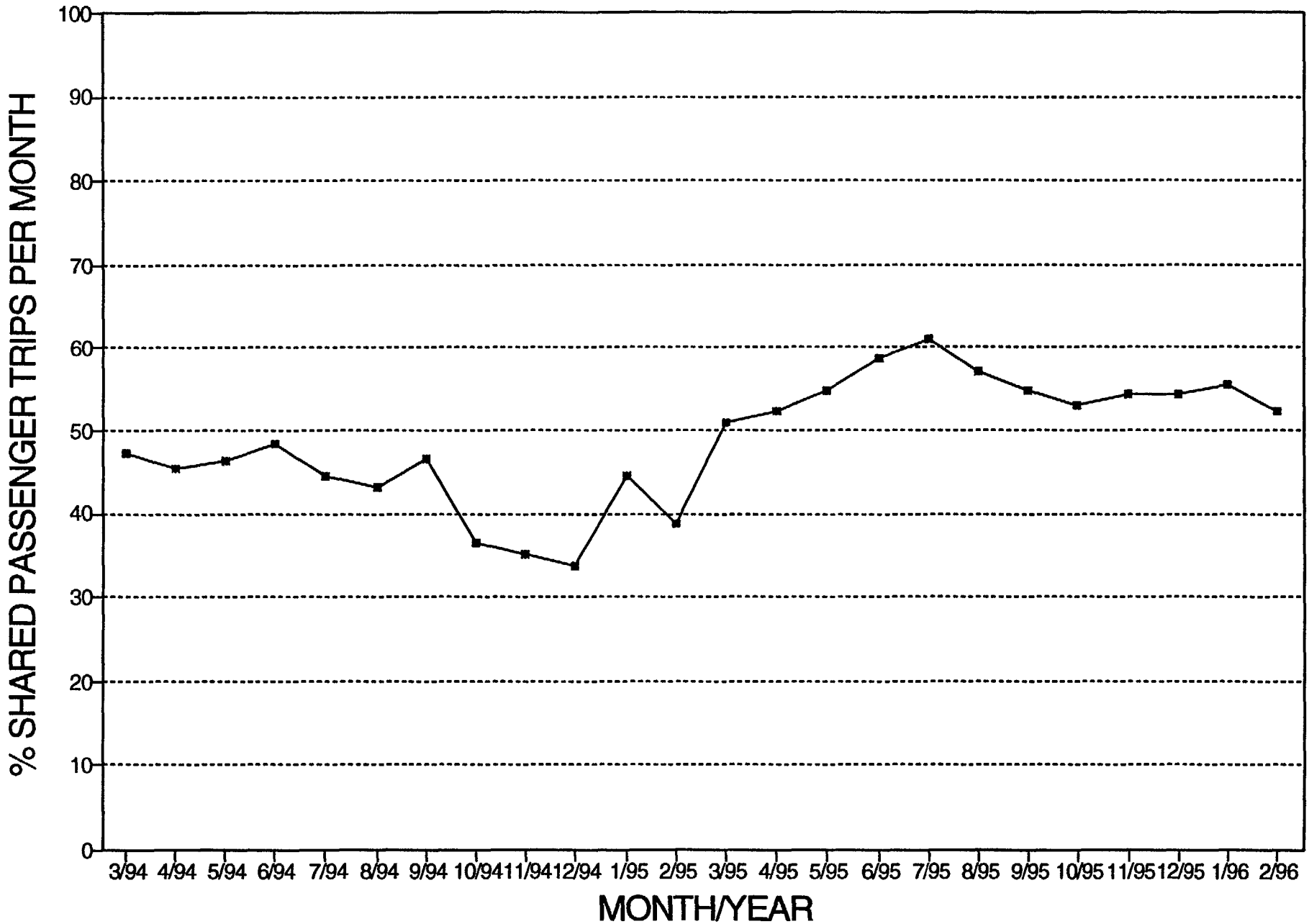
The 42% increase in taxi deadheading miles per passenger trip in the after-ATSS period must be interpreted with care. Average passenger trip lengths in the after-ATSS period has increased following the addition of new cities to the OUTREACH service area. Increased average passenger trip length in turn resulted in higher total passenger-miles of travel. Ideally, we should compare vehicle deadheading miles per passenger mile of travel between the before-ATSS and after-ATSS periods in order to neutralize the effects of the service area expansion, and to isolate the ATSS's effect, on vehicle deadheading. Unfortunately, we could not easily measure passenger-miles of travel accurately during onboard observations; and data on vehicle deadheading miles were only available from the onboard observations (neither OUTREACH nor the vendors keep record of vehicle deadheading miles).

In light of the above data limitation, we had to compute a change in average taxi deadheading miles per passenger-mile between the two periods using two data sources (i.e., the change in average taxi deadheading miles per passenger trip from the onboard observations, and the change in average passenger trip length from OUTREACH's database). The computation results (Appendix 3B) indicate that average taxi deadheading miles per passenger-mile increased about 13% in the after-ATSS period (relative to the before-ATSS period), after having adjusted for the effects of the service area expansion. Therefore, the ATSS use plus the dedicated-vehicle policy could be said to probably increase average taxi deadheading miles per passenger mile by about 13%.

Percent Shared Rides

Shared rides are defined as more than one passenger sharing all or part of their trips with at least another passenger. OUTREACH considers companions or personal attendants who accompany OUTREACH clients as shared rides. Shared rides, expressed as the percent of total passenger trips, are termed the percent shared rides. The analysis of the percent shared rides used aggregate data from OUTREACH's operational database. The percent shared rides for taxis and vans from March 1994 through February 1996 are shown in Figure 3.5. In the before-ATSS period, the percent shared rides decreased over time indicating that OUTREACH's old manual system had reached its capacity, quite possibly before 1994. In 1994, the percent shared rides achieved by the old system had been

FIGURE 3.5
PERCENT SHARED RIDES PER MONTH



about 50%. Although we do not have data on the percent shared rides before 1994, an extrapolation of the trend line of Figure 3.5 immediately suggests that the percent shared rides before 1994 (when total passenger-miles were lower due to lower paratransit demand and the fact that OUTREACH then served only seven cities) was likely to be higher than 50%. Figure 3.5 indicates that the percent shared rides had steadily decreased since 1994 to about 34% just before the ATSS deployment. After the ATSS implementation, however, the percent shared rides increased sharply.

The percent shared rides is likely to be influenced by the service volume and the efficiency of vehicle assignment. The higher the number of passenger trips served, the higher the potential for ridesharing will be. The effects of passenger volume and the ATSS on the percent shared rides per month were examined by means of a regression analysis, which combined the taxi and van modes. The best-fit shared rides model indicates that the percent shared rides is influenced by both the service volume and the ATSS use, as follows:

$$Y = 70.20 - 0.0027(X_1) + 0.00017(X_1X_2) \qquad \text{,..Eqn 3.4}$$

where Y = % Shared rides.

X_1 = passenger miles served (sum of vans and taxis).

X_2 = 0 for before period, 1 for after period.

The estimated coefficients for X_1 and X_2 are statistically significant at a 0.05 significance level. R^2 was 0.78, the estimated standard error 3.71, and the sample size was 24.

From equation 3.4, the average percent shared rides in the before ATSS period can be expressed as:

$$Y = 70.20 - 0.00027X1$$

...Eqn 3.5

The percent shared rides in the after ATSS period can be expressed as:

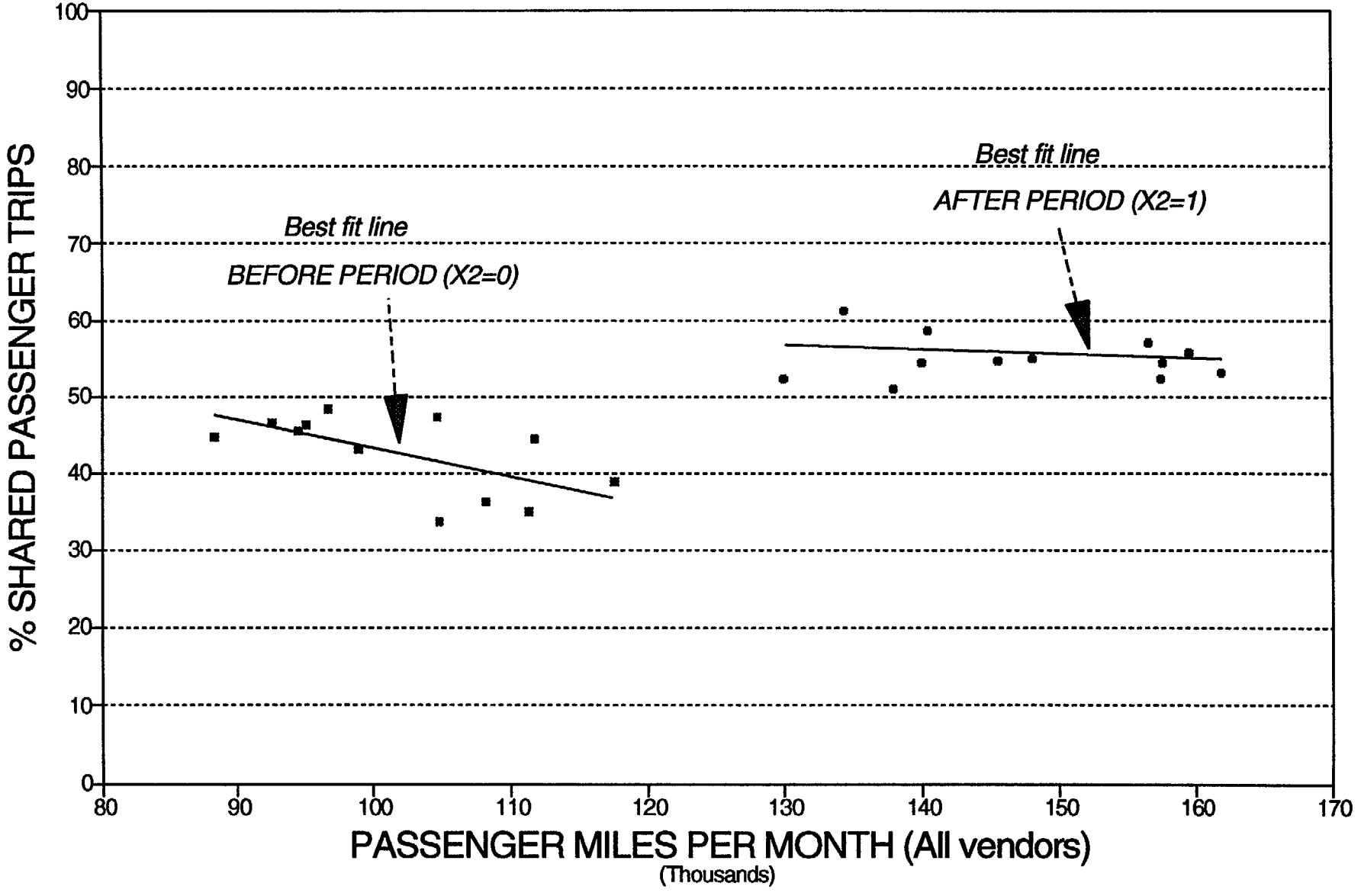
$$Y = 70.20 - 0.00010X,$$

...Eqn 3.6

In Figure 3.6, monthly percent shared rides are plotted against the number of passenger miles served. The figure indicates that:

(a) In the before-ATSS period, the percent shared rides steadily decreased with increasing passenger miles. This is because both the person-hours available for building shared rides and the number of shared rides that could be built in the before ATSS period was constant,with one OUTREACH employee working full time at this task. This had reduced the proportion of total trips that were shared rides as the trip volume continued to grow. This

FIGURE 3.6
PERCENT SHARED RIDES vs PASSENGER MILES



implies that the old trip scheduling procedure had reached its capacity in the before-ATSS period, possibly long before the ATSS deployment.

(b) The percent shared rides increased sharply after the ATSS implementation. Further, the percent shared rides during the after-ATSS period showed little sensitivity to the service volume. This implies that the ATSS has helped OUTREACH to remove the capacity constraint on the number of shared rides that could be built, and thus higher paratransit demand could be accommodated in a more efficient manner than before. These results are consistent with earlier reported findings, which indicated that vehicle trips per passenger mile decreased by 13-20 percent between the before-ATSS and after-ATSS periods.

To summarize the impacts of the ATSS on vehicle productivity, the ATSS has resulted in productivity gains for OUTREACH. First, it has enabled OUTREACH to achieve a significantly higher percent shared rides, and has helped OUTREACH to overcome serious capacity problems throughout the before-ATSS period. Second, vehicle revenue miles per passenger mile decreased in the after-ATSS period (relative to the before- ATSS period). However, it appears that the use of ATSS plus the dedicated-vehicle policy might have resulted in a 13% increase in average taxi deadheading miles per passenger mile. This implies that the productivity gains for OUTREACH might not have been passed on to taxi vendors, at least during the first year of ATSS operation.

SERVICE QUALITY

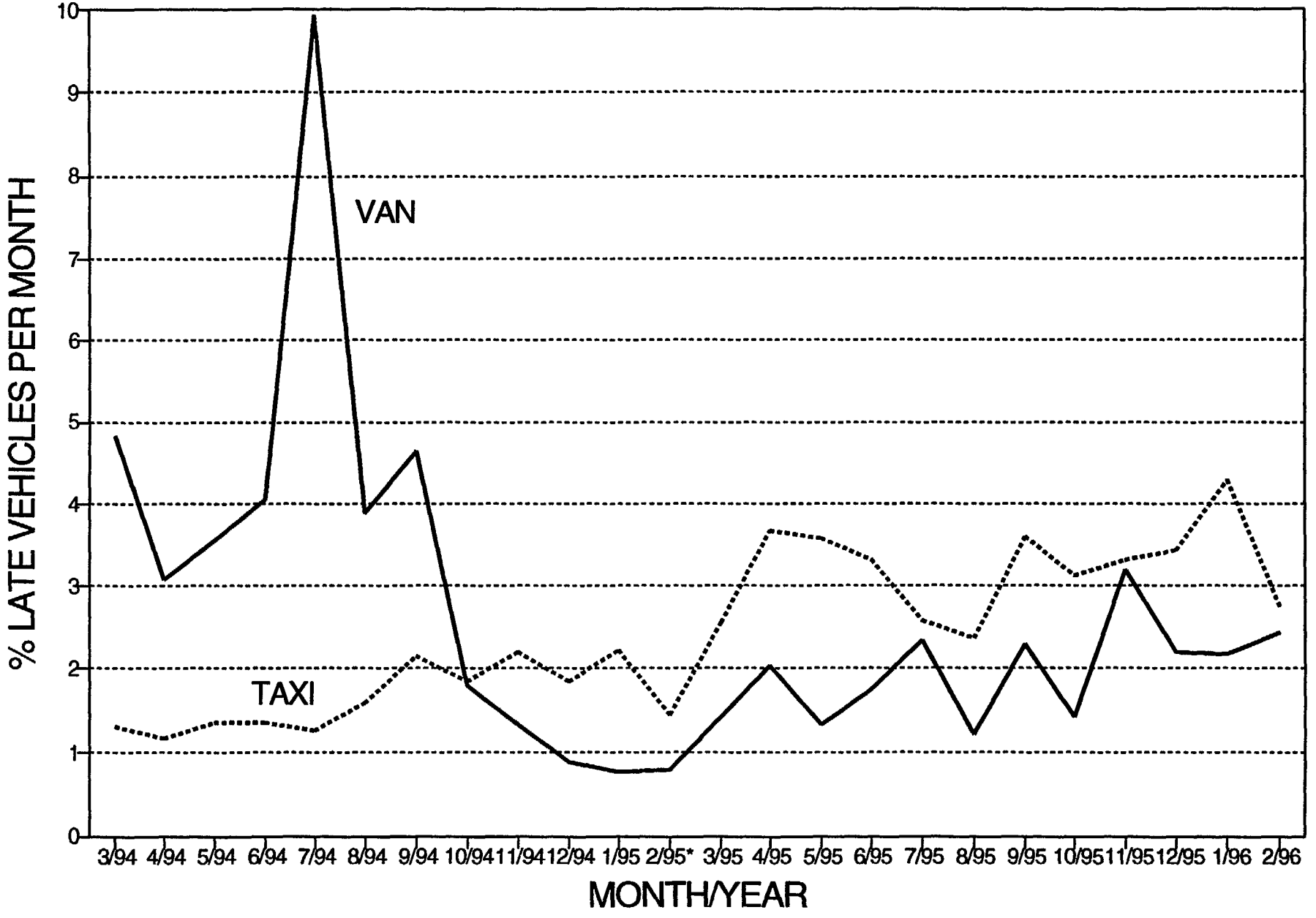
The impacts of the ATSS on three aspects of customer service quality were analyzed: vehicle on-time performance; in-vehicle travel times; and ease of clients requesting trips on the telephone. These evaluations are based on the OUTREACH's database as well as data from the onboard observations. User perceptions of changes in service quality after the ATSS implementation based on client interviews are presented in the next chapter.

Vehicle On-Time Performance

According to OUTREACH's definition of vehicle on-time performance, any vehicles arriving at pick-up locations within +/- 15 minutes of the promised time are considered to be on-time. In this section, the number of client complaints about vehicles that were more than 15 minutes late for scheduled pick-ups were examined.

Monthly data on the number of late vehicles was provided by OUTREACH, from which the percent of total client trips associated with late vehicles was calculated (termed the percent of late vehicles). The percent late vehicles per month for both the taxi and van modes is shown in Figure 3.7. In the before-ATSS period (up till November 1994), the percent late vans was high, particularly for July 1994 when the van vendors were still unfamiliar with the new OUTREACH service areas that had just been added. The percent late vans was lower during the after-ATSS period than during the before-ATSS period. For the taxis, the percent late taxis between March 1994 and January 1995 (the before

FIGURE 3.7
% LATE VEHICLES PER MONTH



-ATSS period) ranged from 1.2% to 2.1%. After the ATSS implementation, the percent late taxis rose to higher levels (with an average of 3.4% between March 1995 and February 1996). The difference in the percent late taxis between the after ATSS and before ATSS period is statistically significant at a 0.05 significance level.

The above findings suggest that the ATSS might have had a slightly negative impact on the on-time performance of taxis. This might have been due to a couple of factors. First, vehicle schedules recommended by the ATSS algorithm leaves drivers and dispatchers with less flexibility to respond to unexpected changes in schedules. Second, during the initial period of expansion of the service area, vendors did not have enough vehicles to provide adequate service in the new North County cities. Third, the larger service area in the after-ATSS period (compared with the before-ATSS period) might have also contributed to poorer on-time performance of taxis. Nevertheless, the levels of late vehicles of taxis (as well as vans) serving OUTREACH clients in the after-ATSS period are still well below the limits of 5-15% typically used by other paratransit operators in the San Francisco Bay Area[5].

In-Vehicle Travel Times

Client in-vehicle travel times were measured in onboard observations for the before-ATSS and after-ATSS periods, and

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5 See METROPOLITAN TRANSPORTATION COMMISSION, "The Use of Performance Measures in the Bay Area Paratransit Industry". Oakland, California, 1995.

summarized in Table 3.13. The table indicates that the average in-vehicle travel time of van users decreased from 16.7 minutes in the before-ATSS period to 15.1 minutes in the after-ATSS period, and those of taxi users from 16.0 minutes to 15.2 minutes. However, neither of these changes are statistically significant at the 0.05 significance level. These imply that clients did not spend more time onboard the vehicle in the after-ATSS period, despite significant increases in the percent shared rides brought about by the ATSS. This represents one important contribution of the ATSS's trip scheduling capability.

Ease of Client Requesting Trips on Telephone

OUTREACH clients schedule non-subscription trips by telephone, within 14 days before the trip. Client waiting times on the telephone before their calls were answered and the daily percent of telephone calls that were abandoned before being answered are shown in Table 3.14 for the before-ATSS, during-ATSS implementation, and after-ATSS periods. The table was derived from OUTREACH's daily telephone logs. The table indicates that, apart from the long waiting times experienced during February 1995 (when the ATSS was being implemented), average client telephone waiting times before being served decreased by 58% in the after-ATSS period compared with the before-ATSS period. This difference is statistically significant at a 0.05 level. The percent abandoned calls also decreased from 28% in the before-ATSS period to 11% in the after-ATSS period, which is statistically significant at a 0.05 level.

TABLE 3.13 AVERAGE TIME CLIENTS SPEND ON-BOARD VEHICLES (Source: Sample data, On-board Observations)

	PASSENGER TRAVEL TIMES (minutes per passenger trip)			
	VAN BEFORE	VAN AFTER	TAXI BEFORE	TAXI AFTER
AVERAGE	16.73	15.05	16.02	15.16
STANDARD DEVIATION	10.29	9.75	13.39	12.48
NO OF PASSENGER TRIPS OBSERVED	37	42	57	67
FREQUENCY DISTRIBUTION				
<10	29.7%	33.3%	45.6%	47.8%
10-15	27.0%	28.6%	21.1%	16.4%
15-20	16.2%	19.0%	10.5%	11.9%
20-30	13.5%	4.8%	14.0%	11.9%
>30	13.5%	14.3%	8.8%	11.9%
TOTAL	100.0%	100.0%	100.0%	100.0%

TABLE 3.14 TELEPHONE WAITING TIME AND PERCENT ABANDONED CALLS

	NO OF DAYS OBSERVED	AVERAGE TELEPHONE WAITING TIME (seconds)	AVERAGE % ABANDONED CALLS
BEFORE: Jan 1995	12	240.9	28.0%
DURING: Feb 1995	22	257.1	25.2%
AFTER: Apr/Jun 1995	9	100.2	11.6%

Both results imply that OUTREACH has improved the ease of clients requesting trips by telephone. This was probably due to OUTREACH adding five more telephone schedulers at the same time that the ATSS became operational. OUTREACH's telephone schedulers, who were interviewed (before and about 18 months after the ATSS became operational), consistently indicated that they were able to book more rides per day with the ATSS than without it. This is true once they were fully familiar with the ATSS (which took them 3-6 months). However, we do not have hard data on the number of ride bookings each telephone scheduler accomplished in the before-ATSS and after-ATSS periods.

To summarize the impacts of the ATSS on customer service quality, the ATSS deployment had relatively small impact on customer service quality. This implies that overall, the ATSS has helped OUTREACH to achieve better cost-effectiveness and productivity gains without significant penalties to its customers.

APPENDIX 3A
REGRESSION MODEL AND RESULTS: ANALYSIS OF SCALE ECONOMY EFFECTS

MODEL	ESTIMATED COEFFICIENT	STATISTIC	
Taxi Payment: Vendor Payment/Passenger mile = 01 + C2*(passenger miles) + C3*X + C4*X*(passenger miles) where X = 0 for Before ATSS Period 1 for After ATSS Period	Cl = 2.037 c2 = -1.2E-6 c3 = -0.278 c4 = 1.57E-6	-- -0.91 -1.79** 0.95	R^2 = 91.9% Std Error ofY Est = 0.022 n = 20, deg.of.frdm = 16
Jan Payment: Jendor Payment/Passenger mile = Cl + C2*(passenger miles) + c3*x + C4*X*(passenger miles) where X = 0 for Before ATSS Period 1 for After ATSS Period	Cl = 4.965 C2 = -4.73-6 c3 = -1.02 C4 = l.OlE-5	-- -0.48 -3.59* 0.92	R^2 = 90.3% Std Error of Y Est = 0.127 n = 20, deg.of.frdm = 16

COMMENTS :
* Significant at the 95% confidence level
** Significant at the 90% confidence level

Both models were reestimated without the passenger mile terms. The results are as follows:

MODEL	ESTIMATED COEFFICIENT	STATISTIC	
Taxi Payment: Vendor Payment/Passenger mile = Cl + C2*x where X = 0 for Before ATSS Period 1 for After ATSS Period	'1 = 1.928 32 = -0.135	-- -13.92*	R^2 = 91.5% Std Error of Y Est = 0.0212 n = 20, deg.of.frdm = 18
Van Payment: Vendor Payment/Passenger mile = Cl + C2*x where X = 0 for Before ATSS Period 1 for After ATSS Period	Cl = 4.889 c2 = -0.707	-- -12.42*	R^2 = 89.5% Std Error of Y Est = 0.1247 n = 20, deg.of.frdm = 18

COMMENTS:
• Significant at the 95% confidence level

APPENDIX 3B

COMPUTING TAXI DEADHEADING MILES PER PASSENGER MILE

In Chapter Three, it was reported that average vehicle deadheading miles per passenger trip for the taxi mode (observed through onboard observations of a sample of taxis) increased 42% in the after-ATSS period, compared with the before-ATSS period. This increase might be attributable to: (a) the ATSS use plus the dedicated-vehicle policy; and (b) the expansion of OUTREACH service area in the after-ATSS period, which resulted in increases in both average vehicle and passenger trip length. Chapter Two reported that average passenger trip length in the after-ATSS period (estimated from OUTREACH's database) was 26% higher than that in the before-ATSS period.

This appendix presents the computation of a change in taxi deadheading miles per passenger mile for the after-ATSS period relative to the before-ATSS period from the above statistics. By comparing taxi deadheading miles per passenger mile between the two periods, the combined effect of the ATSS use plus the dedicated-vehicle policy may be isolated from the effect of the expansion of OUTREACH service area.

Let V_a be vehicle deadheading miles in after period.

V_b be vehicle deadheading miles in before period.

T_a be the number of passenger trips in after period.

T_b be the number of passenger trips in before period.

M_a be passenger miles in after period.

M_b be passenger miles in before period.

The observed 42% increase in average vehicle deadheading miles per passenger trip in the after period relative to the before period can be expressed as:

$$(V_a/T_a)/(V_b/T_b) = 1.42$$

Multiplying the numerator by (Ma/Ma); the denominator by (M_b/M_b):

$$\frac{(V_a/M_a)}{(V_b/M_b)} \times \frac{(M_a/T_a)}{(M_b/T_b)} = 1.42$$

Rearranging the above equation:

$$\frac{(V_a/M_a)}{(V_b/M_b)} \times \frac{(M_a/T_a)}{(M_b/T_b)} = 1.42$$

The second term of the left-hand side is a change in average passenger trip length, thus:

$$(V_a/M_a) \times (1.26) = 1.42$$

$$(V_a/M_a) = (1.42/1.26) \times (V_b/M_b)$$

or $$(V_a/M_a) = 1.13\,(V_b/M_b)$$

That is, average vehicle deadheading miles per passenger mile in the after period increased by 139% relative to the before period.

CHAPTER FOUR

USER PERCEPTIONS

This chapter describes the perceptions of OUTREACH clients of the paratransit service before and after the ATSS implementation. The assessment of user perceptions focuses on the following service attributes:

- Vehicle on-time performance for pre-scheduled trips.
- Promptness with which vehicles respond to open return requests.
- Ease of clients making trip reservations.
- OUTREACH's ability to meet to clients' special requests.
- Ride comfort.

CLIENT SURVEYS

The assessment of client perceptions is based on telephone interviews conducted before and after the ATSS deployment. The before-period interview took place on May 23-27, 1994 (eight months before the ATSS deployment), and the after-period interview took place in May 1995 (four months after the ATSS deployment). The questionnaires used in both periods are similar (Appendix 4A).

As previously mentioned, some policy and operational changes took place (in addition to the ATSS deployment in February 1995)

between the before-period and after-period interviews (Figure 1.1). Possible influence of these policy and operational changes on the survey results is explained later in a section titled "Survey Design".

Survey Sampling Protocol

On each day of the interview, interviewees were selected at random from the lists of all clients who had just completed trips on the day before. A stratified random sampling technique was used to select clients served by all vendors to assure reasonable sample sizes for all vendors. Table 4.1 shows the sample sizes and sampling rates by vendors for both periods. Client names on the lists had already been sorted by vendor, and appeared in order of pick-up times. Interviewees were selected from this list at every n^{th} entry. In cases where the n^{th} entry was non-English speaking or could not communicate due to disabilities, a substitute interviewee was selected by taking the immediately next entry on the list.

A total of 132 clients completed the interviews in the before period. Another independently-selected group of 167 interviewees completed the interviews in the after period. About a month after the before-period interview was conducted, OUTREACH added five new cities (in North County) to its service area. Twenty four interviewees in the after period lived in these new cities, and thus they were not included in the evaluation of the user perceptions presented in this chapter. This reduced the number of

Table 4.1 Sampling Rates by City of residence

Vendor	BEFORE PERIOD			AFTER PERIOD		
	Sample Size	Total estimated no. of users during survey period	Sampling Rate (%)	Sample Size	Total estimated no. of users during survey period	Sampling Rate (%)
Yellow Cabs	28	599	4.7	57	1399	4.1
Alpha Cabs	27	531	5.1	22	296	7.4
United Cabs	29	200	14.5	20	266	7.5
Golden Star	24	192	12.5	20	322	6.2
Mv Transportation	24	179	13.4	20	302	6.6
Yellow, Palo Alto	-			7	99	7.1
Grosvenor Bus	-			22	598	3.7
Weighted Average		1701	7.8		3282	5.1

after-period interviewees for the evaluation to 143.

Two independent samples of interviewees were used in the before and after period for a number of reasons. First, each client generally does not make trips every day, or always make trips on the same days of the week. This made it difficult to develop a sample design to capture the same clients in both periods. Second, the two interview periods were one year apart, and there was no way to assure that the clients captured in the before period were still OUTREACH clients in the after period.

The rationale for the client perception survey is to compare how randomly selected clients in the before-ATSS and after-ATSS periods perceived a number of service attributes in the respective periods. An implicit assumption is that the before-period and after-period samples are representatives of the client populations of each of the two periods.

Survey Design

The survey was designed to obtain two types of information from OUTREACH clients: clients recalling of pick-up times for the last two trips (from and to home) that they had just made on the day preceding the interview; and the client overall perception of each service attribute of interest. The rationale for these two types of information follows.

Client Recalling Times of Trips Completed on Previous Day

Each interviewee (in both the before and after periods) was

asked to recall vehicle arrival times for the last home trip and return trip he/she had just completed on the day preceding the interview as best he/she could. In this way, client-reported vehicle punctuality for that trip can be assessed from these reported vehicle arrival and promised pick-up times. Average vehicle punctuality for all trips between the two periods can then be compared. Any difference in vehicle punctuality between the two periods is attributable to all changes occurring between the two survey periods including the ATSS deployment. The rationale for asking the interviewees about the last two trips made on the day preceding the interview lies in the hope that most interviewees would be able to reliably recall actual pick-up times associated with the trips that they just made.

Perceptions of Service Attributes

The second type of information sought is the client overall perceptions of three service attributes during the before-ATSS and after-ATSS periods: vehicle on-time performance for pre-scheduled trips, ride comfort, and OUTREACH responsiveness to special requests. To enable us to quantify changes in client perceptions between the two periods due to the collective impacts of all changes that had occurred between the two interviews, the following survey approach was employed.

For before-period interviews, each client was asked to compare his/her overall experience of each service attribute during the previous week with that about three months before (when there was

no significant changes of any kind taking place three months before). The client was asked to express his/her experience using subjective, ordinal rating in the form of: better than, worse than, or about the same as, during the previous week compared with three months before. For after-period interviews, each client was asked to compare his/her perception of each service attribute experienced during the previous week with that about six months before. The client was asked to respond using the same subjective, ordinal rating scale as in the before period. In this way, the before-period responses represent the baseline against which the after-period responses can be compared in an attempt to assess the collective impacts on client perceptions of all changes that had occurred between the two survey periods. Such a baseline is useful because it enables clients' inherent perception biases of the service to be factored out. For example, some clients may, by nature, always complain about the current service (relative to past service) even though no service changes have actually taken place. Other clients may be reluctant to criticize current service upon which they are dependent for their travel needs.

As an illustration, if 15 percent of before-period interviewees said that vehicles were more on-time during the previous week than about three months before, and 45 percent of after-period interviewees said that vehicles were more on-time during the previous week than six months before. Then, all changes that had occurred between the two survey periods (including the ATSS deployment) may be said to have probably contributed to 30

percent (45 minus 15) of clients perceiving improved vehicle on-time performance in the after period relative to the before period.

Ideally, we would have wished that there were no policy or operational changes of any kind occurring within the three months preceding the before-period interview. As it turned out, OUTREACH stopped providing same-day service about one month prior to the before-period interview. Nevertheless, we believe that this policy change is not likely to affect the above-mentioned rationale because the overall client perceptions specifically sought on vehicle on-time performance for pre-scheduled trips, ride comfort, and OUTREACH responsiveness to special requests should not be influenced by whether same-day service was being offered.

CLIENTS' DEMOGRAPHICS

The demographic information of the interviewees were obtained from the OUTREACH's client database -- city of residence, age, gender, income, disability code, equipment need code, car ownership, number of rides in the last year and the last three months, and number of months the client had been on the database.

City of Residence of Interviewees

Geographical distributions of the interviewees and OUTREACH client population by city of residence are shown in Table 4.2. About two-thirds of the interviewees in both the before and after periods lived in the city of San Jose. Statistical tests indicate that there is no significant difference (at a 0.05 significance

Table 4.2 Distributions of Interviewees and OUTREACH Client Population by City of Residence

City	Interviewees		Client Population	
	% Before	% After	% Before	% After
San Jose	68.9	65.0	70.7	69.0
Santa Clara	12.1	6.3	10.4	10.1
Milpitas	1.5	2.8	2.2	2.4
Cupertino	3.8	2.8	3.1	3.1
Los Galos	0.8	1.4	1.5	2.4
Morgan Hill	1.5	4.2	2.4	2.3
Gilroy	2.3	4.2	2.8	2.9
Campbell	8.3	8.4	5.2	5.0
Saratoga	0.8	4.9	1.1	2.0
Other	0	0	0.6	0.8
Total	100.0 (n=132)	100.0 (n=143)	100.0	100.0

level) in geographical distributions of the interviewees between the before and after periods, or between the distributions of the interviewees and OUTREACH's client population by city of residence. This in turn implies that the sampled interviewees were representative of OUTREACH's client population with respect to city of residence.

Age and Gender of Interviewees

Age and gender distributions of the interviewees are shown in Table 4.3, which indicates similar distributions for both the before and after periods. Most survey respondents were female (78 percent), or over 60 (79 percent). The average age of the respondents for both periods was about 71 years.

Income of Interviewees

Average monthly incomes for before-period and after-period interviewees were $906 and $1,260, respectively. The difference in these two means was statistically significant at a 0.05 level.

Automobile Use

Most interviewees in both periods did not own a car, or were not able to drive. For those few interviewees who owned a car, they drove only occasionally.

Equipment and Assistance Requirements

The interviewees were grouped into four categories according

TABLE 4.3 DISTRIBUTIONS OF AGE AND GENDER

	BEFORE ATSS PERIOD			AFTER ATSS PERIOD		
AGE (years)	FEMALE	MALE	% TOTAL	FEMALE	MALE	% TOTAL
20 or less	1	0	0.8	1	0	0.7
21-30	0	1	0.8	2	2	2.8
31-40	0	3	2.3	1	0	0.7
41-50	6	4	7.6	4	6	7.0
51-60	10	2	9.1	11	4	10.6
61-70	13	11	18.2	13	6	13.4
71-80	37	6	32.6	40	8	33.8
81-90	33	1	25.8	32	6	26.8
More than 90	4	0	3.0	6	0	4.2
TOTAL	104	28	100.0	110	32	100.0

to the degree and kind of assistance needed. Table 4.4 shows the distributions of equipment and assistance requirements for both periods. A statistical test indicates that the distributions between the two periods are significantly different at a 0.05 significance level. Relative to the before period, a larger proportion of interviewees in the after period required wheelchairs or driver assistance to get into or out of the vehicle.

Trip-Making Frequency

Distributions for trip-making frequencies in both periods are shown in Table 4.5, where a passenger trip is defined as a one-way trip. This table indicates that about 40 percent of the people interviewed made fewer than five trips per month, while about 60-70 percent made fewer than 10 trips per month. A statistical test indicates that there was no significant difference in average trip-making frequencies between interviewees of the two periods at a 0.05 significance level.

Time-of-Day of Client Trips

Table 4.6 shows the time-of-day distributions for pre-scheduled trips from home (i.e., home trips), pre-scheduled return trips, and open return trips for the before and after periods. This table indicates, as expected, that the majority of home trips were made during morning hours, while pre-scheduled return and open return trips were often made during mid-day, afternoon, and evening hours.

TABLE 4.4 DISTRIBUTIONS OF EQUIPMENT & ASSISTANCE REQUIREMENTS

EQUIPMENT	% BEFORE	% AFTER
Wheelchair	29.5	34.3
Need Driver Assistance	40.2	45.4
Walking Aid	15.9	14
No Assistance or Equip.	14.4	6.3
TOTAL	100.0	100.0

TABLE 4.5 DISTRIBUTIONS OF TRIP FREQUENCY

MONTHLY TRIPS	% BEFORE	% AFTER
<5	40.9	39.8
5 - 10	33.3	23.8
10 - 15	6.8	16.8
15 - 20	3.8	8.4
20 - 25	5.3	2.8
25 - 30	6.8	3.5
>30	3.1	4.9
TOTAL	100.0	100.0

TABLE 4.6 DISTRIBUTION OF TIME-OF-DAY OF TRIPS

HOUR	BEFORE PERIOD						AFTER PERIOD					
	INITIAL TRIPS		RETURN TRIPS				INITIAL TRIPS		RETURN TRIPS			
			SCHEDULED		OPEN RETURN				SCHEDULED		OPEN RETURN	
	NUMBER	%	NUMBER	%	NUMBER	%	NUMBER	%	NUMBER	%	NUMBER	%
Before 8am	15	11.4	0	0.0	0	0.0	7	5.9	0	0.0	0	0.0
8-9	34	25.8	0	0.0	3	4.2	27	22.7	1	1.5	1	2.8
9-10	23	17.4	1	2.0	6	8.3	25	21.0	1	1.5	3	8.3
10-11	10	7.6	4	8.2	6	8.3	11	9.2	7	10.8	7	19.4
11-12	8	6.1	7	14.3	11	15.3	10	8.4	11	16.9	9	25.0
12-lpm	24	18.2	5	10.2	4	5.6	16	13.4	13	20.0	1	2.8
l-2	12	9.1	9	18.4	10	13.9	9	7.6	4	6.2	0	0.0
2-3	6	4.5	16	32.7	12	16.7	5	4.2	9	13.8	4	11.1
3-4	0	0.0	3	6.1	6	8.3	4	3.4	8	12.3	4	11.1
4-5	0	0.0	3	6.1	4	5.6	1	0.8	8	12.3	2	5.6
After 5pm	0	0.0	1	2.0	2	2.8	1	0.8	2	3.1	2	5.6
Unknown	0	0.0	0	0.0	8	11.3	3	2.5	1	1.5	3	8.3
TOTAL	132	100.0	49	100.0	72	100.0	119	100.0	65	100.0	36	100.0

ANALYSIS OF SURVEY RESULTS

The analyses of the survey results are presented below.

Vehicle On-Time Performance for Pre-Scheduled Home Trips

For pre-scheduled trips (from or to home), OUTREACH asks the client to be ready 15 minutes before promised pick-up time. If the vehicle has not arrived within 15 minutes after the promised pick-up time, the client is urged to call and notify OUTREACH. OUTREACH's definition of on-time is that the vehicle arrives within 15 minutes of promised pick-up time.

A. Client Percentions

Interviewees in both the before and after periods were asked to rate whether pre-scheduled home trips during the previous week were more on-time, less on-time, or about the same compared with many months before. Table 4.7 shows the distributions of responses between the two periods, for taxis and vans. Statistical tests performed for the taxi and for the van samples indicate that, for each mode, the distributions of responses between the before and after periods were significantly different at a 0.05 significance level. That is, the percent of interviewees who perceived "more on Time" increased, while the percent of people perceiving "less on time" decreased, significantly in the after period for both taxis and vans (relative to the before period). This implies that OUTREACH clients perceived better overall vehicle "on-time" performance for pre-scheduled home trips during the after period than during the before period, for both the taxi and van modes.

TABLE 4.7 PERCEPTIONS OF ON-TIME PERFORMANCE FOR PRE-SCHEDULED HOME TRIPS

RESPONSE	TAXI		VAN	
	% BEFORE	% AFTER	% BEFORE	% AFTER
More on-time	26.5	46.5	33.3	57.7
Less on-time	13.7	12.8	25.0	7.7
About the same	59.8	40.7	41.7	34.6
TOTAL	100.0 (n=102)	100.0 (n=86)	100.0 (n=24)	100.0 (n=26)

TABLE 4.8 CLIENT-RECALLED VEHICLE PUNCTUALITY FOR PRE-SCHEDULED HOME TRIPS

VEHICLE ARRIVED:	TAXI		VAN	
	% BEFORE	% AFTER	% BEFORE	% AFTER
lb60 min early	0.9	0.0	0.0	0.0
46-60 min early	0.9	0.0	0.0	0.0
31-45 min early	1.9	1.8	0.0	0.0
16-30 min early	0.9	4.7	8.3	0.0
11-15 min early	11.5	5.6	16.7	14.8
6-10 min early	6.6	7.4	4.2	14.8
l-5 min early	15.3	8.3	4.2	3.7
Exactly on time	29.7	32.4	29.1	40.8
l-5 min late	6.6	12.9	8.3	7.4
6-10 min late	6.6	7.4	4.2	3.7
11-15 min late	6.6	8.3	8.3	7.4
16-30 min late	10.6	4.7	12.5	7.4
31-45 min late	1.9	5.6	0.0	0.0
46-60 min late	0.0	0.9	4.2	0.0
TOTAL	100.0 (n=104)	100.0 (n=108)	100.0 (n=24)	100.0 (n=27)

B. Clients Recalling Pick-Up Times

In both the before and after periods, each interviewee was also asked to recall vehicle arrival time for the last home trip that he/she just completed on the day preceding the interview. Table 4.8 shows the distributions of vehicle arrival times relative to promised pick-up times for pre-scheduled home trips for the before and after periods, separately for the taxi and van modes. Statistical tests indicate that there was no significant difference in vehicle on-time performance between the before and after periods (at a 0.05 significance level), for either the taxi or van modes.

The above results for pre-scheduled home trips indicates that clients perceived vehicles being more on-time (for both the taxi and van modes) during the after period than during the before period. However, the results obtained from clients recalling of trip times associated with the last two trips indicate that there was no statistically significant difference in vehicle on-time performance between the two periods for either mode. These results combined suggest that client-reported vehicle on-time performance for vans and taxis servicing pre-scheduled home trips was not degraded in the after period relative to the before period.

Vehicle On-Time Performance for Pre-Scheduled Return Trips

A. Client Perceptions

Each interviewee was asked to rate the overall perceptions of vehicle on-time performance for pre-scheduled return trips (i.e., more on-time, less on-time, or about the same) during the previous

week compared with many months before. Table 4.9 shows the distributions of responses between the before and after periods, for the taxi and van modes. For the van mode, more clients in the after period (than in the before period) perceived vans to be "more on time", while fewer clients in the after period (than in the before period) perceived vans to be "less on time" A statistical test indicates that the difference in client perceptions between the two periods was statistically significant at a 0.05 significance level. For the taxi mode, client perceptions on taxis' on-time performance in the after period (relative to the before period) were inconclusive. That is, more clients in the after period (than in the before period) perceived taxis to be "more-on-time" as well as"less on time"; a statistical test indicates that these perception differences between the two periods were statistically significant at a 0.05 significance level.

B. Clients Recalling Pick-Up Times

Each interviewee was also asked to recall vehicle arrival time for the last pre-scheduled return trip that he/she just completed on the day preceding the interview. Table 4.10 shows the distributions of vehicle arrival times relative to promised pick-up times for pre-scheduled return trips between the before and after periods, separately for the taxi and van modes. A statistical test for the taxi mode indicates that there was a significant difference between the before and after period at a 0.05 significance level. Based on OUTREACH's definition of vehicle on-time performance,

TABLE 4.9 PERCEPTIONS OF ON-TINE PERFORMANCE
FOR PRE-SCHEDULED RETURN TRIPS

RESPONSE	TAXI		VAN	
	% BEFORE	% AFTER	% BEFORE	% AFTER
More on-time	21.7	28.2	30.4	50.0
Less on-time	4.4	15.4	17.4	4.5
About the same	73.9	56.4	52.2	45.5
TOTAL	100.0 (n=23)	100.0 (n=39)	100.0 (n=23)	100.0 (n=22)

TABLE 4.10 CLIENT-RECALLED VEHICLE PUNCTUALITY
FOR PRE-SCHEDULED RETURN TRIPS

VEHICLE ARRIVED:	TAXI		VAN	
	% BEFORE	% AFTER	% BEFORE	% AFTER
>60 min early	0.0	0.0	0.0	0.0
46-60 min early	0.0	1.9	0.0	0.0
31-45 min early	0.0	0.0	0.0	0.0
16-30 min early	0.0	5.8	0.0	0.0
11-15 min early	8.3	5.8	0.0	7.4
6-10 min early	0.0	3.9	13.0	0.0
l-5 min early	8.3	2.9	4.3	7.4
Exactly on time	50.0	36.6	43.5	44.4
l-5 min late	12.5	0.0	17.5	3.7
6-10 min late	4.2	11.9	0.0	7.4
11-15 min late	4.2	11.9	4.3	7.4
16-30 min late	12.5	13.5	8.7	7.4
31-45 min late	0.0	0.0	8.7	11.2
46-60 min late	0.0	0.0	0.0	3.7
>60 min late	0.0	5.8	0.0	0.0
TOTAL	**100.0** (n=24)	**100.0** (n=52)	**100.0** (n=23)	**100.0** (n=27)

about 87 percent of taxis were on time in the before period compared with about 72 percent in the after period. Therefore, taxis exhibited worse on-time performance in the after period than in the before period. This finding probably reflects the impacts of several policy and operational changes that occurred between the two survey periods. First, during initial months of ATSS operation, taxi vendors were still adjusting to new logs and new ways of providing service to OUTREACH's clients under the dedicated-vehicle policy. Therefore, the use of dedicated vehicles and adherence to ATSS-built itineraries on any given day was not uniform at that time. Second, during an initial period of service expansion into the North County cities, OUTREACH used taxi vendors to provide service in this new service area. Taxis' on-time performance at that time was not as good as it had been. They were having some problems with vehicle on-time performance in many service areas, probably because they were still learning about, and compensating for, operations in North County.

For the van mode, a statistical test of the distributions of van on-time performance between the before and after periods indicates that they were not significantly different at a 0.05 significance level. About 82 percent of vans were on time in the before period compared with about 78 percent in the after period. Please note that the after-period interview took place at the time when one of the three van vendors (MV Transportation) was in the process of adding new vehicles and converting to the "mixed van" mode (see Chapter One for definition), in order to get ready to

serve three new cities in West Valley about one month later.

The above analyses of vehicle on-time performance for both pre-scheduled home and return trips reveals a definite trend in client perceptions of vehicle on-time performance. Clients generally expressed that they perceived overall improvement in on-time performance for both vans and taxis in the after period relative to the before period for all pre-scheduled trips. The exception being the on-time performance for taxis servicing pre-scheduled return trips during the after period compared with the before period, where client perceptions were inconclusive. However, the analysis of client-reported vehicle arrival times for the last two trips that had just been made on the day preceding the interview indicates that vehicle on-time performance for pre-scheduled trips in the after period was not any better than that in the before period.

Why were client perceptions of vehicle on-time performance during the after period (relative to the before period) consistently more positive than the evidence derived from client recalling of vehicle arrival times of the last two trips? Possible reasons include:

- It is conceivable that many interviewees might have somewhat fuzzy overall perceptions of past service in a period of many months before the interview. When they were asked to compare their perceptions of the service during the previous week with those during 3-6 months before, their response might be based on vague memory of

past service.

- According to our interview personnel, some interviewees sincerely appreciated service received from OUTREACH. These individuals might have wished to convey a gesture of their appreciation for OUTREACH through the interviewers, by stating that current vehicle on-time performance were better than before.
- Some interviewees were clearly dependent on OUTREACH service for their travel needs, and might feel obliged to express particularly favorable opinions of the current service.

Vehicle Promptness to Open Return Requests

As previously mentioned, clients do not pre-schedule open returns. Instead, they call OUTREACH when they are ready to return home. Response time for an open return is defined as the time elapsed between vehicle arrival and when the client requests an open return. In October, 1994 (after the before-period interview was completed), OUTREACH changed the allowable vehicle response time for open returns to within 60 minutes (as opposed to the original 30 minutes).

Clients Recallins Pick-Up Times

Each interviewee (in both the before and after period) who had just completed an open return trip on the day preceding the interview was asked to recall the time he/she requested the open

return and the time the vehicle arrived. The distributions of response times for the two periods are shown in Table 4.11. The mean response times for the before and after periods were very similar (26.7 and 26.9 minutes, respectively). This was despite a change instituted by OUTREACH (that has lengthened allowable vehicle response time from 30 during the before period to 60 minutes during the after period). A statistical test indicates that this small difference in the mean response times between the two periods was non-significant at a 0.05 significance level. This implies that vehicle response time to open returns, based on client reporting, did not change significantly between the before and after periods despite OUTREACH increasing allowable vehicle response time by another 30 minutes.

Capability to Meet Client Special Requests

About 14% of interviewees in the after period made special requests when reserving trips. The ATSS is capable of automatically assigning a vehicle that is equipped to accommodate a special request to the client during the trip scheduling stage. This is different from the before period, in which a special request was noted by OUTREACH telephone operator and passed on to the vendor's dispatcher, who then assigned a vehicle to meet the special request.

Each interviewee in the after period was asked whether he/she had recently made any special requests when requesting rides, and

TABLE 4.11 CLIENT-RECALLED RESPONSE TIMES FOR OPEN RETURNS

RESPONSE TIME (minutes)	% BEFORE	% AFTER
0 - 5	2.8	4.7
6 - 10	9.7	7.0
11 - 15	11.1	11.6
16 - 20	13.9	11.6
21 - 25	5.6	2.3
26 - 30	16.7	9.3
31 - 35	6.9	0.0
36 - 40	2.8	2.3
41 - 45	2.8	0.0
46 - 60	2.8	7.0
61 - 90	1.4	0.0
More than 90	1.4	2.3
Unknown	22.1	41.9
TOTAL	100.0 (n=72)	100.0 (n=43)

how well OUTREACH responded to the special requests (i.e., better, worse, or about the same compared with many months ago). These questions were not asked in the before-period interview. Of the 19 interviewees in the after period who had recently made special requests, their perceptions of OUTREACH's responsiveness to special requests during the previous week compared with many months before are as follows: better (42%), worse (10%) about the same (20%), and no opinion (8%). The fact that the number of people responding **better** was considerably higher than the number responding **worse** suggests that these clients perceived that OUTREACH's responsiveness to their special requests had improved in the after period.

Ride Comfort

Client perceptions of in-vehicle comfort can conceivably be influenced by several factors: the number of passengers onboard (i.e., crowding), in-vehicle temperature, vehicle ventilation, seating availability, etc. Each interviewee (in the before and after periods) was asked whether he/she perceived the ride to be more comfortable, less comfortable, or about the same during the previous week compared with many months before. Table 4.12 shows the distributions of the responses for the before and after periods.

Table 4.12: Client Perceptions of Ride Comfort

Perception	% Before	% After
More comfortable	15.9	7.8
Less comfortable	11.9	3.5
About the same	72.2	88.7
Total	100.0	100.0

A statistical test of Table 4.12 indicates that client perceptions of ride comfort between the before and after periods were inconclusive. The table indicates that a smaller percent of clients in the after period (than in the before period) perceived that the rides were more comfortable. Interestingly, the table also indicates that a smaller percent of clients in the after period (than in the before period) perceived that the rides were less comfortable.

Ease of Client Making Trip Reservations

The use of ATSS changes the method used by OUTREACH telephone schedulers to book rides. Advantages of the ATSS in booking subscription and pre-scheduled rides were previously described in Chapter Three.

Each interviewee (in the before and after periods) was asked whether and how long he/she had waited before being served by OUTREACH's telephone schedulers when calling to make a reservation for the last trip he/she had just completed on the day preceding the interview. About 23 and 27 percent of before-period

interviewees and after-period interviewees, respectively, were either on OUTREACH's trip subscriptions or did not call to schedule the rides themselves. Therefore, these individuals did not answer this question. The survey did not ask client perceptions of the ease of making reservations for subscription rides.

Table 4.13 shows responses for the two periods for the remaining interviewees. A statistical test indicates that the distributions of clients having to wait before being served were significantly different between the two periods at a 0.05 significance level. About 41% of after-period respondents said that they had to wait, compared with 63% of the before-period respondents. Therefore, the ease of clients making reservations for pre-scheduled trips, based on client reporting, has improved in the after ATSS period relative to the before ATSS period.

About 88% of after-period respondents who had to wait before being served did not remember how long they waited. Therefore, we do not have data to meaningfully compare client-reported telephone waiting times between the before and after periods.

Table 4.13: Clients' Wait on Telephone Before Being Served

Response	% Before	% After
Being put on hold	62.7	40.9
Not on hold	14.7	24.8
Cannot remember	22.6	34.3
Total	100.0 (n=102)	100.0 (n=105)

In addition to adopting the ATSS, OUTREACH also implemented two other changes shortly before the ATSS deployment: the installation of a new telephone system in September 1994; and hiring of additional telephone schedulers in February 1995. Both these events could by themselves have a beneficial effect in reducing the percent of clients who waited on telephone before being served (when calling to reserve trips) in the after period (relative to the before period). It is not possible to isolate these effects and that of the ATSS on the percent of clients waiting on telephone before being served.

Other Paratransit Service Attributes

The service attributes examined above are not the only ones the interviewees considered to be important to them. In the after-period interview, interviewees were asked to describe other important service attributes. They were also asked to compare their perceptions of these other attributes between the previous week and about six months before. Thirty after-period interviewees (or 21 percent of after-period interviewees) responded to this question. The driver was mentioned most frequently (by 10 interviewees) as another important service attribute. Nine of these 10 interviewees said drivers in the after period were more polite and had better knowledge of where they were going than those in the before period. This is not surprising because OUTREACH requires dedicated vehicles in the after period. Drivers of vehicles dedicated just to OUTREACH clients on a particular day

might have more incentives to establish particularly good rapport with OUTREACH clients since these clients are likely to become regular passengers for the driver and taxi vendor.

Chapter Summary

A survey of OUTREACH clients indicates that clients, on average, perceived somewhat better overall vehicle on-time performance for most pre-scheduled trips in the period after the ATSS deployment than in the before period. These clients* positive perceptions for the after period, however, were not substantiated by evidence derived from client-recalled vehicle arrival times for the last two trips the interviewees had just made on the day preceding the interview. The latter results indicate that vehicle on-time performance in the after period were not any better than that in the before period.

Client perceptions of in-vehicle ride comfort for the after period relative to the before period were inconclusive.

According to client reporting, their telephone calls to OUTREACH to schedule rides, on the average, were answered more quickly by OUTREACH telephone schedulers in the after period than in the before period. This was probably due to the new OUTREACH's telephone system and the hiring of five additional telephone operators in the after period.

The results of the client survey clearly indicate that clients did not perceive degradation in any service quality attributes examined about four months after the ATSS was deployed. The survey

results presented in this chapter should be viewed in the following context:

- The service quality attributes examined in this chapter, as well as the clients' perceptions of them, were likely to be affected by the many policy and operational changes that took place between the two interview periods, as well as the ATSS use. It is not possible to isolate the impact of the ATSS use from those of the other changes.
- The after-period interview was conducted about four months after the ATSS became operational, a period during which it was still undergoing numerous modifications and fine-tuning. Further, during this initial four-month period, the vendors were still adjusting to new trip logs and new ways of providing service to OUTREACH's clients under the new dedicated vehicle policy. That is, the system was still in flux. The use of dedicated vehicles (by the vendors) and adherence to ATSS-built itineraries on any given day was not uniform and evolved sporadically. This suggests that clients' perceptions observed during this initial ATSS deployment period may not be the same as those under more stable vendor operations once they are familiar with the ATSS use.

APPENDIX 4 A QUESTIONNAIRE USED FOR USER SURVEYS

Name of Client: . .....

Date and Time of Interview: .....

***** Remind client of the two trips‘they have just completed ****

FOR THE INITIAL TRIP (from home)

****** First, I 'd like to ask you about the trip from home *****

1. When did you request this trip?

   Date ..... Time .....

2. If you telephoned OUTREACH to request this trip, were you put on hold?

   [] Yes (how long? . . . .mins) [] No [] can't remember

3. What was the promised pick-up time?

   .....

4. Did OUTREACH call you back with a different pick-up time?

   [] Yes (What time? ..... [] No

5. What time were you <u>actually</u> picked up at your home? .....

6. What time were you dropped off at your destination? .....

FOR THE RETURN TRIP

***** Next, I'd like to ask about the return trip *****

7. Did you have a scheduled return or an open return? If an open return, what time did you call for the vehicle?

   .....

8. What was the promised pick-up time?

   .....

9. Did OUTREACH call you back with a different pick-up time?

   [] Yes (What time? .....) [] No

10. What time were you <u>actually</u> picked up? .....

11. What time were you dropped off at home? .....

IMPRESSIONS OF SERVICE

******* Lastly, I'd like to ask your general impressions of the service during this past week, in comparison with 3 months ago. It* is important *that the interviewer specifically ask the client to state the impressions of the van or the taxi service. *******

12. For trips starting at home, are the vehicles (more on-time, less on-time, or about the same) in this past week compared with 3 months ago?

[] more on-time [] less on-time [] about the same

13. For pre-scheduled return trips, are the vehicles (more on-time, less on-time, or about the same) in this past week compared with 3 months ago?

❑ more on-time [] less on-time [] about the same

14. For open returns, do the vehicles respond to your requests (more quickly, more slowly, or about the same) in this past week compared with 3 months ago?

[] more quickly [] more slowly [] about the same

15. Are the rides (more comfortable, less comfortable, or about the same) in this past week compared with 3 months ago?

[] more comfortable (Why? .....)

❑ less comfortable (Why? .....)

[] about the same

16. Have you requested same-day urgent medical trips recently? If so, does it take (longer, less time, or about the same) for you to be picked up recently compared with 3 months ago?

[] longer ❑ less time [] about the same

CHAPTER FIVE

COST AND BENEFITS OF AVL

This chapter presents the cost and productivity implications of the automated vehicle location (AVL) and remote dispatching systems, which were concurrently implemented in June 1996, about 17 months after the ATSS became operational. The implementation of these two technologies constituted the last phase of the OUTREACH's advanced paratransit system. Forty accessible vans were equipped with the AVL equipment; the AVL equipment was not installed on taxis. A period before the AVL implementation but after the ATSS deployment is termed the before-AVL period, while a period after the AVL implementation is termed the after-AVL period.

The AVL system monitors the real-time status of vehicle and passenger trips (e.g., vehicle arrivals for a pick-up, completions of pick-up, vehicle departures, vehicle arrivals for drop-off, completions of drop-off). Such information is accessed by the ATSS, which displays it on OUTREACH's and the van vendors' screens. In addition, the AVL system also provides real-time vehicle locations to OUTREACH on a map screen. At the present time, real-time vehicle location information is not available to any of the van vendors, and OUTREACH is working to have this capability at the vendors' sites in the near future.

The remote dispatching system consists of a remote dispatching computer installed at each vendor site to provide automatic data linkage between OUTREACH and the vendor's dispatcher, which did not exist in the before-AVL period. This remote dispatching link allows OUTREACH to communicate with the vendors about any changes to vehicle schedules in real-time and on-line. For example, when a client requests an open return trip or cancels a scheduled trip, OUTREACH's dispatcher would enter this request into its computer, which would then be automatically displayed on the vendor's computer. In the before-AVL period, OUTREACH's dispatchers had to telephone the vendors about such changes. The configuration of the integrated ATSS/AVL system is discussed in Chapter Two. Examples of the ATSS dispatch screens displaying AVL vehicle status are shown in Figures 2.6 and 2.7.

DATA SOURCES

The analysis of the cost and productivity implications of AVL and remote dispatching systems is based on data obtained from OUTREACH's database, observations onboard the AVL-equipped vans, and interviews of OUTREACH personnel, van drivers, and van vendors. Onboard observations were conducted on a sample of vans in July 1995 (11 months before completion of the AVL installation) and in August 1996 (two months after completion of the AVL installation).

CAPITAL COSTS

The capital costs of the AVL and remote dispatching systems

(expressed as the 1996 value) are summarized in Table 5.1. The total installation cost was $473,805; $437,052 of which was the cost of the AVL equipment installation, and the remaining $36,753 was the cost for the remote dispatching system. Of the $437,052, about 32% (or $139,994) were the hardware and software costs. The software includes: Network Communications Management software, the AVLManager(TM) software and the StarView(TM) real time map display software. The hardware included: new Sun workstations (on which the above mentioned software runs), and tower and differential base station equipment (for transmitting messages between OUTREACH and AVL-equipped vehicles). The cost of integrating the AVL system with the ATSS was $90,160 (or 21%). Another 25% (or $111,280) was the acquisition of the equipment installed onboard vehicles, which included the ECHO(TM) terminals and MAXTRAC mobile radios in each vehicle. Another 21% (or $72,000) was the labor cost for installation and testing, and the remaining 5% (or $23,618) was for miscellaneous expenses.

The cost for installing the remote dispatching system at the three van vendors' sites was $36,753. This included three computers for the three van vendors, three workstations for OUTREACH, the remote dispatching software, modem connections, and the training of the vendors' personnel. The training cost was another $7,500. Van drivers and van vendors' dispatchers were extensively trained on use of the on-board and remote dispatching equipment. OUTREACH's personnel were also trained on use of AVL dispatch screens.

TABLE 5.1 CAPITAL COSTS OF AVL SYSTEMS

COST ITEM	COSTS (1996 COLLARS)	
AVL SYSTEM		$437,052
In-house hardware & software	$139,994	
Software integration	$90,160	
Vehicle equipment	$111,280	
Labor	$72,000	
Miscellaneous	*$23,618*	
REMOTE DISPATCHING SYSTEM		$36,753
Hardware & software	$29,253	
Staff	*$7,500*	
TOTAL PHASE 2 CAPITAL COSTS		$473,805

OPERATING COSTS

The operation of the AVL and remote dispatching systems consists of mobile data terminals (MDTs) and radio equipment onboard vehicles, as well as the communications network housed at OUTREACH. Periodic maintenance of the MDTs is likely to be needed as they are subject to considerable vehicle vibration. However, no maintenance cost data are available at this stage.

OUTREACH hired an additional full-time employee to monitor and "trouble-shoot" problems associated with the AVL equipment. This employee also provides ongoing training for van vendors.

OBSERVED BENEFITS OF AVL DURING INITIAL TWO MONTHS OF OPERATION

Because the AVL and remote dispatching systems have been in operation for a only two months, their benefits observed during this initial period are presented separately from their potential longer-term benefits. The latter will probably not occur until OUTREACH and the van vendors develop action plans to utilize the real-time AVL information to its full potential.

During the initial two months of AVL operation, OUTREACH was focusing on modifying the equipment to meet its own and the vendors' needs, as well as on addressing any equipment problems encountered on the road. These initial two months were also a period of learning and experimenting with the AVL equipment. Unfortunately, the evaluation period did not permit the monitoring and evaluation of the AVL system beyond this initial operation. The reader should take this fact into consideration when reviewing the following reported initial impacts of the AVL system.

Impact on Workload of OUTREACH's Personnel

Interviews of OUTREACH's personnel who interact with dispatchers of the van vendors on a daily basis (about the vehicle status, late vehicles, cancellations, and open returns) revealed that the AVL and remote dispatching systems have reduced the need for OUTREACH's personnel to telephone the van vendors to inform the latter of these events several times a day. For example:

- When a client calls to request an open return, the remote dispatching system automatically relays to the van vendors the request that OUTREACH personnel have entered into the computer.
- The AVL system helps OUTREACH personnel to deal with client queries more easily and speedily. For instance, when addressing a client's query about the status of a vehicle that is to pick up the client, OUTREACH's personnel can locate the exact position of that vehicle on the map screen.
- The automated data linkage capability of the remote dispatching system helps to eliminate transcribing errors that sometimes occurred in telephone conversations, which were the communication medium between OUTREACH and the van vendors in the before-AVL period.

Impacts on OUTREACH's Management Functions

Real-time data from the AVL system represent a wealth of information that supports and enhances OUTREACH's day-to-day

Operation and Management Functions. For example:

(a) Real-time information on vehicle status and locations enables OUTREACH to monitor the extent to which the van vendors follow schedules that were built by the ATSS, as well as to determine how well the ATSS-built schedules work. In this regard, the AVL data provide ongoing feedback about actual average journey speed (i.e., a parameter in trip scheduling by the ATSS). By comparing this observed value against the average journey speed parameter used in trip scheduling, OUTREACH could adjust this parameter as necessary to improve the accuracy of the trip scheduling algorithm.

(b) Real-time vehicle status enables OUTREACH to learn about how long it takes clients to board and alight from vehicles. For clients who need extra time to complete these tasks, OUTREACH could take this fact into consideration when scheduling their rides in the future.

(c) Real-time information about the vehicle status on any day makes it possible to reliably determine whether an open-return trip should be inserted between the trips that have already been scheduled for that day.

(d) AVL data enable OUTREACH to automatically and accurately monitor vehicle on-time performance of any van vendors by examining vehicle and trip status data, which did not exist in the before-AVL period. Before AVL, OUTREACH generally relied on client feedback and/or formal client surveys for knowledge about the performance of individual vendors. OUTREACH is developing a daily Vehicle On-Time

Performance Report, which summarizes the schedule adherence of all vehicles on any given day (Figure 5.1). Such reports will be made available to vendor managements on a regular basis.

Impact on Incident Responses

OUTREACH and the vendors define an incident as a same-day change to schedule (e.g., a trip cancellation, open return, vehicle breakdown, or "no show"). A "no show" refers to a vehicle arriving for a passenger pick-up but not finding the passenger (who has not made a trip cancellation). In case of an incident, the automated data linkage between OUTREACH and the vendor alerts the vendor's dispatcher to this change immediately and automatically, thus enabling the vendor to address this incident in a more timely manner. Further, the ability for the AVL system to delete scheduled trips that have been canceled from the trip list broadcasted to the MDT onboard the vehicle results in automatic and much more timely updating of the schedule of that vehicle. In the before-AVL period, when a client called to cancel a scheduled trip on a service day, OUTREACH's telephone scheduler entered that change in the computer, and then telephoned the vendor. The vendor in turn communicated this change to the driver through two-way voice radios, which could sometimes be crowded. Therefore, there could be considerable delay in the entire communication process from the client to the driver on the road.

The results of onboard observations revealed that, during the initial two months of AVL operation, two-way radios were still

Figure 5.1: Example of Information in On-Time Performance Report

Vendor: xxxxxxxxx

Date: xxxxxxxxx

Vehicle ID	# of Trips	# of lates by > 15 min.	# of lates by > 45 min.
1	18	0	0
2	20	1	0
3	15	1	0
4	16	0	0
5	17	0	0
6	21	1	0

often the choice communication medium between the dispatcher and the driver in conveying incident information. One reason for this was that some problems were encountered with the AVL system during these initial months; for example: information about some pick-ups that was transmitted to the MDTs was incomplete, resulting in those trips not appearing on the MDTs. Also, some incidents originating with the drivers could not be transmitted by MDT to the vendor's dispatcher because only a limited number of pre-coded messages could be sent from the vehicles. Such incidents included traffic congestion, drivers not finding clients, and transferral of passengers from one vehicle to another. OUTREACH has since been fine-tuning the AVL system to correct these kinds of problems. OUTREACH and managers of the van vendors expect that the use of two-way radio between the dispatcher and the driver would diminish significantly once the AVL system is problem-free.

Impact on Passenger Trips per Vehicle Service Hour

The AVL system provides real-time information on the vehicle status to the vendors. An evaluation was performed to assess whether, in this initial two-month period, the van vendors were able to use this information to better assign: (a) vehicles for open return trips; (b) trips that were not yet assigned for the service day (e.g., "virtual vehicle" trips); and (c) passenger transfers to different vehicles due to unexpected events such as vehicle breakdowns so as to minimize the amount of vehicle deadheading. "virtual vehicle" trips and open-return trips account

for as much as l0-20% of daily trips. This evaluation involved comparing the numbers of passenger trips per vehicle service hour between the before-AVL and after-AVL periods, using the data collected from onboard observations. Table 5.2 shows that daily averages for the before-AVL and after-AVL periods were nearly identical (1.272 and 1.259 passenger trips per vehicle service hour, respectively). This small difference is not statistically significant at a 0.05 level. This implies that there did not appear to be any impact of the AVL system on this aspect of the vehicle productivity during initial two months of operation. This non-significant finding is not surprising for a number of reasons. First, during these initial two months, learning of and experimentation with the AVL and remote dispatching systems were still ongoing. Second, the vendors did not (and still do not) have real-time vehicle locations on their screens. This might have made it difficult for them to effectively improve vehicle utilization in real-time. Third, the vendors and OUTREACH are yet to develop and implement a strategy for real-time scheduling of open-return trips using information from the AVL.

Impact on Vehicle Schedule Adherence

Even though OUTREACH and the van vendors have not yet developed a strategy to improve vehicle schedule adherence in real-time using information generated from the AVL system, it was of interest to determine whether, during the initial two months of the AVL operation, the presence of real-time vehicle information per

TABLE 5.2 PRODUCTIVITY OF VAN VENDOR VEHICLES
(SOURCE: ON-BOARD OBSERVATIONS)

OBSERVATION PERIOD	JULY 1995 WITHOUT AVL	AUGUST 1996 WITH AVL
NUMBER OF VEHICLE-DAYS OBSERVED	5	5
NUMBER OF PASSENGER TRIPS OBSERVED	39	43
PASSENGER TRIPS PER VEHICLE SERVICE HOUR		
DAILY AVERAGE	1.272	1.259
STANDARD DEVIATION	0.299	0.306

TABLE 5.3 SCHEDULE ADHERENCE OF VAN VENDOR VEHICLES
(SOURCE: ON-BOARD OBSERVATIONS)

OBSERVATION PERIOD	JULY 1995 WITHOUT AVL	AUGUST 1996 WITH AVL
NUMBER OF VEHICLE-DAYS OBSERVED	5	5
NUMBER OF PASSENGER TRIPS OBSERVED	39	43
PERCENTAGE OF PICKUPS:		
MORE THAN 15 MINUTES EARLY	36%	16%
15 MINUTES EARLY TO 15 MINUTES LATE	56%	74%
MORE THAN 15 MINUTES LATE	8%	9%

se, plus the drivers' knowledge that the vehicle status is monitored, might have improved vehicle schedule adherence. In this regard, the on-time performance of vans between the two periods was compared using the data collected through on-board observations. Adherence to schedule is measured as the difference between scheduled vehicle arrival times and actual vehicle arrival times. Deviations were aggregated into three categories according to OUTREACH's definition of on-time performance: vehicle was more than 15 minutes early ("EARLY"), +/- 15 minutes of scheduled times ("on-time"), and more than 15 minutes late ("late").

Table 5.3 shows the distributions of vehicle schedule deviations for both periods. The table indicates that the percentages of observed "late" vehicles were 8.3% and 9.3% for the AVL-before and AVL-after periods, respectively. This difference between the two periods is statistically non-significant at a 0.05 level. There is also no significant difference in the percent of "early" plus "on-time" between the two periods at a 0.05 level. Therefore, the initial two-month AVL operation did not affect vehicle schedule adherence.

POTENTIAL LONGER-TERM BENEFITS OF AVL SYSTEM

More substantial benefits of the AVL system than those reported above for the initial two-month period are possible, when OUTREACH and the vendors develop and implement action plans to utilize the real-time information provided by the AVL system to its full potential. These longer-term benefits include the following:

(a) Interviews with managers of the van vendors indicate that one of their priorities would be to use the real-time vehicle location information to help drivers who are lost (or uncertain about the direction) while on the way to pick up or drop off passengers. According to these managers, "lost" drivers are an issue that, if successfully addressed, could lead to significant improvement in the vehicle on-time performance.

(b) One important long-term goal of OUTREACH is to use the real-time vehicle status and location information to schedule open-return trips in real-time, so as to increase the vehicle productivity, enhance customer service quality, and reduce the amount of vehicle deadheading. To achieve this, OUTREACH is currently working toward providing vendors with real-time vehicle positions on their screens. It is expected that this function will be available by early 1997.

(c) Another long-term goal of OUTREACH is to utilize the real-time information from the AVL system to create a multi-modal, timed-transfer transit service, in which some paratransit clients who travel long distances could connect with the light rail system and fixed-route buses (the SCVTA is currently installing AVL equipment on their fixed-route bus fleet). This "hybrid" service would be possible when vehicles serving OUTREACH's clients are equipped with the AVL equipment, and when there is an action plan to facilitate timed transfers between these paratransit vehicles, AVL-equipped buses, and the light rail system. This "hybrid" service could significantly decrease the unit cost (per passenger

trip and mile) of OUTREACH's paratransit service, particularly for trips over long distances.

(d) Another long-term goal of OUTREACH is to develop an action plan to improve vehicle schedule adherence in real-time using information generated from the AVL system. A number of approaches to achieve this are possible. At this time, it is not clear what strategy OUTREACH will finally consider.

CHAPTER SIX

INSTITUTIONAL ISSUES

This chapter describes key participants and their roles in the implementation of the advanced paratransit system. It also presents relationships between key participants and the impacts of the new system on these relationships, problems encountered and lessons learned from the implementation, perceptions of key participants on the demonstration project, and implications of the demonstration project to the national APTS objectives.

KEY PARTICIPANTS

OUTREACH

In 1993, OUTREACH identified the need for an advanced paratransit system in anticipation of sharp increases in trip volumes. It also identified potential funding sources for implementing such a system. OUTREACH took the leadership in planning this demonstration project, which included the preparation of a proposal requesting funding assistance from the Division of New Technology of Caltrans. OUTREACH worked closely with the SCVTA and the manufacturers of component technologies through a steering committee. This committee, chaired by an OUTREACH board member and including representatives from the SCVTA and the manufacturers of

all component technologies, was charged with guiding the planning and implementation of the new system. The committee met monthly from the planning stage until the completion of the demonstration project.

OUTREACH was responsible for the implementation and operation of the advanced paratransit system, which included:

- The integration of the ATSS with the existing AS/400 computer system.
- Obtaining the FCC approval to operate the AVL frequencies.
- The installation of AVL equipment on 40 accessible vans.
- Testing of the ATSS and AVL equipment and software, as well as modifications of hardware/software to meet the needs of OUTREACH and the taxi and van vendors.
- Providing training on the ATSS to managers and dispatchers of the vendors, and training on the AVL equipment to drivers and dispatchers of the van vendors.
- Working closely with the vendors to fine-tune the ATSS's routing parameters and procedure throughout the demonstration project.
- "Trouble-shooting" as problems arise.

The SCVTA

The SCVTA is the responsible agency for, and thus maintains the ownership of, the advanced paratransit system. It contracted with OUTREACH to develop and implement this new system, and it

worked closely with OUTREACH throughout the planning and implementation stages. An SCVTA's staff person was part of the steering committee. The SCVTA maintained oversight of all financial and deployment aspects, and informed Caltrans of the implementation status. The reporting structure during the system implementation was: OUTREACH reporting to SCVTA, and the SCVTA in turn to Caltrans.

The relationship between the SCVTA and OUTREACH during the demonstration project is described in the next section.

Manufacturers of Technologies

The manufacturers of component technologies assisted OUTREACH throughout the planning and implementation phases. First, NavTech donated the DGD to the project. Second, technical personnel of the manufacturers visited OUTREACH during system installation. During initial ATSS operation, OUTREACH relied on the advice of the ATSS manufacturer regarding parameter values for the scheduling algorithm. These initial values were subsequently revised many times during the first two years of ATSS operation. Third, the manufacturers trained OUTREACH's personnel. The involvement of the manufacturers diminished once the equipment became operational.

Caltrans

Caltrans contributed toward the capital cost of this demonstration project. Caltrans maintained overall supervision of the project via the SCVTA. Caltrans contracted with the Institute

of Transportation Studies, University of California at Berkeley, to perform this evaluation study.

Van and Taxi Vendors

The vendors' cooperation and ability to use the new system are vital. Even though OUTREACH started publicizing the new system to the vendors in 1993, van and taxi vendors did not become actively involved in the demonstration project until shortly before the ATSS became operational. Prior to the ATSS becoming operational, OUTREACH held meetings with managers of the vendors, and started training their dispatchers and managers about the ATSS use. These individuals in turn conducted training of their own staff. The ATSS use has resulted in the vendors having to adjust their own personnel's tasks accordingly.

The van vendors designated 40 vans to be equipped with the AVL equipment. Van drivers and other personnel received AVL training from OUTREACH's staff.

RELATIONSHIPS BETWEEN OUTREACH AND OTHER PARTICIPANTS

OUTREACH and SCVTA

During the ATSS implementation, the SCVTA worked closely with OUTREACH and, on numerous occasions, helped OUTREACH to resolve unexpected technical, financial, and manpower problems. These unforeseen difficult situations taxed the staff of both the SCVTA and OUTREACH to the extent that both agencies had to redirect staff from other projects and ongoing duties to focus on solving the

problems at hand.

The SCVTA worked with OUTREACH on two major budget revisions to address OUTREACH's budget overrun midway through the ATSS implementation. In this regard, the SCVTA provided OUTREACH with additional funds necessary to keep the demonstration project on course. At the present time, the SCVTA is working with OUTREACH to identify routine maintenance costs for the new system, as maintenance activities will be funded by the SCVTA.

OUTREACH and Vendors

The implementation of the advanced paratransit system has changed the dynamics between OUTREACH and the vendors in a number of ways. For example:

(a) Service quality prior to the implementation of the advanced paratransit system was largely dependent on the vendors' vehicle dispatching capability and practices. Then, any one vehicle could serve OUTREACH clients as well as non-OUTREACH customers on a given day. Therefore, the vendors had a good deal of flexibility in planning the itineraries of their own fleet as long as scheduled client pick-up times provided by OUTREACH were met. When the vendors saw fit to break up the multiples that had been manually built by an OUTREACH employee, OUTREACH often paid the vendors according to the revised trip plan.

The use of the ATSS was accompanied by OUTREACH requiring the vendors to provide dedicated vehicles to serve OUTREACH clients during designated shifts. The purposes are to maximize the

potential benefits of the ATSS in building shared rides, and to assure that a sufficient number of vehicles would be available for OUTREACH clients. OUTREACH requires each vehicle to follow the ATSS-built itinerary, and rarely allows (and thus pays) the vendors to break up the ATSS-built shared rides. Further, OUTREACH can monitor and better assure compliance of the dedicated-vehicle policy plus the vendors' adherence of ATSS-built trip plans through AVL-equipped vans. Therefore, the ATSS use plus the dedicated-vehicle requirement has taken away the vendors' flexibility in vehicle dispatching, as well as the ability for a vehicle to serve both OUTREACH clients and non-OUTREACH customers on the same day.

Managers of the taxi companies expressed negative perceptions of the ATSS use plus the dedicated-vehicle policy, citing loss of driver income, pick-up schedules being too tight for drivers to comply and increased vehicle deadheading as the primary reasons. The loss of taxi drivers! income has been the biggest concern because most taxi drivers are independent drivers whose daily earnings directly depend on the number of passenger trips they can make on a day. When a taxi driver (of a dedicated vehicle) is only allowed to serve OUTREACH clients during a dedicated-vehicle shift, his/her total earning during that shift could be reduced. The fact that taxi vendors have been much less happy with the ATSS use could influence the extent to which taxis will be able to provide paratransit rides in Santa Clara County in the future, as ride volumes continue to grow and more paratransit scheduling functions are automated.

On the other hand, managers of the van vendors expressed positive perceptions of the ATSS-built trip itineraries. Managers of the van vendors believed that the use of dedicated vehicles and the ATSS has enhanced productivity of vehicle and driver resources. This is because whereas the van companies' revenues depend on the number of passenger trips the companies make in a day, van drivers are salaried employees. Therefore, daily incomes of van drivers are not directly tied to the number of passenger trips they make. Managers of the van companies believed that the ATSS use could keep their vehicles and drivers busier than before. The share of OUTREACH clients served by the van mode has already been on the increase in the last few years, and the van companies' positive perceptions of the ATSS use may increase their role in serving OUTREACH clients even further in the future.

For OUTREACH, the advanced paratransit system makes it possible to monitor and have more direct control over the service quality and costs of providing rides than before.

(b) Another feature of the ATSS's trip scheduling function that did not exist before is the "virtual rides" policy. Virtual rides are ride requests that are not yet scheduled and assigned to any dedicated vehicle on the day of service. OUTREACH usually provides a list of "virtual rides" to the vendors to serve as they see fit. Alternatively, OUTREACH may ask the vendors to specify additional dedicated vehicles to handle "virtual rides". However, the vendors generally like to have a few "virtual rides" on any given day so that they can make up for client cancellations on the

day of service.

(c) During the initial period of service area expansion into North County, OUTREACH used taxis in North County which did not perform to expectations (in terms of vehicle on-time performance). This led OUTREACH to contract with a van vendor (GreyLines) to service both ambulatory and accessible clients in the entire North County instead. Van vendors exhibited flexibilities in providing minivan fleet to service a client population that was once served almost exclusively by taxis. The capability of the ATSS to configure the minivan fleet for both types of clients was the key to successful and cost-saving service in North County. This experience could conceivably open up more paratransitmarket niches for minivan operations in the future.

The kinds of working relationships that OUTREACH has with the van and taxi vendors during this demonstration project appear to suggest that van and taxi companies may have different inherent capabilities for growth and automation. More evidence from other similar demonstration projects are needed on this issue. Evidence from this demonstration project indicates that the ability of vendors to grow may vary from vendor to vendor.

(d) The ATSS operation has created ongoing feedback loops between the vendors and OUTREACH. During the demonstration project, OUTREACH used feedback from the vendors to fine-tune the ATSS parameters and functions to increase the accuracy of its output. Dispatchers of some vendors have also spent time with OUTREACH personnel who book rides to learn more about the ATSS and

how it can help them in providing better service to OUTREACH clients.

(e) Van vendors were initially apprehensive that OUTREACH would use the AVL system as a means to reprimand them. However, their apprehension was short-lived, and the van vendors now look forward to utilizing the AVL system's capabilities to improve performance and productivity of their fleet.

OUTREACH and Clients

In addition to enabling OUTREACH to have more direct control over the service quality than before, the advanced paratransit system also enables OUTREACH personnel to address clients' queries, complaints, and problems directly and in a more timely manner. This is because OUTREACH's personnel can now access any relevant information on various screens. Before the advanced paratransit system, OUTREACH personnel often had to telephone the vendor to ask about any vehicle or late scheduled pick-up.

Another marked improvement in client service quality is that the advanced paratransit system enables each client to book more than one ride during one telephone call. This is particularly important at the time when the ride limit per client is being continually increased. The old system allowed a client to book only one ride per telephone call.

OUTREACH'S Employees and Internal Reorganization

As previously mentioned in Chapter Three, the advanced

paratransit system requires new, higher-level technical skills than before. It also resulted in elimination of many manual tasks, and addition of new tasks, within OUTREACH. This in turn required OUTREACH to reorganize its staff's responsibilities, and to provide training to its staff.

Nearly every category of OUTREACH personnel has been impacted by the advanced paratransit system. The manner in which the advanced paratransit system facilitates booking and processing of pre-scheduled and subscription rides, and thus the impacts on telephone schedulers' workload and required skills, were previously described in Chapters Two and Three. Interviews of OUTREACH's telephone schedulers revealed that it took them between three and six months to become proficient with the new system. However, after that initial "learning curve" the new system makes their tasks easier and less stressful than before. They could book more rides now with the new system than with the old system. The telephone schedulers said that they probably would not have been able to do trip booking well with the old system in the face of the growth that they have been experiencing.

The advanced paratransit system also impacts OUTREACH's customer services personnel. They have to be proficient in working with the ATSS and the AS/400, as they often use the ATSS to review information (e.g., clients' ride history and future rides) to address customer problems. Further, they also provide information to clients about how to book rides under the ATSS operation.

OUTREACH MIS personnel (who do client accounts, vendor

invoices, sponsor invoices, client refunds, monthly reports, fare adjustments for vendors, and data processing) were impacted by the ATSS. The ATSS was customized to do vehicle faring by vendor. The fare information is then input into the AS/400 for use in transportation accounting and reporting.

During initial months of ATSS operation, OUTREACH had a geocoding specialist to handle difficult geocoding situations. Now all OUTREACH's staff are trained to do geocoding, including difficult geocoding cases.

The advanced paratransit system increased OUTREACH managers' workload considerably during the initial operation period. This was due to: (a) the added demand on their time to learn about the new system, conduct staff training, and "trouble-shoot" problems; and (b) the need to, at the same time, assure smooth day-to-day operation under the sharp growth in trip volumes and expanded service area.

PROBLEMS ENCOUNTERED AND LESSONS LEARNED

There were many problems encountered and lessons learned during the ATSS and AVL implementation. They include:

Emulation of Proven Software on Different Platforms

Emulation of proven software on a different platform, and integrating it with existing in-house software, proved to be difficult and costly for OUTREACH, as manifested by many unforeseen serious software errors and integration problems that were

encountered during initial months of operation. Any transit agencies wishing to implement similar systems should seriously consider alternative strategies.

Flexibility in Hardware and Software Acquisition

When developing a plan for an advanced paratransit system, the transit agency should make allowance for a possibility that the purchased hardware and software may not necessarily be exactly the same as what had been initially proposed. This is because new technologies typically change rapidly, and the agency's perceived functional requirements may also change after its knowledge of the new technologies increases. The agency needs to have flexibility in reallocating capital expenditures among component technologies as necessary, while staying within the overall budget. For example, the integration of the ATSS with the AVL system incurred a higher cost than OUTREACH had originally estimated. This called for a special re-design of the integration, and reallocation of the capital expenditures accordingly. OUTREACH sought approval from Caltrans for this change and was able to stay within the overall original budget.

Software Modification Cost

The ATSS software purchased by OUTREACH from the manufacturers was coded in a certain way by the manufacturer, and lacks flexibility for inexpensive modifications. The design of the ATSS is currently manufacturer and product specific. As a result, the

SCVTA (via OUTREACH) had to pay the manufacturer a substantial additional cost every time the software was modified to meet the needs of OUTREACH and the county.

Budgeting

The budget for implementing a new paratransit system should include adequate funds for project management and technical staff's time. Unforeseen expenses could occur during the installation, testing, and operation of the new system. For example, the integration of the ATSS with OUTREACH's existing AS/400 computer turned out to be a particularly demanding task for OUTREACH staff. Not only did it incur considerable delay, it also resulted in a budget overrun.

OUTREACH's problem with the project management budget was further compounded by the county's requirement for OUTREACH to run both the new and old system in parallel during the initial week of ATSS operation. This was to assure uninterrupted service to clients in case of "glitches" in the new system. This parallel run created additional demand on staff time and resulted in many technical problems, and was terminated after a few days.

Requirement and Availability of New Technical Skills

During the ATSS implementation, OUTREACH quickly realized that the level of new technical skills required was far more than any one technical person could ever handle (e.g., programming in multiple languages, system configuration, operating different

platforms, etc). Instead, there needs to be adequate budget to assemble a team of technical persons with appropriate expertise to work on the project. The team leader should have good technical background with some management skills in order to coordinate work of various team members. Alternatively, as was the case with OUTREACH, a non-technical manager could fill this capacity if he/she has access to necessary experts' advice. The non-technical manager must be able to accurately judge whether and to what extent the technical team is on the right track and progressing in a timely manner.

Both OUTREACH and the SCVTA badly needed staff with considerable knowledge and experience in software/hardware engineering and communications to implement and operate the ATSS, which neither agency had during the initial months. This suggests that it is unrealistic for any transit agencies to expect successful implementation of similar advanced paratransit systems with just assistance from the manufacturers of individual technologies.

Rigor of Pre-Planning Activities

Based on the experience of this demonstration project, the SCVTA and OUTREACH stated that they should have been more critical during the pre-planning phase, particularly regarding issues such as the compatibility between the new system and existing in-house computer system. The SCVTA wished it had had more expertise and manpower to develop critical check-lists at the outset to: (a)

assure smooth operation of the new system from the outset; (b) anticipate problems that might occur during implementation; and (c) evaluate other potential alternative systems. Rigorous pre-planning might have prevented the delays and cost overrun.

In hind sight, the SCVTA and OUTREACH felt that they probably had been over-confident about the success of the ATSS deployment during the project identification and formulation stages. They thought that they had proven technologies, and that manufacturer assistance was all that was needed to install and operate the system. As a result, OUTREACH was caught without competent computer analysts during initial months of ATSS operation.

During the planning phase, agencies wishing to implement similar systems should also consider acquiring hardware with higher capacity than the required minimum. This would assure satisfactory system performance and speed under real-world conditions.

Placement of AVL Equipment Onboard Vehicle

During initial AVL operation, it was found that the vehicle unit which had been placed high up on the dash board sometimes functioned erratically under intense sunlight. As a result, vehicle units were re-installed at another location inside the vehicle to shield them from intense sunlight.

PERCEPTIONS OF PARTICIPANTS

Caltrans

Caltrans considered the advanced paratransit system deployment

in Santa Clara County to be a successful demonstration of untried APTS technologies. Caltrans' project manager attributed the success of this demonstration project to the dedication of OUTREACH managers and staff, as well as the financial and administrative support of the SCVTA at crucial moments. Caltrans believed that the technology components used were good products, and that the manufacturers provided adequate service in implementing them. Finally, Caltrans acknowledged that the partnership between the state, local government, transit operators, and the private sector is essential in planning, implementing, and operating this and other APTSs. All partners in this demonstration project benefitted from the exchange of ideas, resulting in a better project.

The SCVTA

The SCVTA had believed from the outset that the ATSS would enable the county to accommodate much higher level of paratransit demand as required by the ADA by 1997. The SCVTA believed that OUTREACH's old system was becoming less efficient as early as 1993. The SCVTA considered the ATSS to be the cornerstone of the advanced paratransit system, and that the ATSS deployment was a success and worthwhile investment.

The SCVTA considered the vendors to have been responsive to the operation of the new system, and have made themselves flexible to the need of the project. The SCVTA believed that the success of this demonstration project was attributable to the hard work of OUTREACH's managers and staff.

OUTREACH

OUTREACH's primary goal in deploying the advanced paratransit system was to maintain high levels of service in an era of reduced funding, rising demand, and expanded service area. Specifically, OUTREACH believes that the advanced paratransit system has improved client service (e.g., on-time performance, and accountability of vendor performance); reduced the unit cost of operation; and decreased total staff time, particularly telephone schedulers. Further, OUTREACH also hopes that, in the long run, the AVL deployment would lead to coordination between the vans and the Santa Clara light rail system, so that some clients would be able to make part of their trips on the light rail. In this way, the cost of providing service could be further reduced.

OUTREACH considered the demonstration project to have achieved most of its goals, and that automation of paratransit planning and scheduling functions was critical to accommodating both the increases in trip volumes and operations in new cities. The new service area, in particular, would have been impossible for OUTREACH's old manual scheduling system to handle, due to unfamiliarity with the new cities. With the new system in place, OUTREACH expects to meet all 21 ADA requirements by early 1997.

Finally, OUTREACH is happy with the reliability of the products used in this demonstration project.

The Van Vendors

The van vendors like the ATSS because it makes their task of

providing rides to OUTREACH's clients easier. The ATSS-built logs result in reductions in dispatcher-hours, and improved driver efficiency. They believe that the new system enables them to provide more rides to OUTREACH without extra vehicles or manpower. This, they believe, is a decided advantage they have over other van companies who do not have the technologies.

Taxi Vendors

In contrast with the van vendors, taxi vendors have stated that they prefer operation under the old system to that under the ATSS. Interviews of managers of the taxi vendors revealed that their objections were related to both the ATSS use and the dedicated-vehicle policy. First, they believed that the ATSS results in lower fare estimates than under the old system. This, plus the dedicated vehicle requirements, results in loss of income for taxi drivers. Other reasons against the ATSS include: ATSS-built vehicle itineraries have more vehicle deadheading miles than the old manually-built multiples; and the new ATSS-built logs require more person-hours to deal with than the old logs.

IMPLICATIONS TO NATIONAL APTS OBJECTIVES

The Federal Transit Administration has defined four principal national APTS objectives: enhance customer service quality; improve system productivity and job satisfaction; enhance the contribution of public transportation systems to overall community goals; and expand the knowledge base of professionals concerned

with APTS innovations.

The Santa Clara advanced paratransit system demonstration project has the following implications to the national APTS objectives:

(a) Certain emerging APTS technologies can be successfully deployed to significantly improve the productivity of paratransit operations. Specifically, full automation of vehicle scheduling and trip reservation functions that utilizes technologies such as automated trip scheduling systems (ATSSs) in combination with digitalgeographicaldatabases (DGDs) can help paratransit agencies to increase the percent shared rides, achieve efficient utilization of vehicle and driver resources, and substantially reduce the operating costs. As illustrated by this demonstration project, the savings in OUTREACH's operating costs due to the use of such automation have been substantial and have far outweighed the capital costs of the ATSS. Such automation would make it possible for paratransit agencies to accommodate significant growth in trip volumes and expansion of service areas without increasing manpower resources. This contribution of ATSSs is particularly important for large and medium-sized paratransit operations that are undergoing rapid growth in paratransit demand and ridership.

(b) The ATSS technology automates many aspects of trip reservation, which enhances the service quality to paratransit users. For example, customers are able to book rides with the paratransit agency more easily and reliably; customers are able to book multiple rides with one telephone call. Further, workload and

stress of telephone schedulers could be significantly reduced, as ATSSs are capable of providing all desired information at their finger tips while booking ride requests (i.e., they can call upon desired information on the screen in a timely manner).

(c) New technologies such as ATSSs can be configured to meet the needs of any paratransit provider regardless of the ride volume and size of the coverage area. Therefore, the technology holds promise for facilitating coordination and consolidation of paratransit services where needed, either among various cities within the same county or among counties, such that the agencies' productivity and service quality to the user are both enhanced.

(d) The benefits of the ATSS technology may vary from agency to agency. The benefit level achieved may depend on other policies that the paratransit agency implement concurrently with an ATSS; for example: the use of dedicated vehicles to assure that a sufficient number of vehicles would be available to receive assigned ride requests at all times; policy regarding open-return trips; selection of vehicle size and mix to serve particular service areas; etc. Further research is needed to develop guidelines or "road maps" to help paratransit agencies to maximize the potential benefits of the ATSS technology.

For paratransit agencies contracting private companies to provide transportation to their customers, the productivity implications of ATSSs to contractors are inconclusive. This demonstration project suggests that while the ATSS use has resulted

in a decrease in vehicle revenue miles, it has increased vehicle deadheading miles (per passenger mile) for the taxi mode by 13%. Research is needed to study the impacts of ATSSs on transportation contractors.

(e) The ATSS used by OUTREACH in this demonstration project was assembled from "off-the-shelf" component technologies, none of which is a mature or near-mature technology. Large-scale use of ATSSs is likely to depend on a number of factors, including the following.

- Availability of Complete and User-Friendly ATSSs Further R&D is needed to develop next-generation ATSSs that are complete and user-friendly systems. The rationale is that the paratransit agency should not have to perform integration of the various "off-the-shelf" component technologies. Further, future ATSSs should be complete systems such that they can readily be deployed in place of the paratransit agency's existing computer system (where client, business, accounting, and other information is usually housed), to avoid the need for the agency to integrate a new ATSS with the agency's existing computer system. Such system integration tasks, as experienced by OUTREACH, are not only complex and expensive, but could also interrupt normal paratransit service and operation. Besides, most paratransit agencies would not have adequate financial resources, time, and technical skills to accomplish such system integration tasks themselves.

- Technical Assistance for System Installation and Operation Even with the availability of complete and user-friendly ATSSs,

paratransit agencies are likely to need considerable assistance in deploying them. The manufacturer of future ATSSs must provide qualified personnel to work closely with the paratransit agency throughout the installation, testing, "debugging modifications, and operation of the system. The manufacturer must also provide adequate training to key personnel of the paratransit agency throughout these phases.

In addition, the paratransit agency must have adequate resources and time to run tests of a new ATSS in parallel with the old system it is intended to replace over a sufficient time period. This is to gain assurance that the new ATSS can indeed meet the needs of the agency, and that it would be problem-free and ready for operation.

o Staffing The use of the ATSS technology will change the skill requirements of the paratransit agency's personnel. The agency will need a system analyst with considerable experience in computer hardware/software. All personnel must be able to use computers. The manager (or the leader of the project) must have technical hardware/software background and management skills sufficient to coordinate work by various personnel. Such skills and personnel may not readily exist in many paratransit agencies, and considerable training of existing personnel would be needed. For some agencies, the ability to recruit an experienced system analyst may be a barrier to adopting the ATSS technology.

o Funding The paratransit agency must have adequate funding to purchase, install, test, "debug", and modify a new system.

Additional funding would also be needed to recruit employee(s) with needed technical skills that do not exist within the agency, as well as to provide extensive training to existing staff. Of these, the system purchase price is likely to be the biggest cost item. Because there are currently no ready-made complete, user-friendly ATSSs available on the market, it is difficult to project the purchase price of such systems. The OUTREACH's ATSS is a pre-prototype system, and its capital cost previously reported in Chapter Three is not likely to be applicable for future complete and user-friendly ATSSs. The cost of running tests of the new system in parallel with the existing system to ensure smooth operation of the new system could also be substantial, and is likely to vary with the size of the paratransit operation.

(e) The Federal and state governments should encourage and provide incentives for demonstration projects of the ATSS technology in various locales and under differing conditions. This would help to accelerate the development of next-generation, user-friendly ATSSs, as well as to advance the use of such systems toward a critical mass. The latter in turn would stimulate further development of the ATSS technology toward maturity. Further, more demonstration projects are needed to derive reliable estimates of the benefits and impacts of the ATSS technology under differing conditions.

(f) The ATSS technology is likely to be the cornerstone of advanced paratransit systems. Automatic vehicle location (AVL) technology, when used together with the ATSS technology, have the

potential to further enhance the performance of ATSSs. AVL systems are capable of providing real-time information about vehicle locations and status. ATSSs without AVL equipment would produce vehicle and passenger trip plans for a given day. In case of a trip cancellation or an open-return request made on the service day, it would not be easy to alter the ATSS-built trip plans for that vehicle in real-time. Real-time information about the vehicle locations and status from AVL would enable the ATSS to insert a trip (or trips) in real-time for that vehicle as appropriate. Another example is that real-time information from the AVL can provide an automatic feedback loop for the ATSS, for use in modifying parameter values of the vehicle-scheduling algorithm of the ATSS in a timely manner. Without AVL systems, such parameter values can be modified using information obtained from other sources whenever it is available.

The use of ATSSs in combination with AVL systems can also lead to efficient coordination between paratransit service and fixed-route services (buses, rail), through implementing timed transfers between modes. In this regard, some paratransit users who are able to used fixed-route services would use paratransit as a feeder service. That is, the user will use paratransit to access the fixed-route mode, and then use paratransit again after exiting the fixed-route mode to the final destination. In this way, the cost of providing transportation to paratransit users can be substantially reduced.