TRANSIT COOPERATIVE RESEARCH PROGRAM

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TCRP Report 18

A Handbook for Acquiring Demand-Responsive Transit Software

Transportation Research Board
National Research Council

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Report 18

A Handbook for Acquiring Demand-Responsive Transit Software

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Subject Area

Public Transit

Research Sponsored by the Federal Transit Administration in Cooperation with the Transit Development Corporation

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY PRESS
Washington, D.C. 1996

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The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions*, published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transit Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA; the National Academy of Sciences, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

TCRP REPORT 18

Project A-6 FY'93
ISSN 1073-4872
ISBN 0-309-05724-8
Library of Congress Catalog Card No. 96-61606

Price $26.00

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The project that is the subject of this report was a part of the Transit Cooperative Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council. Such approval reflects the Governing Board's judgment that the project concerned is appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the National Research Council, the Transit Development Corporation, or the Federal Transit Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

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Published reports of the

TRANSIT COOPERATIVE RESEARCH PROGRAM

are available from:

Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America

FOREWORD

By Staff
Transportation Research Board

This handbook will be of interest to agencies engaged in managing and operating demand-responsive transit (DRT) services. The handbook is intended to assist DRT providers with assessment of software needs and procurement of software to meet those needs. It is intended to be useful to readers at all levels of computer literacy and to be applicable to DRT systems of various configurations and sizes.

Under TCRP Project A-6, *Software Requirements for Demand-Responsive Transit*, research was undertaken by a team headed by SYSTAN, Inc., to specify requirements for the development of future computer software to assist in the management and operation of demand-responsive transportation systems. An implementation handbook was developed to assist transportation providers in the procurement and implementation of such systems. To achieve the project objectives, the researchers conducted a comprehensive review of the literature and current practice related to computerization of DRT systems; reviewed and summarized federal legislation and regulations that directly affect DRT systems; prepared statements of needs and objectives for automating the management and operations functions of DRT systems; developed software specifications for each of the functions; and documented advance technology features. The information collected was used to develop a handbook to assist demand-responsive providers in their decisions about automating administrative and operating functions and in procuring software that meets the specifications.

The handbook provides a history of DRT service and describes how DRT works. The handbook also discusses DRT software, including a description of the existing state of the art based on a survey of DRT providers and experts in the field. A section on computer hardware is included for those who need a tutorial in order to use the handbook.

The handbook is one of three products developed under this project. The second product is a report directed at software developers. It documents the needs of DRT providers and translates those needs into guidelines that should ensure the development of useful software. A third product, the final report, documents the research results of the project. The final report would be of interest to researchers in the field. Both reports are unpublished, but are available on loan through the TCRP, 2101 Constitution Avenue, N.W., Washington, D.C., 20418.

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ACKNOWLEDGMENTS

The research described in this report was conducted under a Transportation Cooperative Research Program contract (Project A-6, entitled *Software Requirements for Demand-Responsive Transit*) by SYSTAN, Inc., with assistance from Logitrans, Inc., and Norm Y. Mineta International Institute for Surface Transportation Policy Studies.

The Principal Investigator for SYSTAN, and the principal author, was Roy Lave, CEO of SYSTAN, Inc. Roger Teal was the Principal Investigator for Logitrans, Inc. Patrisha Piras of the Mineta International Institute contributed materials to earlier reports. Juliet McNally of SYSTAN conducted survey analysis and Patricia Kaspar of SYSTAN performed technical editing prior to TCRP publication.

Many providers, vendors, and other experts generously contributed material used in this Handbook. While they are too numerous to name, many of their names appear in citations, quotes, and lists in the Handbook. The willingness to contribute to this undertaking demonstrates the spirit of sharing and community that exists among the transit and paratransit community and that makes research possible and fulfilling.

The author is also appreciative of and indebted to the TCRP Topic Panel consisting of Brigitte Benett, Capital Metropolitan Transit Authority (Austin, TX); Ray Boylston, North Carolina DOT; Sandra Draggoo, CATA (Lansing, MI); Roy Glauthier (chair) of DAVE Transportation Services, Inc.; Lawrence Harman, consultant; Naomi Ledé, Texas Southern University; Glenn Millis, NYC Transit Authority; Jack Reilly, Capital District Transportation Authority (Albany, NY); Nancy Senn, Milwaukee (WI) County; Peter Shaw, TRB; Denis Symes, FTA; Marjorie Walsh, consultant; and Nigel Wilson, Massachusetts Institute of Technology.

Finally, the author wishes to acknowledge the support and assistance of the TCRP Project Officer Stephanie Robinson. She accommodates the vagaries of research and the idiosyncrasies of researchers with uncommon grace and civility, and she provided insights that enhanced the research of this project.

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CHAPTER **1**

BACKGROUND, INTRODUCTION, AND SUMMARY

AUDIENCE

This Handbook is written for staff members and policymakers of organizations (henceforth called “providers”) that provide shared-ride, flexibly routed, on-demand transit service, called demand-responsive transit (DRT). It is intended to help them decide whether computerization of their operating functions would be beneficial and to assist them in the selection and procurement of the most appropriate software.

1.1 THE HISTORY OF DEMAND-RESPONSIVE TRANSIT

1.1.1 What Is DRT?

DRT services are those public transportation services characterized by the flexible routing and scheduling of relatively small vehicles (occupancy of four to 20 persons) to provide shared-occupancy, personalized transportation on demand (*1*, p. 9).[1] DRT belongs to a family of services called *paratransit*, which also includes conventional exclusive-ride taxis, ride-sharing, and bicycling. DRT is distinguished from conventional taxi service by its ride-sharing feature, which poses difficult control problems; however, when taxi service is offered as shared-ride service, it is a DRT service. Current usage interchanges the words paratransit and demand-responsive transit, but demand-responsive transit is the more precise term for the material in this Handbook so that it, or its abbreviation DRT, will be used throughout.

It is of historical interest to note that this name was not the preferred one by early writers in the field. For example, Bhatt and Kemp (*2*, p. 126) proposed dial-a-ride as a preferred name with the following argument:

> We have advisedly chosen to use the term *dial-a-ride* in preference to a number of other names which have been applied to this type of service. We prefer it to the terms *demand-responsive* and *demand-activated*, because the latter are more general and can be applied equally to taxicab and limousine service. We also prefer it to the name *dial-a-bus*, which implies a vehicle large enough to be called a “bus.”

Since the term dial-a-ride could also be applied to taxi and limousine service, the argument for using dial-a-ride is not compelling. We believe DRT is the more descriptive term although dial-a-ride is a more marketable name for actual services and a number of them do include dial-a-ride in their names.

As originally conceived, a DRT system would accept telephone requests for both immediate and advance reservation service, develop a continually changing set of vehicle schedules (also known as vehicle tours) which would accommodate these trip requests, and route vehicles to the appropriate passenger origins and destinations in accordance with the schedule. Because both the trip requests and the vehicle scheduling and routing decisions were occurring in real time, the control problem became complex when any significant number of vehicles and trip requests were involved.

1.1.2 Role of DRT

DRT service has been one of the most significant service innovations in public transportation in the last two to three decades, but it is the rebirth of a much older service. Almost as long as there have been automobiles in the United States, they have been used as jitneys, originally offering an alternative to streetcar service. (The name “jitney” came from the slang word for a nickel, the typical jitney fare.) Most of these early services were regulated out of business by more politically connected transit operators fearing the competition. DRT had a rebirth in the United States in the early seventies with research on computer-controlled service and experiments in manually dispatched services. A count of current DRT services operating, including social service agency services but excluding conventional taxicab services, would yield several thousand. Collective riding in sedan vehicles is widespread throughout the world, especially in developing countries.

Although in theory DRT service is extremely user-friendly because of its door-to-door capability and semiprivate, comfortable vehicles, its adoption has not been widespread due to the relatively high cost of operation. DRT is a labor-intensive mode with costs comparable to the taxicab, due to inherently low passenger productivity (passengers per vehicle-hour). As a result, these services are most commonly operated by social service agencies to transport their clients or by transit districts, counties, and cities for persons with special needs or qualifying conditions. Nevertheless, in many rural and small towns in which labor rates are low, DRT provides the only transit in town.

[1] References are indicated by numbers in parentheses and are listed at the end of the chapters.

Most recently, demand-responsive paratransit service was promoted to prominence as a result of the enactment of the 1990 Americans with Disabilities Act (ADA) (*3*). The ADA put every U.S. transit agency into the DRT business by requiring fixed-route transit operators to provide complementary paratransit service for persons with disabilities within their service areas who are unable to use fixed-route services. The issue of high cost was set aside by a national policy which deemed that accessible transit is a civil right. The ADA mandate is causing expansion of the number of paratransit services and growth in the size of existing services. This growth, in turn, motivates the search for more cost-effective means of operating DRT because already financially troubled transit must find funds for new services. One promising means of improving the cost-effective performance of demand-responsive paratransit is the use of computerization and other information technologies.

1.1.3 Role of Computerization

Several functions required to offer demand-responsive operations—such as trip reservation, scheduling/dispatching, financial management, and reporting—lend themselves to computer assistance and can be greatly enhanced by computerization. In fact, the potential of the computer to make it possible to cost-effectively operate large demand-responsive transit systems for all users was a motivating factor for the study of scheduling/dispatching in academic and research circles in the early 1970s. The computers at that time were too expensive and too slow, and the several large systems that were implemented—in Haddonfield, New Jersey; Rochester, New York; and Santa Clara County, California—were discontinued by the eighties. Only the fully computerized system in Orange County, California, survived.

While the use of computer control may have diminished, the use of demand-responsive transit did continue in smaller towns and rural areas and in large cities to serve special populations such as persons with disabilities and the elderly. Eventually, the desire among operators to find better, more cost-effective methods led to the development of a market for software to serve the systems that did exist. As the systems evolved and became larger or more demanding of efficient operations, a demand for software evolved as well. This demand was filled by a number of products developed either by operators for their own systems or by consulting firms, academics, and researchers for sale in the general market. Today, software is available that runs on relatively inexpensive computers and serves both small and large systems with a variety of DRT functions. Several newly implemented systems utilizing sophisticated scheduling/dispatching software, automatic vehicle location technology, and digital communications may bring the original vision well within the realm of technical and economic feasibility.

In summary, from the inception of demand-responsive transit circa 1970, computer control of the core DRT functions—scheduling, routing, and dispatching of vehicles in response to trip requests—has been a key issue for this transportation service. The history of computer use is described in more detail in Section 3.2.

1.1.4 Current DRT Issues

The paratransit industry now has an increasingly varied menu of technological options from which to choose. Different vendors of DRT control software have different features and functions in their systems. They use different programming languages, operating systems, database systems, and networking systems to implement their packages, and they provide different levels of interfaces with other technological options. These other technological options have proliferated in recent years and include such technologies as: in-vehicle computers or mobile data terminals, vehicle location devices, mapping systems, interactive telephone systems, and wireless data communications. Each of these technologies holds promise for increasing the effectiveness of DRT service. However, they complicate each provider's decision concerning how many and which technologies are warranted.

Moreover, there are no industrywide standards or even expectations as to what features and functions a system should have or the degree to which it should interface with other software or hardware systems. This can make a decision to purchase one vendor's software more binding on future automation decisions than would be desirable in the best of all worlds.

The requirements of ADA-complementary paratransit add yet another level of complexity to this process. The potential need for determining trip-by-trip eligibility for service, and for providing certain service-level guarantees to ADA riders, poses additional functional requirements for DRT software. Vendors have adopted different approaches to fulfilling these requirements, and the ADA elements of their systems are usually tightly bound with their overall system design.

While a number of providers have navigated among these problems, there are still frustrated and unhappy providers who have unsuccessfully tried to use DRT software, and there are even more providers who believe computerization would be helpful but lack the resources and know-how for the task of selecting, acquiring, and implementing the technology.

In summary, several factors motivated the project to create this Handbook. The promise of the potential benefits of the use of software and the complementary technologies is a compelling reason to develop methods of analyzing and acquiring software. Since the software can be expensive and its benefits are uncertain, mistakes in selection can be expensive and demoralizing. Moreover, the acquisition and implementation process is difficult and laden with problems an agency must overcome. This Handbook is intended to help address these issues for both those acquiring new software and those updating software.

1.2 PURPOSE AND SCOPE OF THE HANDBOOK

> Selecting software is a difficult task that commits considerable resources and risks the integrity of the service on a single decision in an area in which many providers have little experience.

The purpose of the Handbook is to assist DRT providers in dealing with the complexities described above and, specifically, to assist demand-responsive providers in making their decisions about automating administrative and operating functions by helping them select, acquire, and implement software. Additionally, it is intended to assist the process of incorporating other automated technologies into DRT to realize the promise of current technologies for improving the operations of DRT.

The material in this Handbook focuses on software that performs the operations functions necessary to offer demand-responsive services. These are the services that operate automotive vehicles from sedans to small buses; that respond to individual riders' requests for services that pick up and deliver passengers to points usually designated by that passenger; and that attempt to carry multiple passengers at one time to increase productivity and decrease unit costs. The study does not include exclusive-ride taxis, although some of the software used for DRT service is related to taxi software.

Software that performs the following operations functions is included:

- Eligibility determination—verifying the eligibility of the person requesting the service;
- Trip reservation—taking the passenger's call, verifying eligibility, recording the date and time of the trip requested;
- Service scheduling—determining a pickup time for the passenger and conveying that information to the passenger;
- Vehicle dispatching—assigning a sequence of trip requests and times to a driver/vehicle combination;
- Vehicle routing—providing the precise street routing to the driver/vehicle; and
- Reporting—collecting, processing, and documenting the operational information required to manage the system and to report to those having oversight responsibility.

The study includes all of the functions mentioned above but concentrates on the scheduling and dispatching functions.

Software packages are on the market that perform the functions of accounting, invoicing, maintenance scheduling, purchasing and inventory control, planning, and project management. These administrative packages are often included in operations software. Reporting, for example, is included in almost all the operations software packages. Except for reporting, other administration functions are not explicitly discussed in this Handbook. The selection of these packages is not as difficult as selecting specialty software for DRT operations. Additionally, the impact of adopting administrative software is typically not as large and pervasive as is the impact of operational software.

Special purpose software is often required by certain new technologies, such as communications or automatic vehicle location. These technologies are included in the Handbook, but we do not explicitly deal with the special purpose software necessary to operate them.

It is not possible to present guidance for the selection and implementation of software without a discussion of computer hardware, so our work includes material on computers. Usually the hardware and software decisions must be made in concert. However, both buyers and vendors of software have embraced the personal computer as the preferred computer platform, so the decision is not as complex as it may be in other fields.

The needs for software and hardware are examined over about a 5-year horizon. This short time horizon was selected as an estimate of the rather short economic life of computer systems and software. It is expected that the rapid changes of the past decade will be replicated in the future as new technologies are integrated with operations software. However, a good deal of the Handbook material concerning procurement and implementation should have a much longer life.

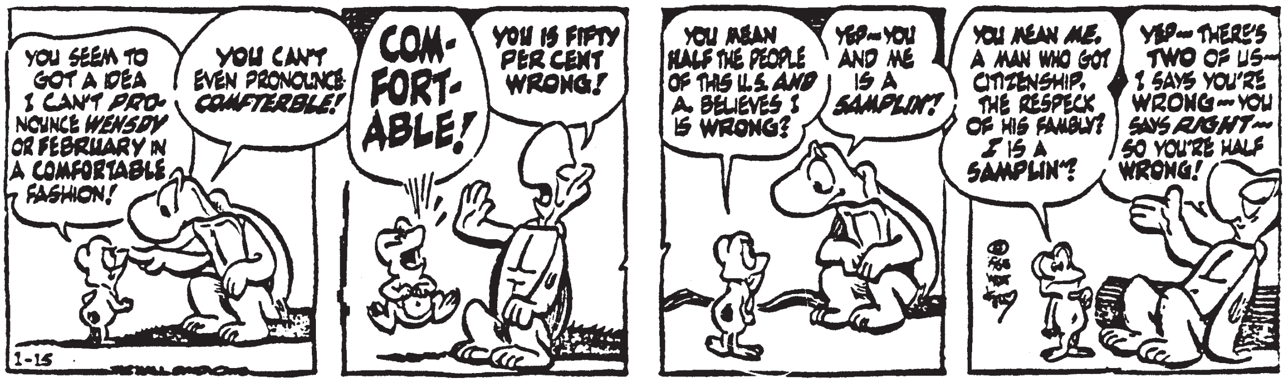
Although it does contain a list of vendors in the Appendices, the Handbook is not intended to be a consumer guide to specific software products by vendor or brand name. It is intended to identify the factors that should be considered when evaluating software packages and vendors of those packages. To understand the experiences of other users of the software, it is suggested strongly that you talk to these users. To help you do this, the Handbook provides a list of users of various packages whose vendors responded to our requests for references (see Appendix 6-A, at the end of Chapter 6).

The Handbook focuses on the acquisition decision, both whether or not to acquire and if acquiring, how to do so. It does not deal exhaustively with the issues of implementation but does provide selected implementation advice.

1.3 SOURCE OF INFORMATION IN THE HANDBOOK

1.3.1 Surveys

Information gathered in two surveys is used to describe the present and anticipated future use of computerization in paratransit (*4*). One is a survey of paratransit providers, and the second is a survey of 20 "experts" in paratransit. The providers' list was selected to include as wide a range of



experience as possible. The list of providers was identified from several sources. Persons on the list of experts surveyed were asked to identify exemplary systems of all sizes and with any degree of computerization. Additionally, providers identified in an earlier study (*5*) as having adopted certain paratransit innovations were included on the list. The list contained 347 providers, 119 of whom completed a mailed survey. The vast majority of systems surveyed are in the United States, although about 7 percent are in Canada, where DRT has been generally more advanced than in the U.S.

This process of selecting providers was not intended and did not result in a sample that can be considered representative of all paratransit providers. Rather it is a collection of exemplary systems which are sufficiently innovative and mature so that their staff would have thoughtful opinions on computerization.

The "experts" group consisted of persons with special knowledge of DRT service, including consultants, researchers and teachers, providers with extensive computer experience, software suppliers, and the TCRP panel. The mailing list was compiled from a list of paratransit experts maintained by SYSTAN and augmented by names from the mailing list of the Transportation Research Board (TRB) Committee on Paratransit. Of the 150 persons identified, 20 completed the survey.

1.3.2 Literature

The project included a literature search of the TRIS database and the transportation libraries at U.S. Department of Transportation in Washington, D.C., Northwestern University, and the University of California at Berkeley. Over 100 documents have been identified and are listed in the Phase I Report of this project (*4*).

1.3.3 Vendors

Information was solicited from more than a dozen vendors who claim to have paratransit scheduling/dispatching software. Additionally, demonstrations of the leading software products were viewed, and extensive interviews were held with members of the leading vendors' staffs. Some of the vendors on the list may have products that are not adequate for meeting ADA requirements or for integrating with other technologies and may not be viable in today's market. On the other hand, about a half-dozen companies seem to have market acceptance of their products and can be deemed to be viable based on their longevity, the number of installations of their software, the sophistication of their marketing including customer support, their plans for the future, and their understanding of the market. New vendors enter the market periodically; in fact, a new vendor entered the market as the Handbook was being completed, and two of the largest vendors merged.

1.3.4 Other Sources

Over the course of preparing the Handbook, the authors had many discussions with the major vendors of specialty software, many of the significant users, and the most active consultants in helping providers select software. Impressions from these discussions are included in the guidance presented throughout the Handbook.

Additionally, the authors have been involved in evaluating DRT software since the earliest demonstrations in Haddonfield, New Jersey, and Rochester, New York. Over the past two decades, we have developed our own impressions of the use of computers. Naturally, all the presentations in the Handbook have been selected and interpreted by the authors, and any shortcomings are our responsibility.

1.4 USING THE HANDBOOK

The most likely audience for the Handbook will be staff members and policymakers in the small (10 to 15 or fewer vehicles) to medium (10 to 50 vehicles) DRT provider agencies. (See Section 2.2 for a discussion of classifying DRT systems by the size of vehicle fleet and other measures.) The large providers (over 50 vehicles) have more limited choices for software, offered by fewer vendors. They also have either the staff capable of the acquisition analysis or the resources to hire the consultants to help. Moreover, the control problem is sufficiently complex that the need for computerization is obvious. Small agencies first have to decide if they need computers at all and then which software packages and which hardware. Although these agencies are resource-limited, inexpensive software packages exist that may provide an affordable means of getting started with software at little financial risk. Medium-sized systems have to decide what level of computerization is worthwhile and then must choose from a wide range of software from the simplest to the most complex. They, too, are probably resource-limited; yet they may have to spend a substantial sum for the appropriate software, so they bear a considerable financial risk from a bad decision. For these reasons, the medium-sized agencies may have the most difficult task in selecting software.

Individual readers of the Handbook are assumed to have a wide variety of experience levels, both with demand-responsive transit and with computers and computer software, ranging from almost none to those with advanced computer programming skills. We have tried to address all these readers by including primer material on both demand-responsive transit and computers. However, it is not the purpose of the Handbook to introduce either of these subjects to novice readers. Much of the material can be skipped by some readers. There are many cross-references among materials. Some redundancy is included to make the most significant sections stand alone for the convenience of readers who may have skipped previous material. Material that is thought to be of interest but is not essential to understanding is placed in footnotes. We have tried to provide guidelines at the beginning of each chapter concerning who we believe will find the material useful.

Understanding terms used in the Handbook is essential to using it. In this regard, it may be more difficult for readers who have experience since the usage of DRT terms does differ and there is no standard and universally accepted set of definitions. We define many terms when they are used and include an extensive glossary at the end of the Handbook, and we suggest it be used often. The glossary contains both computer and DRT terms. Where possible, terms have been adapted from other reports, glossaries and dictionaries (*5–10*). When we believed those sources to be inadequate, we supplied modified definitions.

The Handbook is organized into seven chapters. This first one provides background information on the project, a guide to the content, and a summary of the most significant recommendations. The second chapter defines and describes demand-responsive transit and identifies the functions required to offer the service and which are appropriate for computerization. Chapter 3 discusses DRT software, and Chapter 4 contains a tutorial on computer hardware. The fifth chapter contains a discussion of methods for ascertaining how much, if any, automation is warranted. All five initial chapters build toward Chapter 6, which describes the process of acquisition of software, which is the heart of the Handbook. It describes the steps and issues involved in selecting and acquiring software and provides guidance on implementation. Chapter 6 has two appendices—one contains a list of references for various software vendors, and the second contains two sample requests for proposals. The last chapter (Chapter 7) contains a discussion about complementary technologies that enhance the benefits of DRT software.

The references for the material in each chapter are listed at the end of each chapter. A complete bibliography on DRT software is contained in a different document, the Final Report of the project.

1.5 OUR MOST IMPORTANT ADVICE

We have summarized some of the most important advice contained in the Handbook and listed it in this section. It will not substitute for the full discussion contained in the places cited, but it serves to preview what is coming and summarizes what you should take away from reading the Handbook.

- Make sure you are doing the best you can with your existing operations systems and procedures before you spend money on computerized enhancements. Take the opportunity to reconsider the need for the things you have been doing and how you do them. Are the existing reports necessary? Are responsibilities clearly assigned? (Section 5.3.1)
- Don't assume that you are just computerizing your existing manual system. Computerization may be more effective if you change the way you do things and the way you organize the work. (Section 5.4)
- Carefully document in advance your needs (specifications) and expectations for the system you wish to acquire and make the specifications available to proposing vendors. (Section 6.2.2)
- Prepare your staff for new software by including them in the specification writing and assure that they will be well trained for the specific software. (Section 6.2.2)
- In some cases, a seat-of-the-pants decision to use software is justified, but for the most part, base your decision on analysis. (Section 5.2)
- When acquiring a computerized DRT package, you are blending software, hardware, and service. It is usually wise to make one vendor responsible for all three. (Section 4.3)
- Buy the capabilities you need now and will need in the next couple of years, or until you anticipate a major change in your service. (Section 3.5.4)
- Try to design your computer software to maintain flexibility to adapt to changes or to compensate for mistakes in estimating needs. (Section 3.5.3)
- Identify peers and talk to them about their experience with software and software vendors. If possible, talk to users of the actual software packages you are considering. (Section 6.2.4)
- Do not purchase anything you have not seen actually working in the field. Demonstrations do not count (*11*). (Section 6.2.4)
- If you can justify fully automated scheduling/dispatching software, evaluate the possible value of comple-

mentary technologies (Chapter 7). If you do add technologies, try to make one vendor responsible for the entire system.

- Good implementation takes time—be realistic about schedules and take the time necessary. (Section 6.3.2)
- The ability to move your files easily to new software and hardware is an important capability to allow updating or change if it becomes necessary. (Section 3.5.3)
- Don't pay or release the vendor until you are satisfied. Don't be satisfied until you know the system works under a variety of conditions. (Section 6.2.9)

As with most things in life, hard and fast rules are rare, and exceptions to any set of guidelines almost always exist. However, if you deviate from the suggestions on this list, you should have well-defined reasons for doing so.

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CHAPTER **2**

DEMAND-RESPONSIVE TRANSIT

AUDIENCE

This chapter describes demand-responsive transit (DRT) and the functions required for DRT operations. It is intended as a primer for those not totally familiar with a functional view of DRT systems. It can be skipped or skimmed by readers who are familiar with this viewpoint, although you may wish to read it merely to be sure you know how we define the terms used in the Handbook.

2.1 OVERVIEW

DRT operations require a core set of functions which must be performed whether computer software is utilized or not. We call these the *operating functions.* These core functions are *trip reservations* (order taking and confirmation of a trip request), *scheduling* by assigning a pickup time to patron trip requests, and *dispatching* of vehicles to actually provide the promised service. For target market systems serving a restricted clientele, *eligibility determination* is an additional core function usually performed in combination with trip reservations. In some systems, actual street *routing* is calculated and given to the driver. Finally, *reporting* is also included as a core function because it is necessary to manage paratransit systems effectively and the information for reports comes from the other operating functions. A diagram indicating the relationship of these functions is shown in Figure 2.1. Paratransit software packages typically provide some degree of automation—up to and including full automation—for each of these functions.

In addition to the operating functions noted above, a number of administrative functions are required by DRT systems as well but they are not unique to DRT and general business or transit software is available to perform them. These functions include: accounting and invoicing, maintenance scheduling, purchasing and inventory control, and project management.

Computerization of DRT functions is the subject of the next chapter; however, references to computerization are made in this chapter when it is logical to do so.

2.2 CATEGORIZING DEMAND-RESPONSIVE TRANSIT SYSTEMS

2.2.1 Introduction

DRT systems come in a variety of configurations and sizes and operate under different passenger demand conditions. These factors will have an effect on the functionality required from software applications so that the software appropriate for a DRT operation is dependent on the type of service offered and the characteristics of the service area. This principle may become less significant in the future as vendors develop more robust software packages, but now some software seems to work better for some types of systems than for other types of systems. For you, the buyer of software, this fact creates two requirements: 1) you must identify the characteristics of your system in terms that make it possible to analyze how well a software package will work for you; and, 2) we recommend that you identify other systems, so-called peers, in other areas that are sufficiently similar to yours so that you can take advantage of their experience with software. The impact of each of these characteristics on DRT systems generally, and on software requirements specifically, is discussed in this section.

The characteristics that define a DRT system for the purposes of selecting hardware/software are the following:

- Number of vehicles—a measure of supply;
- Number of riders—a measure of demand;
- Ridership eligibility requirements, e.g., ADA services;
- Immediate, advanced, and subscription reservations—a measure of scheduling effort;
- Service area size and existence of barriers—a measure of scheduling effort;
- Trip patterns—a measure of scheduling effort; and
- Reporting requirements as a function of funding sources or other legal requirements.

2.2.2 Number of Vehicles

The number of vehicles in a fleet is an attractive measure of system size for our purposes because it defines the complexity of the scheduling/dispatching task and, in most cases, it is easily determined. As the number of vehicles in a DRT system increases, scheduling and dispatching become increasingly complex and burdensome in use of resources.

For purposes of relating software to DRT systems by size, three levels of vehicle fleets are considered. Small systems are those of 10 or 15 vehicles or fewer. Medium systems are those of 10 to 50 vehicles, and large systems are those with 50 or more vehicles.

However, vehicle fleet size is not always a definitive measure because many demand-response services are offered by

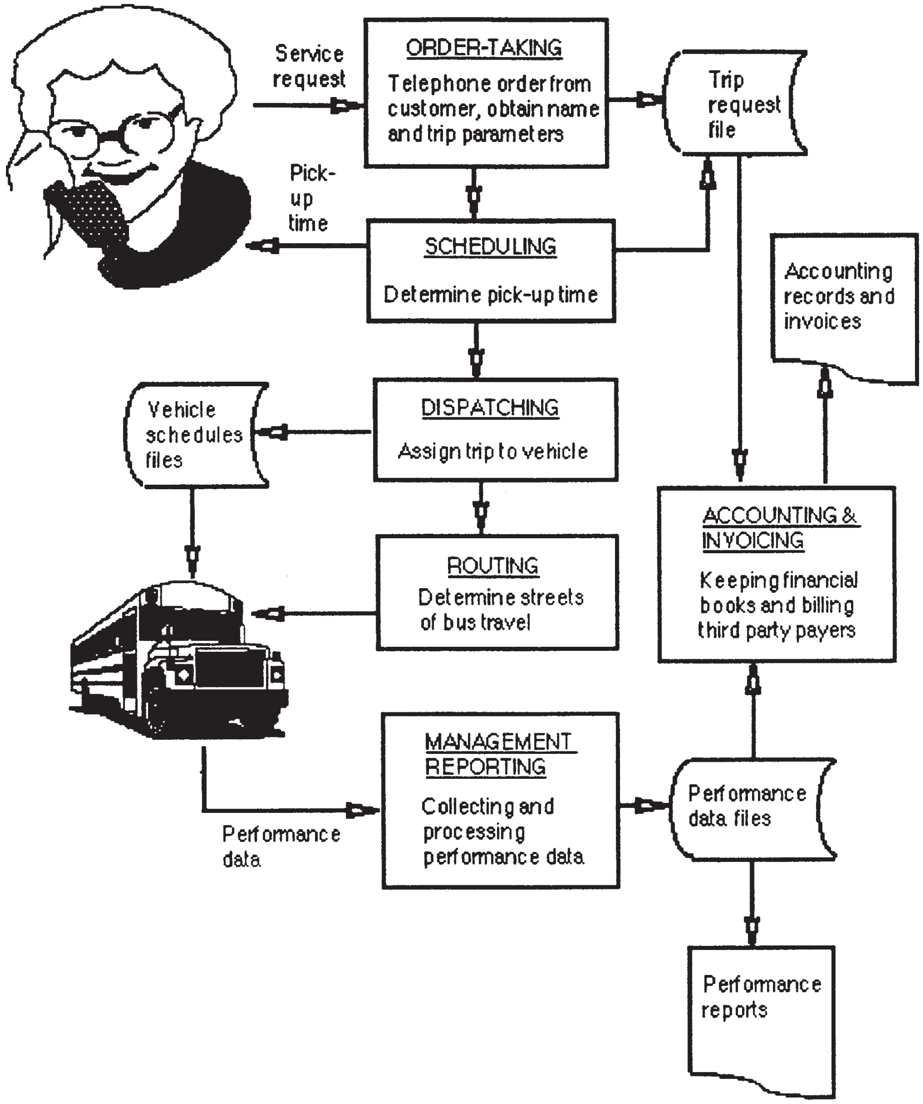

Figure 2.1 Overview of Functions of DRT Operations.

vehicles that the taxi operators share between an exclusive-ride service offered for their own account and shared-ride service under contract to a public or not-for-profit agency. While use of vehicle-hours or vehicle-miles as measures might help overcome the shortcoming of vehicle fleet size as a measure of supply, no guidelines are known to have been published to suggest how this more detailed data should be used. Therefore, the number of vehicles in the fleet will be used as a measure of size in this Handbook.

2.2.3 Number of Riders

Ridership, measured in trips per day or trips per year, is another measure of size that is typically recorded by providers. Ridership is a useful measure when used together with vehicle fleet size to suggest the level of automation required. However, not every rider places the same demands on the scheduling/dispatching function, and other factors must be considered simultaneously, as discussed in the section on reservations.

2.2.4 Ridership Eligibility Requirements

DRT systems can be categorized by whether their service is restricted to certain categories of individuals, called target market or restricted ridership systems, or is available to the general public, called general market systems. These ridership classifications are important for determining software needs. First, target market or restricted ridership systems impose an additional requirement on the paratransit software, namely to determine at the time of trip reservation whether the caller is eligible to use the service. Second, general public systems typically are used much more intensively than restricted ridership systems. Intensity of use is measured by demand density, i.e., trips per square mile per hour. The more intensively a system is used, the more demands are placed on the scheduling component of the paratransit software.

2.2.5 Immediate, Advance, and Subscription Reservations

There are generally two modes of reservations accepted depending on the response time of providing service. DRT systems may operate by taking reservations for immediate service—taxi-like response in 20 minutes to an hour—or advance (prescheduled) service to be provided at some time in the future, usually 24 hours or more. A special type of advance reservation service is called subscription because it recurs at regular intervals, usually daily for work trips. Immediate service has clear advantages for the patron, but it places the greater burden on the scheduling/dispatching function because of the limited time to calculate schedules. However, an immediate reservation mode is thought to have operating advantages since its use reduces cancellations and *no-shows* (instances when the rider does not show up), which occur fairly frequently in advance reservation systems. No-shows and cancellations waste vehicle time, causing reductions in operating efficiency, and require recalculating of the schedules, which places a burden on the scheduling/dispatching function. Subscriptions up to a level of half of all trips, as allowed under the ADA regulations, are usually seen as being desirable since the users are typically more reliable and do not cancel or fail to show up and thus form a solid core for planning vehicle trips.

Both immediate and advance service can be offered by a DRT service without conflicts. However, until recently, most DRT services offered advance reservation service as a means of rationing scarce capacity. Now with the passage of the Americans with Disabilities Act (ADA), which prohibits rationing, it is expected that more systems will offer immediate service, which has clear advantages to the users and which many professionals hypothesize has advantages to providers as well.

2.2.6 Service Area Descriptions

There are no standard means of categorizing the service areas in which DRT systems operate. While providers can generally define their areas as urban, suburban, rural, or a combination of these, descriptors of the difficulty of offering service based on geography, street layout, barriers, and the like are not well defined. A sometimes useful measure of service area is what is called the *demand density*, that is, the number of trips per hour per square mile. This can be useful for defining the complexity of the schedule/dispatch task—areas of high demand density offer the possibility that computerized scheduling can perform very much better than manual schedules because there are so many trip assignment possibilities that the computer can process better than a person. On the other hand, when demand density is low, a human dispatcher may be able to do as well as a computer. In fact, some providers report that some software does not seem to perform well in areas of low demand density. Finally, demand density can be a misleading measure in cases in which the service area is not homogeneous and demand density varies greatly within different parts of the service area. As a proxy for a more detailed analysis, the urban-suburban-rural classification can be used to identify your system.

2.2.7 Trip Patterns

A trip on a DRT system is determined by the passenger who selects both the origin and destination. When all trips made on a system are considered together, they may fall into certain patterns. If the provider places no constraints on the trips, they may form a random pattern consisting of many origins and destinations. This pattern is called *many-to-many* service. Often, however, there will be some destinations that are quite popular, such as hospitals, shopping areas, and the like. In these cases, the pattern would consist of many origins, presumably the homes of the patrons, and a few destinations. This service is called *many-to-few* and the return trip would be *few-to-many.* A service designed to serve a single destination, such as a senior center or a hospital, may serve only one destination—their facility. In this case, the pattern is *many-to-one*. These patterns are shown graphically in Figure 2.2, together with a representation of fixed-route service for comparison.

One of these patterns may emerge because of the patrons' choice of trips or because the provider limits origins and destinations. This fact makes it difficult to classify systems using trip patterns for purposes of determining performance and identifying similar providers. Providers may tell you that they offer many-to-many service because they are willing to serve any destination, but their actual patterns may be many-to-few because of passenger behavior, so they are not comparable to a true many-to-many system.

Pattern is an important characteristic of a service because many-to-many is much more difficult to schedule and dispatch than are many-to-few or many-to-one services and it will typically have lower productivity than the other two. Systems offering many-to-one or many-to-few destinations generate a much smaller burden on scheduling/dispatching than do systems offering many-to-many patterns.

There are two additional types of service that may be offered which are hybrids that combine features of fixed route and demand-responsive service. A service that operates on a fixed route but will make deviations from the route to make pickups and drop-offs is called *deviation from route* service. A service that arrives at certain points in the service area at scheduled times but is free to make pickups and drop-offs between those points is called *deviation from point* service. The essential difference between these two is that deviation from route must follow a fixed route and deviation from point need not. If there are no requests for demand service, both these services may look like a fixed route service. These two services are not as prevalent as the more unconstrained

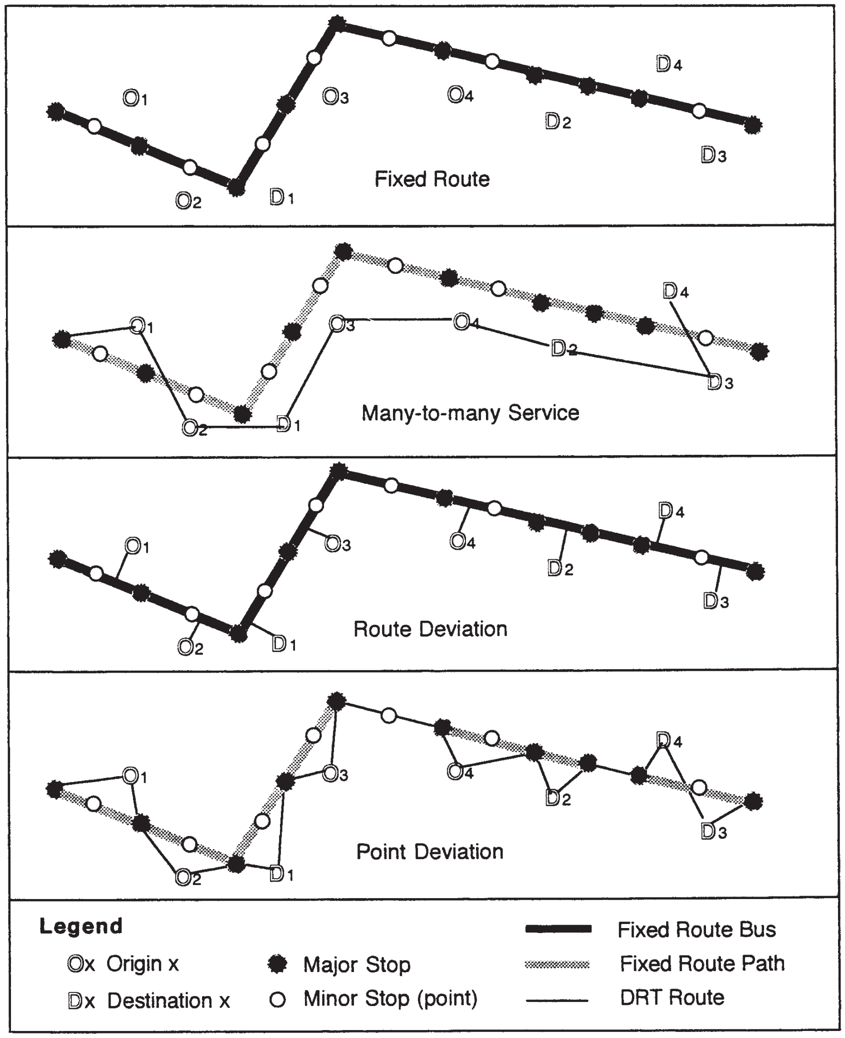

Figure 2.2 Patterns of DRT Service.

services, but they are thought to have underutilized potential that may be realized by better technology.

2.2.8 DRT Service Trade-Offs

The major choice in the design of DRT service is between efficiency and quality or level of service from the users' point of view. Service quality ranges from the most costly exclusive-ride taxi service, in which only one person rides at a time, to trips in which vehicles are shared, and each rider may have to ride longer than is needed for his trip while the vehicle drops and picks up other riders. Assigning many passengers to a vehicle at the same time results in efficiency due to minimizing the total vehicle miles traveled and the fewer vehicles required. However, high passenger loads lower the quality of the service by raising the average ride time and increasing the variability of promised pickup and arrival times. These trade-offs are usually determined by specifying minimum service levels in terms of the longest ride times allowable and the maximum lateness for a promised pickup or arrival. Within the constraints of these specifications, dispatchers will try to maximize the number of trips provided by each vehicle hourly.

2.2.9 Summary

In summary, the number of vehicles and the number of daily riders are the most significant variables for assessing whether you are a candidate for computerized scheduling/ dispatching. Other factors that should be considered include reservation lead time and the density of the service area. The suggested analysis is covered in Chapter 5.

2.3 DEMAND-RESPONSIVE TRANSIT FUNCTIONS

2.3.1 Eligibility Determination

In many DRT systems, prospective patrons must meet certain eligibility criteria before they are permitted to utilize the system. These may involve age, physical condition, agency affiliation, and ADA certification. Whatever the criteria, only those who have previously been registered as eligible riders are allowed to utilize the DRT service.

In such systems, the software must be capable of determining at the time the prospective rider calls that this individual is eligible to use the system. This typically requires the computer to search a database of eligible patrons in an attempt to locate the individual who is requesting service. If individuals are found in the registration database, they can then make a trip reservation.

In systems serving ADA-eligible patrons, a further eligibility determination may be made, notably whether both the origin and destination of a patron's trip are within three-fourths of a mile of a bus transit route and a rail station. Also in ADA systems, the rider may be conditionally eligible for a trip, depending on both time-varying factors such as the customer's health and the weather, and semipermanent features such as the accessibility of sidewalks around a transit stop. Not all these factors can be determined objectively by a third party but the ones that can, such as accessibility, could be made by a scheduler using information that can be stored in the customer's database records. Whether it is wise for providers to have their schedulers make a determination of conditional eligibility is another matter.

Often eligibility determination is performed as part of the trip reservation or order-taking function, which is described next.

2.3.2 Trip Reservation (Order Taking)

The terms *trip reservation* and *order taking* are often used interchangeably, as they are in this report. In immediate response DRT systems, the term order taking is more appropriate, whereas in a prescheduled operation, a customer truly is making a reservation for service to be delivered at some point in the future.

In either case, the essence of this function is for the order taker/reservationist to obtain the parameters of the trip request from the patron—pickup point, drop-off point, desired pickup or delivery time, number of passengers, and any special requirements (such as wheelchair accessibility)—and then to communicate to the patron whether the system is able to accommodate the trip request with these specific parameters and, if so, when a vehicle will arrive. If the trip cannot be accommodated due to unavailability of resources for this specific trip request, the order taker/reservationist must indicate to the patron the reason for the problem. The reservationist must then interact with the customer and attempt to find acceptable trip times which the system is able to accommodate. If either initially or on subsequent attempts the trip reservation can be accepted, the order taker/reservationist then informs the patron of the estimated pickup time, typically using a time window rather than a single point estimate, e.g., 8:40 a.m. to 9:00 a.m.

2.3.3 Service (Trip/Vehicle) Scheduling

> Bad drivers do what they are told; good drivers fix the schedule.
>
> —Park Woodworth, Senior Planner,
> Seattle Metro

Scheduling is the process of inserting a trip request into an actual (for an immediate response operation) or provisional (for prescheduled operations) schedule in such a way that no system constraints are violated by the new schedule. *Scheduling is the core function which distinguishes DRT systems from other transit.* In conventional transit, buses are scheduled by the clock to predetermined origins and destinations, and patrons adapt to the schedules. In DRT service, the schedule adapts to patrons' desired timetables, origins, and destinations.

These system constraints typically involve maximum ride time, maximum wait time (for immediate response operations), and promised pickup and delivery times for those trips already scheduled. Once a trip has been scheduled, it has an estimated time of arrival (ETA)—usually a time window—at the patron's pickup location.

It is important to note that once the trip has been scheduled, the DRT system has entered into an implicit contract with the customer to deliver service as specified. That is, the system is pledging that it will accomplish pickup within a certain time window; delivery by a specified time, if this is one of the requirements of the trip; and a maximum ride time, which depends upon system policies—usually 45 to 60 minutes.

The process of scheduling individual trip requests while the customer is on the phone is called *interactive* or *on-line scheduling* by the industry. This term is used in this Handbook and refers to a scheduling system in which some means of accepting or denying a trip request is based on available system capacity and, if a request is accepted, an estimated time of arrival of the vehicle is given to the requester, usually within a specified time window. Although the actual assignment of this passenger trip to a vehicle tour (the sequence of pickups and deliveries) may not yet have been made or may subsequently be changed, the time window for vehicle arrival will not be changed except in unusual circumstances. Interactive scheduling is *not* real-time, or immediate, service. Interactive scheduling determines the pickup time immediately while the trip may be scheduled for any time in the future, contrasted to immediate service, which accepts requests for a trip as soon as possible. Real-time service requires interactive scheduling, but the converse is not true—many prescheduled operations use interactive scheduling.

The quote by Park Woodworth above reflects dependence on the driver for wisdom in changing schedules created by a process, either human or computer, that is not as in touch with the road as the driver is. It raises the issue of how much, if any, autonomy the driver will be allowed in systems using computers and technologies. There is a conflict between driver initiative and the ability of the dispatcher and computer to know the location of vehicles and to use that information for creating better schedules.

2.3.4 Vehicle Dispatching

Vehicle dispatching is the process of assigning an actual vehicle to a trip that has previously been scheduled by the system and communicating that assignment to the driver of the vehicle, including the order and time during the vehicle tour this patron will be picked up and dropped off.

Although the dispatching process places a trip onto a vehicle tour in a prescheduled operation, the vehicle tours may subsequently be revised and trips reassigned to other vehicles. Trip cancellations and no-shows will almost always require some alteration in the assignment. The dispatching process is responsible for accomplishing these dynamic trip-vehicle reassignments. In an immediate-response DRT system, trip reassignment may also occur, although it is somewhat less frequent because there are fewer cancellations (due to the high proportion of trips that are seeking immediate service). Whatever a system's mode of operation, every trip request must be assigned to a specific vehicle, and the driver of that vehicle must be informed of the sequence of addresses to visit to pick up and drop off patrons.

In real-time scheduling/dispatching, a new trip request can be added to an existing schedule and trip assignment. One way is to search for the best vehicle assignment for the new trip without changing any other assignments. This procedure will not necessarily find the best schedule/dispatch arrangement from a global point of view. It may be possible that a better arrangement exists if all assignments are thrown up in the air and made over again—a procedure called *dynamic rescheduling*, although it is more accurately called *dynamic redispatching* because vehicle assignments may be changed but the promised schedule of pickup times is maintained. This is accomplished by moving already scheduled trips from one vehicle tour to another, or creating an entirely new set of vehicle tours, within the constraint that pickup and delivery time windows cannot be violated. The purpose is to free up time on one or more vehicle tours, thereby enabling more trips to be scheduled and improving system productivity. The advantage of dynamic redispatching is that it may find better assignments than would be made by merely appending a new trip to an existing dispatch. The price paid is the time it takes to redispatch and to communicate frequently with the drivers. It may not even be possible to reschedule in a reasonable time, even by a computerized system. A compromise may be to redispatch after the addition of several new trips. It is not possible to say categorically whether dynamic redispatching is a worthwhile feature. The improved arrangements may not be real, given the normal uncertainties of meeting a schedule. Moreover, the ability to find better tours by rescheduling may be constrained for several reasons. Both promises to subscription patrons that they will get the same driver and the need to assign certain patrons to specific vehicles constrain the ability of redispatching to improve a given arrangement.

For ADA paratransit systems, in which trip requests can be made as many as 14 days in advance, these end-of-day schedule refinements may be done daily for future days on which significant numbers of trips have already been scheduled.

2.3.5 Vehicle Routing

The routing function finds the best route between pickup and drop-off points in terms of the sequence of actual roads taken. The theoretical routing task usually requires solving a mathematics problem called the *shortest path* problem, in which the shortest path may be measured in several different ways—mileage, operating cost, or speed of travel time. Approximate best routes could be prescribed by control room staff, based on their knowledge of the street network without the use of the mathematics, but they would just be substituting their knowledge for that of the driver, and it may or may not be superior to the driver's. The mathematical solution can be performed by a number of mathematical procedures, but performing routing in a system of a practical size requires automation.

2.3.6 Management Reporting and Statistics

While not a core function for the DRT control system per se, management reporting is clearly a key component of the overall DRT operation, as the management reports provide feedback on how effectively the system—and the software—are performing. Management reporting consists of collecting data on all major system processes and analyzing those data to provide system managers with indicators of the efficiency and effectiveness of various system processes. Such indicators as average length of time to book a trip, average ride time, average pickup time deviation, passengers per vehicle service hour, and the like are very important in telling management how well the system is operating. Most DRT software packages provide this information, although they tend to be weakest for indicators that depend on the collection of real-time operational data.

2.3.7 Accounting/Invoicing and Other Functions

Accounting/invoicing is not a function that is unique to DRT operations, but it is necessary to the operations. The other functions of maintenance, inventory, and purchasing, etc., are also not unique to performing DRT functions, and they may be integrated with operational procedures or performed as stand-alone procedures.

CHAPTER **3**

DEMAND-RESPONSIVE TRANSIT SOFTWARE

AUDIENCE

Every reader, even one with extensive DRT software knowledge, should peruse this chapter because we identify the terms used in subsequent discussions, especially in Chapter 6 on acquisition of software.

> The word software has been in widespread use since about 1960, when programs were first sold separately from the computer hardware on which they ran. Implying a malleability lacking in the machines themselves, the term refers to the instructions that tell computers what to do. The replacement of one set of instructions by another can produce protean changes, turning a tool for analyzing stock-market trends into a word processor, or an architect's electronic sketch pad into the control panel for an entire factory. Without detailed orders from a program, a computer can do nothing at all.
>
> —*The Software Challenge*, Time-Life Books, p. 19 (*1*)

3.1 INTRODUCTION

The earliest computers did not have software. The instructions that directed computer operations were wired into their electronic circuitry. Software came to exist when it was realized that instructions could be stored in the computer, in the same way as data are, so that they could be changed easily and each change or new application would not have to be wired into the computer.

DRT software, then, consists of the computer programs that perform one or more of the operations or administrative functions required to offer demand-responsive transit service. This chapter contains a summary of the history of DRT software, a tutorial on software, a description of how DRT software fits into the family of software, a summary of existing DRT packages, and users' evaluations of DRT software in general, not by specific package.

3.2 HISTORY OF DRT SOFTWARE

The history of DRT software can be viewed as consisting of several stages shown in Table 3.1. The descriptions are general and intended to describe the major stages of DRT implementation, but notable exceptions exist in each time period. In the early 1970s, there were two levels of DRT systems. One level consisted of a number of small DRT systems that could be controlled manually and were characterized by low ridership and a small vehicle fleet. They were small either because they operated in small towns and provided the only transit in town or, if they were in larger cities, they served restricted riders—such as elderly persons and persons with disabilities. While computerization might have helped control these small DRT systems, such software was not widely marketed, if it existed at all. Those providers who used computers probably developed the software themselves.

The second level of DRT systems was a vision more than a reality. The vision was of systems that would accept telephone requests for both immediate and advance reservation service, develop a continually changing set of vehicle schedules (also known as vehicle tours), serve passengers within a fairly small window of desired pickup and drop-off times, hold riding time in the vehicle below a reasonable maximum, and do all this with as few vehicles as possible.

The operation of DRT systems under these conditions poses difficult control problems in systems with many vehicles and large demand. The volume and speed requirements needed to handle a relatively high frequency of trip requests that would have to be assigned to many vehicles in a real-time operational setting was thought to be beyond a human dispatcher's capacity. For this reason, it was believed that computer control would be necessary. Computerization of the DRT control system represented the underpinning of the DRT concept as it was developed at MIT during the late 1960s and early 1970s. DRT was seen as a classic operations control problem for which an algorithmic solution was possible. Only algorithms[1] encoded in computer software could handle a control problem of this scope and difficulty. All the earliest major systems—Haddonfield, New Jersey; Rochester, New York; Santa Clara County, California; and Orange County, California—were predicated on computer control. The researchers at MIT and elsewhere devoted

[1] The precise meaning of the word "algorithm" is a computational procedure for solving a particular problem which is assured of discovering the best answer. In more popular use, it is sometimes used to describe a computational procedure which gives a good solution. We prefer the precise use and would use the word "heuristic" to describe a procedure which gives good or "near best" solutions.

TABLE 3.1 Stages of DRT Software Implementation

Time Periods	Service	Software	Computer
Mid '70s to early '80s	State-funded small systems in small towns (CA, MN, MI) Unrestricted ridership	Manually operated Computer not used	Manual
	Large demonstration systems (Haddonfield, NJ & Rochester, NY) or innovative service (Santa Clara Co., CA) Unrestricted ridership Immediate and advance reservation	Fully automatic Full functions	Mainframe and minicomputer
Mid '80s to present	Restricted ridership Advance reservation	Limited functions	Microcomputer
Present to future	ADA service Immediate and advance reservation	Fully automatic	Microcomputer Other technologies: AVL, MDT, digital communications, etc.

considerable attention to the development of such algorithms and their implementation in computer software (*2*). Much of the research and the demonstration of these early systems was financed by grants from UMTA, part of the U.S. Department of Transportation. Further, the early researchers anticipated that *several* automated technologies would be used by DRT systems *in addition to* the computerized reservation, scheduling, and dispatching system, notably radio frequency digital transmission of trip orders to vehicles, in-vehicle data terminals to display or print trip orders, a vehicle location system to keep track of actual vehicle positions, and computer database systems to store trip information and generate reports.

The early research and demonstration work established the technical feasibility of computerized scheduling and dispatching, but other factors held up the widespread adoption of computerization. First, the high operating cost of the large and costly mainframe computers that existed at the time made the service economically questionable. Additionally, a few years of experience with DRT revealed that the magnitude of the control problem in most DRT systems was much reduced from original expectations. This was largely because both the overall level and the intensity of demand (usually expressed as *demand density*, defined as trip requests per hour per square mile) was much less than anticipated. Therefore, the number of vehicles required was smaller than anticipated in many systems, and the control problem was not as complex. Some observers believe that demand fell short of expectations because of inadequacies in the service, due in part to shortcomings in both software and hardware. In some cases, such as Santa Clara County, high initial demand did materialize because of the refusal of the policy board to charge premium fares for the premium service. The software and the limited number of vehicles were not adequate to handle the demand. This swamping of the system together with other issues led to the termination of the service. In addition, many examples of well-functioning manually controlled DRT systems proliferated, further reducing the impetus for computerizing the DRT control function. Finally, federal funding of paratransit research in general, and computerization in particular, dried up with the leaner U.S. Department of Transportation of the early 1980s.

Nevertheless, the use of DRT systems continued to grow during the eighties, although the nature of these DRT systems was vastly different from the ones envisioned for fully automated control in the 1970s. They no longer utilized the cornerstone of the vision—real-time scheduling and dispatching of trip requests. They required their riders to make trip reservations at least one day in advance of their travel. Although many operators anticipated that advance reservation systems would have major advantages over immediate-response (real-time) DRT systems, in practice, this mode of operation has been associated with much lower service productivity (which translates into higher costs per passenger) and with more problematic software requirements. Despite these problems, advance reservation systems have become commonplace because they allow DRT operations to ration capacity easily, and they avoid at least some of the complexity of real-time scheduling and dispatching.

These less sophisticated DRT systems did form a market for computer software with more limited control capabilities. This demand was filled by a number of products developed either by operators for themselves or by consulting firms, academics, and researchers for sale in the general market. Many of these products had limited functionality. For example, virtually all of the scheduling/dispatching software developed for DRT during the 1980s was premised on an advance reservations regime. In fact, the 130-vehicle DRT system implemented in California's Orange County Transit District (OCTD), circa 1980, remained, until it was replaced in the mid-1990s by a new generation system, the most technologically sophisticated DRT system in the country, despite the vast improvements in computer hardware and software which have occurred in the general computer industry over the past decade.

As a result of these two major changes in DRT operations over the past 20 years—the virtual abandonment of fully automated control and the strong trend towards advance reservations systems—the technology of the typical DRT system existing today is quite different from that envisioned by the developers of this mode. Currently, there appear to be between 100 and 150 DRT systems that have installed computer software to automate at least some of their reservations/scheduling/dispatching functions. Even though some of the larger systems are quite sophisticated—the computer hardware is vastly more powerful, the software is better written, and the software-user interface is better—in most other aspects, today's typical *computerized* DRT system is, from a functional standpoint, still lagging behind the OCTD DRT system implemented a decade and a half ago.

Since the late 1980s, however, there has been a renewed interest in the application of computer software, especially multi-function software, to DRT scheduling. This renewed interest has been fueled by three developments. First, computer technology has become relatively affordable for DRT systems with the development of microprocessor-based computers and the remarkable cost reductions in computer hardware that have accompanied the development of a mass market. Second, a number of firms have developed software applications designed specifically for DRT systems; and although these applications vary substantially in their scope and functionality, they all attempt to automate, in whole or in part, the DRT control system.[2] Thus, a variety of software is available to automate the DRT control functions, ranging from almost generic off-the-shelf packages to sophisticated packages that need significant installation effort. Third, the Americans with Disabilities Act (ADA) has imposed new requirements and/or new demands on many DRT systems, and software can be of significant assistance in dealing with these new mandates.

As a consequence of these developments (and others), during the past few years substantial numbers of DRT systems have purchased computer software to automate—in whole or part—their control systems and other aspects of their operations. In addition, other technologies such as mobile data terminals, automatic vehicle location devices, in-vehicle computers, and map-based software systems—all with potential application to many DRT operations—have recently entered the commercial marketplace and have been the focus of interest by some DRT systems. The DRT industry is seeking to better understand how to incorporate DRT software and related electronic technologies into its operations, and is seeking software which will cost-effectively solve its central day-to-day operational control needs. So although the early vision of DRT has yet to be realized on any significant scale, this may change in the near future.

[2] Some of these developments can no doubt be traced to the early work in computerization, either directly through individuals who carried on the work or indirectly by demonstrating the feasibility of the ideas and procedures.

3.3 TYPES OF SOFTWARE

There are four types of computer software involved in computer use—operating systems, programming languages, utilities, and application programs. The software packages of interest in this study are a type of application program. This section may be skipped by those familiar with software, but it is a short tutorial section, and reading it will assure that the viewpoints we use are the same ones you have.

3.3.1 Operating Systems

Operating systems are master programs that coordinate the various hardware components and allow users of other programs to control the operations of the computer. Specifically, they control the microprocessor (the electronic unit that performs the computer's functions), the data transfer functions (input and output), the peripherals (printer, storage units, etc.), the random access memory or RAM (internal storage of data), and the like. Operating systems that you might have heard of include CP/M, DOS, OS/2, UNIX, and Macintosh OS. Since they are so closely related to hardware functions, they are discussed further in Chapter 4 on computer hardware.

3.3.2 Programming Languages

A programming language is a code, or set of instructions, used to communicate with the computer hardware. Instructions are arranged in programs prepared by people called programmers. The programs discussed below—applications and utilities—are prepared in a program language. Program languages you may have heard of include BASIC, C, COBOL, PASCAL, and FORTRAN.

3.3.3 Application Programs

The application software used in the operation and administration of demand-responsive transportation can be classified into three types—generic, special-purpose or specialty, and custom.

Generic software is designed to perform general functions but can be customized for a specific application by the user. Generic software includes the three workhorses of all personal computers—word processing, database management, and spreadsheets. Word processing programs are used to prepare text documents. Database management programs are designed to sort, organize, and retrieve large volumes of data and are therefore appropriate for client data files and the like. Spreadsheets provide a systematic way to perform many computations and to present the results. They are appropriate for processing accounting and performance data. Database and spreadsheet software have some overlapping capabilities as most modern spreadsheets have database capabilities, and databases have limited computational capabilities. These three categories are so widely applicable that they form a class by themselves, but, for purposes of this study, other software such as accounting and project management are also included in this class. Almost all DRT systems that use computers in any way will use one or more of these applications.

The generic packages are relatively inexpensive, costing between $100 and $500, and are easily used by people who are computer literate so that special training is not required. Particular applications of one of these generic programs may require some set-up work but they typically do not require any special computer programming knowledge (although some databases and spreadsheets do include programming languages). The first generation of commercially available DRT software was based on databases and spreadsheets that vendors or agency staff tailored for DRT applications. Some of these packages are adequate for small systems today, although you should make sure they are supported by their developers or someone else if you need support.

The second class of software consists of special purpose packages, called *specialty* here, developed for DRT applications and marketed to providers of DRT service in much the same way that transit vehicles and equipment are marketed with professional staffs that call on potential customers. The effective use of these software programs requires assistance in installing them and special training for your staff. They are more difficult to use than is off-the-shelf generic software, and the mistake of thinking they can be easily implemented is a major pitfall. Installation may require the setting of a variety of parameters that describe the provider's policy, operating policies, and environment; however, these programs do not require one-of-a-kind customizing. If special tailoring is desired, some software vendors may be willing to provide it as a separately priced option.

The software packages that are the focus of this study are the specialty packages developed especially for DRT service. These specialty packages can be further classified by the particular DRT function they perform.

Before DRT software was well established as a commercially available product, a number of agencies contracted or partnered with software programming companies to have software developed specifically for their DRT systems. Most of these are one-of-a-kind applications, usually called *custom* packages, although some of these efforts led to products that are now successful in the commercial market. Commissioning a customized package is still an option available to DRT providers, but it seems less necessary today as there are a number of competing products in the market that provide a range of capabilities. Customized or tailored software will, in most cases, be much more expensive than these commercial products.

Another type of custom software is created by adapting a generic package to DRT use—usually database and spreadsheet applications. In the classifications used throughout the study, the term custom is used for both adaptations of generic software packages and one-of-a-kind, specially prepared packages.

3.3.4 Utility Programs

Utility programs are software packages that perform a number of internal housekeeping or assistance functions, such as copying or organizing files, or other internal functions such as protecting data, verifying proper operations, and the like.

3.3.5 Other Classes of Software

Public domain software is that which is available free to users because ownership rights have been donated (or otherwise passed) to public use. Many application and utility programs that may be useful to DRT operators exist in the public domain, but we know of only one designed specifically for use in DRT operations—the SST3 package distributed by the University of Kansas (see Table 6.3).

3.4 STATUS OF SOFTWARE USE

3.4.1 Databases

A database is any collection of information stored in some logical arrangement so that the information can be retrieved. Any list of names, trips, and the like that is recorded and updated manually can be considered a database but because of the amount of information, the need to change entries easily and quickly, and the need to find elements quickly, computerization is an ideal way to maintain a database. (A description of the structure of a database is located in the Glossary under "Database.")

The most common computerized databases used in DRT operations are shown in Figure 3.1, which also indicates the frequency that the providers indicated they used various levels of automation—manual, generic, or specialty. The responses indicate that most databases are maintained manually.

Generic database software packages can be fairly easily tailored to the uses described in the figure. Advanced pack-

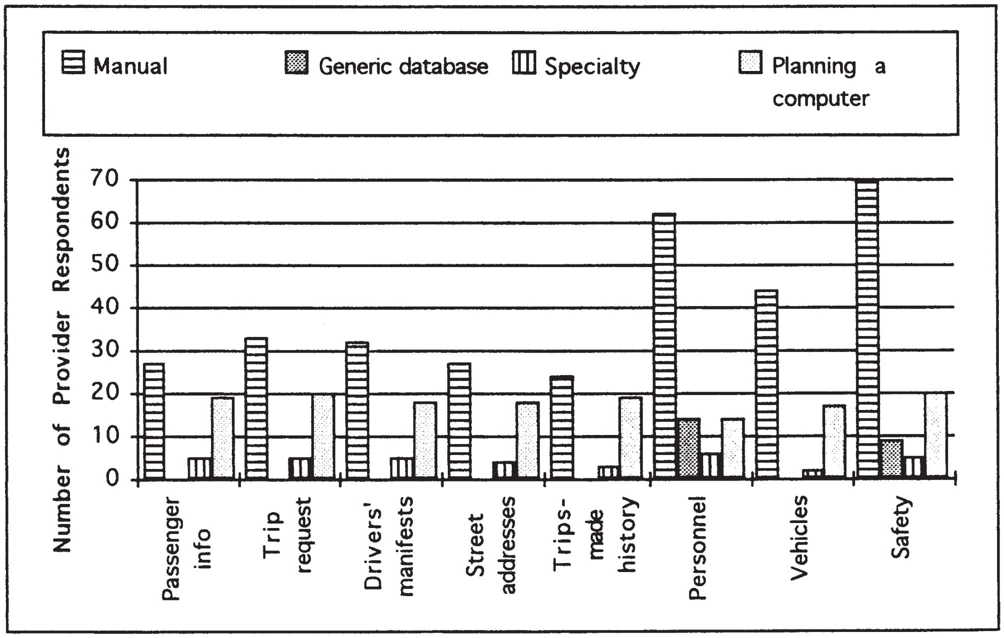

Figure 3.1 Computerization of Data Files.

ages include a programming language that allows the information in the database to be retrieved and manipulated to prepare reports or conduct analysis. Therefore, some of the DRT functions can be performed with generic databases. The use of these databases requires modest programming skills. Some of the software packages on the market are based on generic packages that have already been tailored to DRT functions. (For example, the aforementioned SST3 program for Small Transit Management Software—see Table 6.3—is written in a generic database called dBase III.) Most of the higher-level software packages integrate database capabilities into the software.

Surprisingly, respondents indicated that the DRT specialty software packages are used to a greater degree for database tasks than are the generic packages. This may be caused by the respondents' misunderstanding of the definitions of the terms used. Several DRT databases are written in the languages within generic database packages, but users might consider them to be specialty packages rather than generic ones. The fact that the "specialty" bars in the exhibit have similar heights suggests the hypothesis that those providers using specialty software tend to use the packages for many of the database tasks.

The passenger information database is one which contains a record for each registered passenger (or using passenger if no registration is required). The fields in each record provide everything that is known about the passenger, including mobility aids required, fare basis, eligibility for third-party payment, home address, etc. Computerization of the DRT passenger database is probably the first step taken by providers to use computers in operations. Computerizing databases first is a sound strategy because database installation is probably less disrupting to operations, requires fewer changes in procedures, and requires less training of staff than other computer applications. Moreover, the tailoring of a generic database for use as a customer list is relatively inexpensive and is quickly implemented. Whether the use of a computerized database for customer lists is worthwhile depends on the size of the customer list and the degree to which other functions are computerized. If a system's scheduling/dispatching function is computerized, many of the databases also will be computerized.

Many respondents did not answer the question concerning databases. It may be that they did not consider the records they keep in each of the specified areas to be formal files or databases, or they were misled because the word "computerized" was used in the title of the question which suggested that it only dealt with computerized files.

3.4.2 Computerization of Other Functions

The results of the survey of providers concerning the computerization of functions are shown in Figure 3.2. Manual performance is the predominant means of executing the four key functions of DRT service—due in part because most systems in the survey are small. It is more likely that software is used for the trip reservation function than the other three functions, but DRT specialty packages are used about equally in reservations, scheduling, and dispatching (the last four bars in Figure 3.2). Routing is the function that is least computerized and the one for which specialty software is least used.

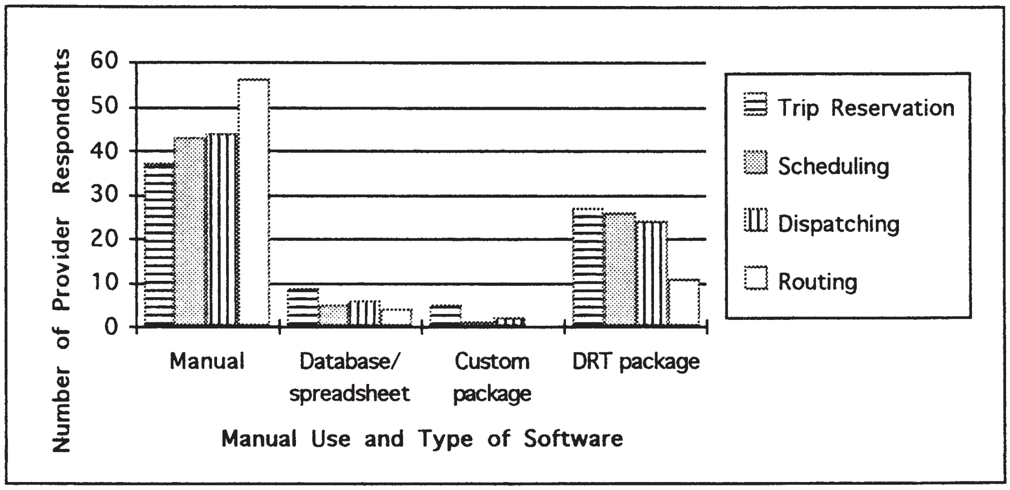

Figure 3.2 DRT Function by Software Type.

3.5 CHARACTERISTICS OF DRT SPECIALTY SOFTWARE

3.5.1 Levels of Automation

A hierarchy of levels of automation for the scheduling/dispatching function is shown in Table 3.2. It ranges from manual performance to fully automated using supporting technologies such as Automatic Vehicle Location (AVL). The first step above manual performance is the use of a generic package, such as a database or spreadsheet, which has been customized or tailored to fit a DRT function. Usually these packages perform the less complex paratransit functions of eligibility determination and recording trip requests and trip information—called low-end—and are written in a generic applications program. This software performs similarly to the generic software except that the screens, database structures, and supporting functions are tailored for paratransit applications.

The next level—which as a class we call high-end—includes specialty programs of varying levels of automation. The first level of specialty software is called computer-assisted, in which the computer will perform calculations and manipulations that provide information to a human scheduler/dispatcher who must make the actual scheduling and dispatching decisions by assigning trips to vehicles. In this case, the computer does not suggest assignments, although it may calculate a measure of merit for assignments proposed by the scheduler/dispatcher. The measures can be used to compare different assignments. The next level is automated scheduling/dispatching, in which the computer will generate the full schedule and dispatch arrangement without human intervention. A feature of some of these automated software packages is that the human scheduler/dispatcher may modify or override the machine-determined schedule/dispatch assignment.

TABLE 3.2 Levels of Scheduling/Dispatching Automation

Manual - Performed without Computers
Customized Generic Software Packages
Specialty - Computer-Assisted
Specialty - Automated
Specialty - Automated with Dynamic Rescheduling
Automated with Other Technologies

The next level of automation introduces a simple but sometimes obscure feature of the scheduling/dispatching problem. Each time a trip is to be added to an existing schedule, a vehicle is reported late, or there is a cancel or a no-show, all trips should be rescheduled to find the optimal assignment of trips to vehicles. This is called dynamic scheduling. Whether this rescheduling is worth performing for each additional trip is an open question. It may be adequate to reschedule only periodically after a given number of new trips or some period of time has passed.

The last level of automation includes the use of DRT specialty software and the use of some other technology which enhances the benefit of the software. Other technologies would include vehicle location, digital communication, and others discussed in Chapter 7.

3.5.2 Quality Characteristics

Clearly, the first necessary characteristic is that the software does what you want it to do. An additional aspect is ensuring that the software operates in all situations without errors, or "bugs," as they are called in the software business. A number of respondents to the survey complained that one or another of the functions they desired does not work.

The providers' evaluation of four additional features is shown in Figure 3.3. The features were evaluated by asking

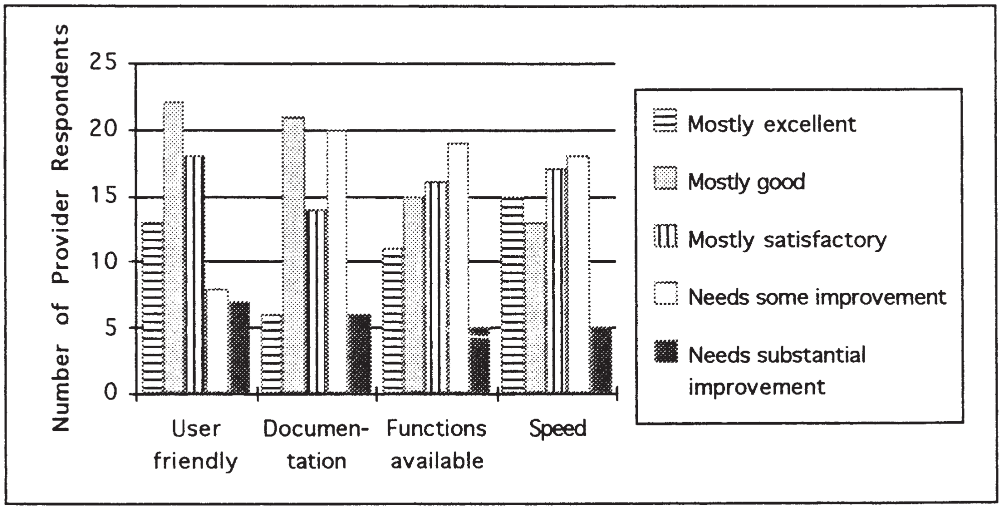

Figure 3.3 Evaluation of Software Characteristics.

respondents to rate them on the following five-point scale—"mostly excellent," "mostly good," "mostly satisfactory," "needs some improvement," and "needs substantial improvement." The characteristics rated were not explicitly defined but are thought to be generally well understood by software users as having the following definitions: *User-friendly* is the attribute of being easy to use without constant reference to user manuals; *documentation* refers to the written manual that accompanies the software; *functions available* refers to the number of functions performed by the software; and *speed* is the quickness with which the computer performs its tasks.

> Writing easy-to-use software is a communications craft. The successful software developer will learn the techniques and thought processes of writers, filmmakers, salesmen, teachers, journalists, and other professional communicators.
>
> —Paul Heckel, software developer/author (*3*)

Several factors contribute to user friendliness; Heckel (*3*) lists 30 *elements* of user-friendly software. The organization of the software is one such factor that includes the layout of computer screens, the arrangement of menus, the terms used, and the like. Activities should be on the computer screens where the user expects to find them, that is, all similar functions are together. Help information should appear on the screen when requested. Friendliness also is the ability to use different levels of sophistication as desired. It should be possible for a software beginner to use the elementary functions without being confused by the capabilities of a higher level. By the same token, a sophisticated user should be able to use the high-level capabilities without having to work through the more elementary functions designed for the beginner. In summary, user friendliness is the ability to use the software without reference to written materials.

The relatively positive response concerning the speed of software operation indicates that speed is not an issue for many users, but, on the other hand, there are a substantial number of users who consider it to be a shortcoming. This mixed reaction is explained by both the variety of computers and their speeds, and software in use.

The greatest number of positive responses—excellent or good—occurred in the "user-friendly" category. The "functions available" category was also rated positively, but again, a substantial number of respondents think it is a characteristic needing improvement. The weakest of the characteristics is "documentation," which may be a general characteristic of specialty software packages in any field during the early years of their commercial sales. Documentation improves as users provide feedback on its shortcomings.

The quality of software was also explored by asking respondents to evaluate the functional performance of the software that they use on a four-point scale—excellent, satisfactory, needs improvement, does not work. The latter category was added after pretests, when respondents indicated that it was needed. The variability of rating may be explained by the great differences among providers' needs and the fact that they were rating a dozen or so different software packages. A package that is excellent for one application may not serve another well.

The quality of the software's performance is shown in Figure 3.4. The number of respondents, rather than percentages, is shown in the graph. Questions that were answered by fewer people have smaller total bar heights. For example, routing was rated by the fewest respondents. The relative height among bars related to a function compared to the other functions indicates respondents' perceptions of quality. The reservations function received the highest positive rating, having the largest number of "excellent" responses, a relatively high satisfactory rating, and no "does not work" comments.

The next most positively rated function was reporting, receiving the second-highest number of "excellent" ratings, the highest total of "satisfactory" ratings, and no "does not

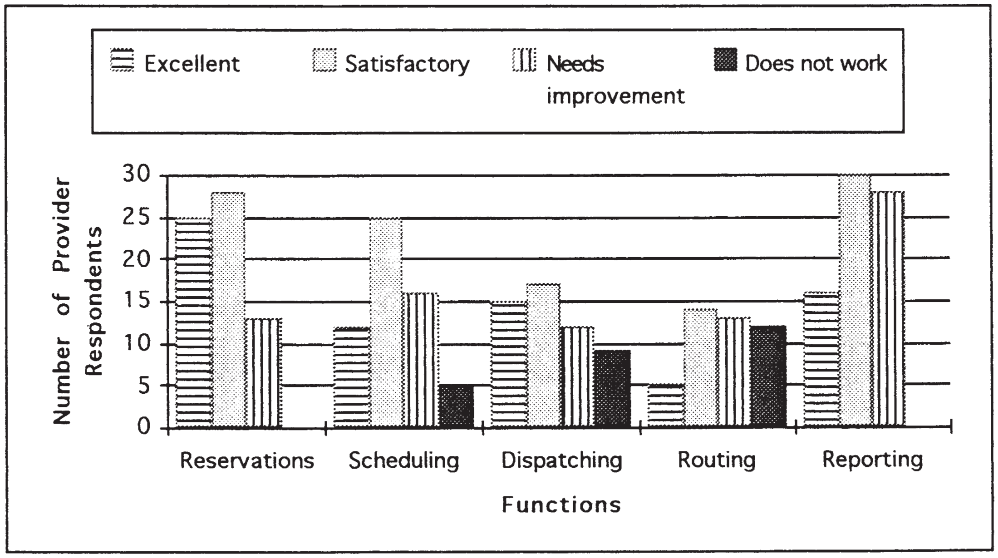

Figure 3.4 Quality of Software by Function.

work" comments. However, it also received the highest level of "needs improvement" responses, suggesting that some software packages need improvement. Shortcomings with reporting capabilities were also a complaint heard during user interviews.

The order of quality rating for the remaining three functions was scheduling, dispatching, and routing. This was also the order of the total number of respondents providing a rating, a direct relationship to the number of software packages offering the functions. All three received some "does not work" comments.

A possible shortcoming of the observations made here may be due to confusion about the definitions of the four functions. Foreseeing this issue, each function was defined in the body of the questionnaire. However, the results may still be corrupted by the respondents' preconceived definitions that were different from the definitions provided.

3.5.3 Other Characteristics

Several other characteristics of software are important. The most important is flexibility or the ability to adapt to changes in operations procedures, demand levels, the size and structure of the service area, and reporting requirements. You do not want your software to constrain either your ability to improve the service you offer or your ability to access the information you need to manage.

Portability is the ability to move your operations to new software and/or hardware. Many users have expressed frustration at having selected the wrong software and then feeling locked in, without the ability to change because of the cost and difficulty of starting over with a new package, and perhaps a new vendor. You could move to new software more easily if you could translate your passenger and trip database files to the new software and if you could use the same hardware. Therefore, the use of standard file formats (discussed in the next paragraph as well) and standard (IBM-compatible) personal computers is a positive attribute to be sought in the software you acquire. Specifically, you will want to specify to vendors that the data files used are in or can be translated to a common database format.

The other side of the portability coin is standardization. As markets mature, standardization usually follows. For example, software for personal computers now comes in essentially two versions: DOS (IBM-compatible) and Macintosh-compatible (we are getting ahead of the organization of the Handbook here as this material is covered in Sections 4.1.2 and 4.1.3). Files of data for these two systems are easily interchangeable. Vendors may resist portability early in the development of a specialty software package because they want their own systems to set the standard for the industry. In fact, the marketplace actually sets standards by what people buy most often. The marketplace set DOS as the standard for personal computers (see Section 4.2.2).

Another desirable characteristic is compatibility of the software with other software that you might use, including databases, spreadsheets, and word processing. Compatibility allows sharing data among DRT software and other application software, transferring data to new software and the like. Most DRT packages now provide this important ability.

Finally, and obviously, the cost of the software is an important characteristic. The users' rating of price versus value from the provider is shown in Figure 3.5. Like many other ratings from the survey, the majority of users find the prices reasonable, but there are a significant number who believe improvement is needed.

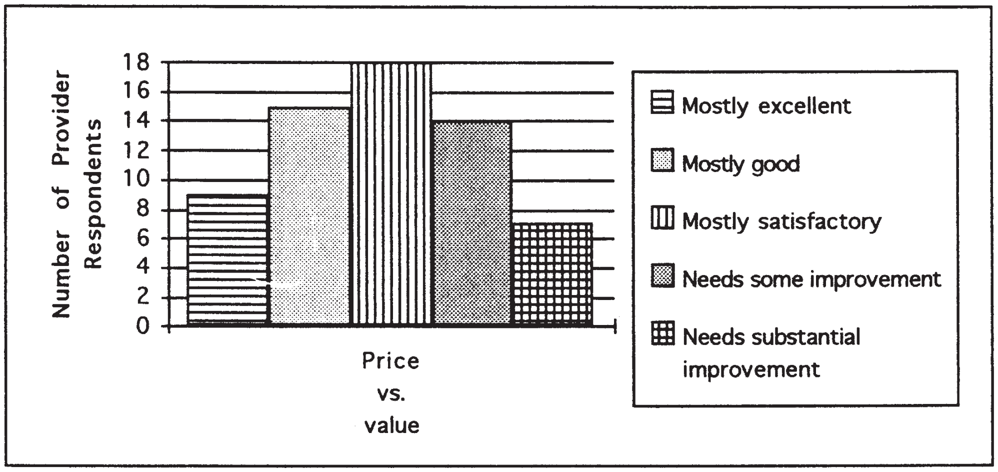

Figure 3.5 User Evaluation of Software Price Versus Value.

3.5.4 Useful Life of Computer Software

How long does software last? With regular support from the vendor (see Upgrades in Section 3.7.2 below), a software package can perform for as long as you are providing a similar paratransit service using similar computer hardware. More likely, hardware advances may make software obsolete, so the life of software is determined by the economic life of the computer you are using. Computers do wear out in the sense that replacing failed components becomes more expensive than replacing the entire computer. Moreover, the cost of personal computers has fallen so rapidly that new ones are bought for added features before the old ones are broken in. The result of rapid advances means that it may become impossible to find replacement equipment since vendors have limited ability to service older machines. While the old software may operate on the new version of the hardware, it may not operate as well as software designed for the new machine. Unless your paratransit service changes and requires new software, you will typically consider replacing software when you replace hardware.

Historically, then, your time horizon for needing vendor support is 5 to 8 years. Upgrading software to new equipment may be greatly aided by vendors who will be aware of the need to provide new versions of their software on new hardware. However, it may be appropriate to investigate the software market when new hardware is considered. Of course, maintaining a relationship with a vendor who has served you satisfactorily has advantages as well.

3.6 FUTURE OF DRT SOFTWARE

3.6.1 Software Use

Of the 78 respondents who answered the questions concerning whether they performed DRT functions with software or manually, 13 systems, or 17 percent, were planning to replace the software they were using, and two of the 19 who used no software were planning to acquire software for the first time. One interpretation of these numbers is that the agencies that can use software beneficially are already using some software packages and they are now seeking better software.

3.6.2 Improvements in DRT Software

The expert respondents were asked for an assessment of the improvements in software that are likely in the future. The majority of expert respondents believe that software will improve substantially in all characteristics during the next 5 years (Figure 3.6). Examining the category of “great improvement” suggests that more experts believe that *speed* of operation will improve relatively more than improvements in the other characteristics. This is not a particularly enlightening observation, given the history of microprocessor speed increases, but the responses to this question provide a benchmark for the assessment of improvements in other characteristics.

Combining the responses in the categories of “great” and “some improvement” indicates that all but a few of the respondent group believe that: (1) the number of functions included in the software will improve, (2) the software will become more user-friendly, and (3) documentation will improve—in that order of intensity.

3.6.3 Future Enhancements in the Functions of DRT Software

The DRT functions explored are divided into operating and management software. The experts anticipate enhancements in all the functions listed in the following order

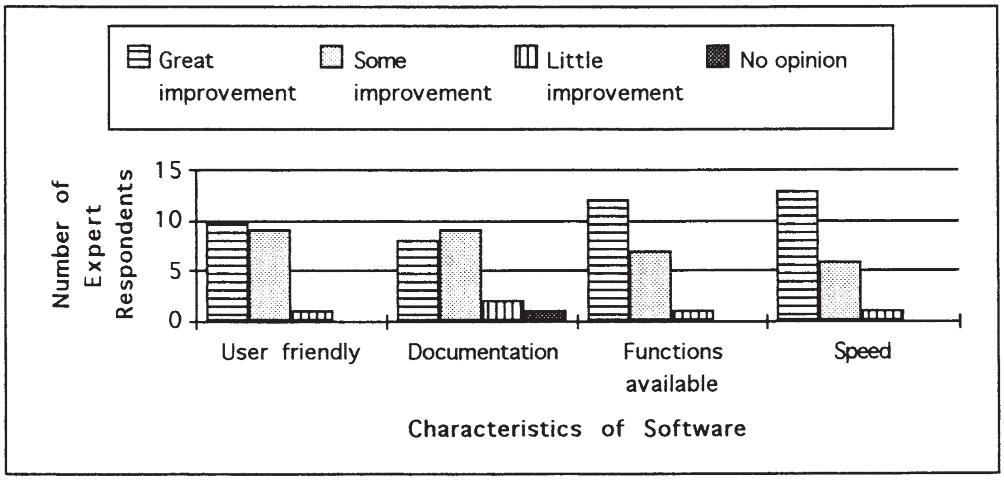

Figure 3.6 Future Improvements in DRT Software Characteristics.

of responses—scheduling, dispatching, trip reservations, routing, and management reporting (Figure 3.7). The experts also expect enhancements in management software in the following order: purchasing/inventory, accounting, invoicing, maintenance scheduling, and project management (Figure 3.8).

3.7 CHARACTERISTICS OF DRT SOFTWARE VENDORS

3.7.1 Nature of the DRT Software Market

Paratransit software is developed and sold by private companies which exist in a competitive marketplace. It is important to describe the structure of the paratransit software market because the characteristics of that market, and the market participants, have major impacts on the nature of DRT software and its pricing. Without an understanding of market realities, it is difficult to appreciate the obstacles to the emergence of more standardized paratransit software and to different software pricing practices.

There are three key characteristics of the paratransit software market. First, it is small—very small. It is unlikely that even 150 paratransit software packages are sold in a year's time, and the actual number is probably fewer than 100. Second, the firms that develop and market paratransit software are small—very small by the standards of corporate America. Only a handful of these firms employ more than 20 people, and the larger firms typically derive most of their revenues from other product lines. The annual revenues of these firms (or the organizational units involved in public transportation) are measured in the millions of dollars or hundreds of thousands of dollars, not in the tens of millions. Third, the organizations that purchase paratransit software are dependent on public sector funds to sustain their operations, are not profit-making entities, and are usually highly constrained financially. Their investments in technology (other than new vehicles) are typically infrequent.

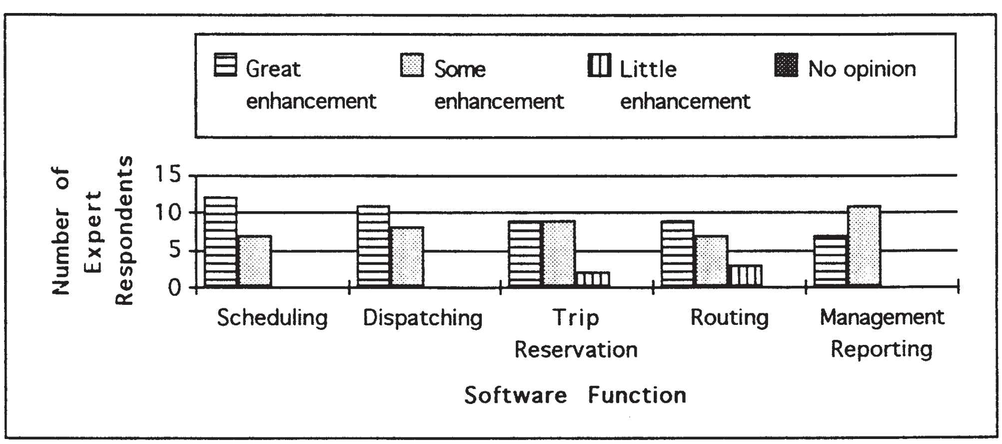

Figure 3.7 Enhancements in Future DRT Operating Software.

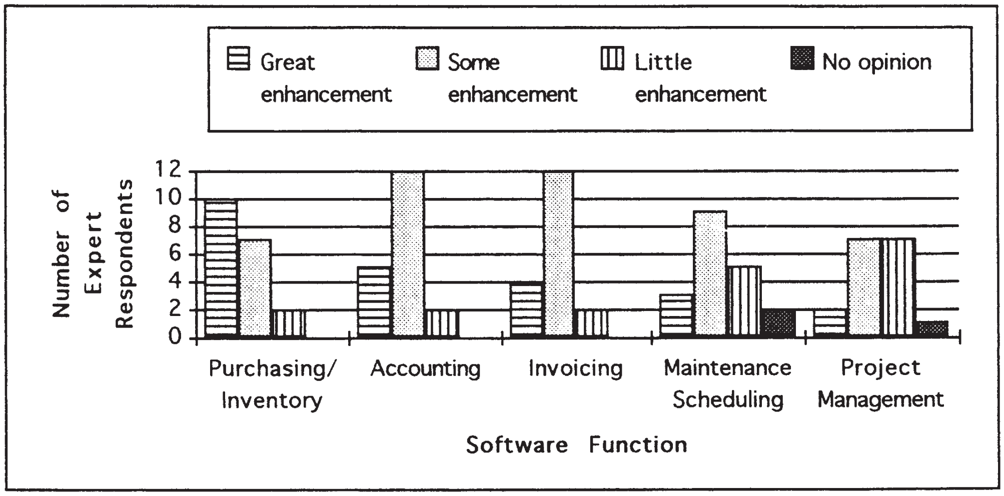

Figure 3.8 Estimated Enhancements in Future DRT Management Software.

These three characteristics, taken together, create a situation in which it is unlikely that quantum improvements in paratransit software will occur in a short time frame, or that prices will be reduced significantly from current levels. Firms serving the paratransit software market cannot expect to sell large numbers of units annually because the market is so small. As a result, these firms are likely to remain small unless they can generate substantial revenues from other product lines. Constrained in organizational size by the size of their market, they do not have abundant funds to allocate to new development activities. Firms serving this small paratransit software market are likely to put significant resources into product improvement only to the extent necessary to meet client requirements (to close a sale) or to keep clients satisfied. Unless a client is willing to pay for a particular feature, or demands it as a condition of a sale, it will only be added as time and internal resources permit. Consequently, new development proceeds relatively slowly.

In a market such as this, software prices must be maintained at relatively high levels because unit sales are limited. Each firm needs substantial revenue from each sale to generate sufficient overall revenues to remain in business. In contrast, a mass-marketed piece of software like a spreadsheet or database system may sell for less than $250, but its annual sales will be in the range of hundreds of thousands (or more) of units. Despite these low unit prices, the large volume of purchases will generate enough revenue to sustain an organization of significant size. This is not possible in the paratransit industry.

Because the paratransit software market is populated predominantly by small firms with limited revenues, the firms tend to specialize in a particular software technology or set of core technologies, and usually do not have wide-ranging capabilities. They may be well-versed in only a single operating system (DOS/Windows, UNIX, etc.), capable of using only two or three software platforms for development, and perhaps may not be fully versed in the intricacies of networked applications. If the purchasers of paratransit software were to decide collectively that they would only buy software which, for example, ran on the UNIX operating system, several of the current market participants would be hard-pressed to make the transition to UNIX in a timely fashion—or at all. The result of this limited capability of vendors to provide their software on many platforms means that your decision concerning software is in reality a combined decision about both the software and the hardware.

The point of this discussion is that the paratransit industry is unlikely to see quantum changes in paratransit software. The simple reason for this is that the paratransit software providers do not have the resources—or the prospects of readily obtaining them—to sustain the level of development required. Given this reality, the guidelines for paratransit software developed elsewhere in this report typically use current product offerings as the point of departure, not some idealized software which does not currently exist.

3.7.2 Technical Support

Technical support consists of three elements—training, technical assistance including help in problem resolution, and periodic release of software improvements called upgrades. The user evaluation of *training* and *support*, assumed to be technical assistance, is shown in Figure 3.9. Both attributes receive high ranking as indicated by the majority rankings in “mostly excellent,” “mostly good,” and “mostly satisfactory.” Nevertheless, a significant number of respondents indicated that some or substantial improvement is needed.

Training. Training of your staff is a necessary part of using paratransit software even for those who are computer literate. Such training may be included in the price proposals

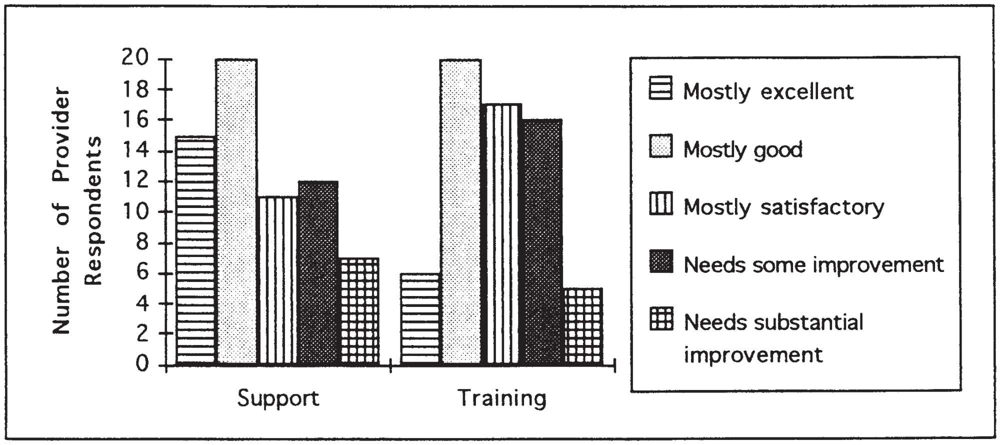

Figure 3.9 Evaluation of Support Provided by Software Vendors.

by vendors. The vendor's commitment may include the number of days of training, the number of your staff persons trained, and the location of the training. Training may also include the provision of printed training manuals for subsequent reference.

Technical Assistance. When you need help in operating the software or when you have a problem, you will turn to the vendor for assistance. This assistance may be provided as part of an annual maintenance contract, which provides a prescribed amount of technical assistance as well as other support, or assistance may be paid for on a fee-for-service basis.

The means of technical support is also important because when you need help, you may need it quickly. Promised response time is therefore an important attribute. Many problems can be solved by obtaining help over the telephone. More difficult problems may require the technician to look at the state of your system. This may be done in some cases by a communication connection directly between your computer and the vendor's computer using a telephone connection and a modem, which translates the computer information for telephone communication. Finally, sometimes a visit by a technician may be the only means of correcting the problems. Some or all of these methods may be offered by vendors.

Upgrades. Upgrades are improvements or the addition of new capabilities (and sometimes corrections) that are made to the software by vendors and made available to users. While vendors are obligated to fix problems, they are not necessarily obligated to provide improvements to old customers, so they may charge a fee for upgrades, either on an individual basis or as part of a maintenance agreement that includes technical assistance as well as upgrades. If vendors are obligated to provide technical assistance, they may want to provide upgrades to every customer so that there is only one version of their software in use to simplify the support task.

Often upgrades are made at the request of an existing or new customer, or they may be made at the initiative of the vendor. Upgrades may be offered on an ad hoc basis, although some vendors have a policy of offering them regularly, say, once a year.

The disadvantage to both user and vendor is that each time a new package is distributed, it can contain new bugs. Moreover, upgrades must be installed, a process that can introduce problems unless the vendors provide a fail-safe means of upgrading—one which preserves all of your prior parameter settings and data.

3.7.3 Strength and Stability

An important characteristic of vendors, and one in which they differ, is their financial strength and stability. It is important because you want the vendor to be around and capable so that it can provide the technical support you need after you acquire the software. These attributes are discussed in Section 6.2.5, which discusses the task of judging vendor capabilities during the acquisition process.

3.7.4 Software Vendors of the Future

The majority of experts surveyed believe there will be improvements in all vendor characteristics (Figure 3.10). "Price" seems to have received the strongest estimate of improvement, followed by "support" and "training." This is consistent with the rating by providers who believe "support" is the greatest strength of vendors.

3.8 FEATURES OF DRT SOFTWARE

3.8.1 Introduction

DRT software can be viewed as a bundle of capabilities designed to execute the functions necessary to offer DRT service. The listing of these capabilities, which we call *features*, can serve as a checklist for determining the features that you specify in your requirements for the software you purchase. This section contains an alphabetic listing and a description of the most significant of the possible features contained in

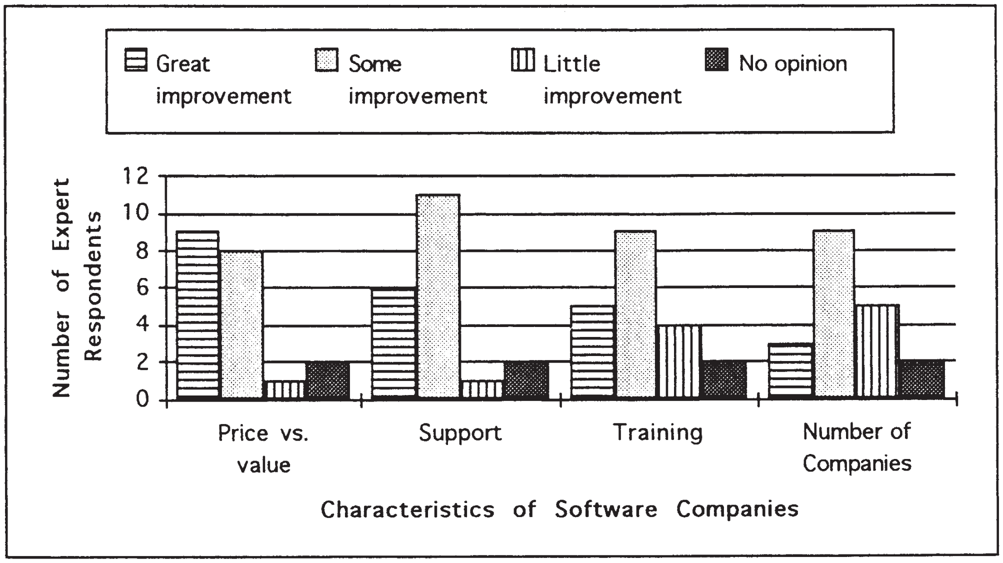

Figure 3.10 Future Improvements in DRT Software Vendors.

DRT software. The features are defined in Appendix 3-A of this chapter.

3.8.2 Perceived Importance of Features

Respondents were asked to indicate what features they currently use and those they want in their future software (see Tables 3.3 and 3.4). Table 3.3 contains a list of 60 software features in the order of number of respondents that have the feature in their current software. The column labeled "Currently Using" indicates the number of providers that use the feature. The column labeled "Want in Future" indicates the number of providers who want the feature in future software.

TABLE 3.3 Ranking of Software Features Currently Used

Rank	Capabilities	Currently Using	Want in Future
1	Automatic retrieval of passenger data	65	50
2	Tracks recent ride history	56	54
3	Multi-user reservation processing	52	49
4	Automatic rider eligibility check	49	58
5	Partial name/address entry	49	53
6	Geocoded addresses	46	57
7	Keyword search and sort capability	46	54
8	Frequent destination list	45	55
9	Manual override of computer-generated schedule	44	57
10	Name recognition of common places	43	54
11	User-defined fields available	42	48
12	User name & date stamping	41	47
13	Performance data calculations	38	60
14	On-line time (pickup, etc.) estimates	36	63
15	On-line address verification	36	56
16	Trip eligibility check (for ADA trips)	35	66
17	Redundant reservation warning	35	62
18	Variable vehicle parameters (number, seating, etc.)	35	59
19	Ad hoc report formats	35	50
20	Batch scheduling/dispatching	34	54
21	Multi-tiered security	31	40
22	Choice of performance criteria (ride/wait times, etc.)	30	64

(*continued on next page*)

TABLE 3.3 **Ranking of Software Features Currently Used (Continued)**

Rank	Capabilities	Currently Using	Want in Future
23	Personalized passenger loading times	30	58
24	Automatic fare calculation	30	40
25	On-line "help" available	29	55
26	Billing codes	29	28
27	Problem passenger warning	28	61
28	Pop-up menus/multiple windows	28	61
29	Automatic vehicle selection for passenger special needs	28	56
30	Immediate (real-time, like taxis) reservations & scheduling	28	55
31	Vehicle speed as a function of traffic, time, geography	28	51
32	Remote terminal access	27	46
33	Import/export ASCII files	27	38
34	Fully computerized scheduling and dispatching	26	68
35	Computerized vehicle route selection	26	57
36	Automatic purge of inactive registrants	26	56
37	Import/export to spreadsheet	24	57
38	Validity checks on all inputs (completeness, legitimacy, etc.)	23	58
39	Import/export to word processor	22	50
40	Group trips	22	38
41	Trips displayed on layered maps	17	64
42	Call-back list generated	17	51
43	Section 15 reports	17	50
44	Flexible invoice formats	17	37
45	TIGER file compatibility	17	36
46	Passenger prioritization possible	16	44
47	Zonal system	16	38
48	Support for brokering (several operators)	15	53
49	Split billing	15	33
50	Batch billing	14	28
51	Simulation training capability	13	65
52	Allows "what if" questions	12	65
53	Paratransit transfers	12	49
54	Flagging of costly trips	9	57
55	Fixed route transfers	9	44
56	Vehicle location on layered maps	8	66
57	Federal HHS report	8	30
58	Automatic call-back confirmation and change of schedule	7	55
59	Automatic in-vehicle data capture	4	55
60	Electronic Document Interchange	2	32

APPENDIX 3-A. DESCRIPTION OF SOFTWARE FEATURES

Ad hoc report formats—Usually, DRT software packages that include reporting will include the ability to generate a number of reports in a predetermined format. This feature allows the user to specify additional report contents and format.

Allows "what if" questions—The software allows easy testing of the impact of various alternatives by determining the impact of changes in the parameters (such as travel time), trip data, assignments, and the like.

Automatic call-back confirmation and change of schedule—Calls are made to patrons who have scheduled trips to confirm the trip or to apprise them of any change in the pickup time.

Automatic fare calculation—Automatically calculates the fare for each rider based on whatever parameters determine fares, i.e., type of rider, distance, time of day, class of service, etc.

Automatic in-vehicle data capture—Records and saves relevant data to be used for calculating performance statistics, including travel and waiting times, distances, and the like. Several levels of automation may be provided, some of which require the driver to input data such as location and passenger identifications.

Automatic purge of inactive registrants—Periodically, the file is searched to identify registrants who have not used the

TABLE 3.4 Ranking of Software Features Wanted

Rank	Capabilities	Want in Future	Currently Using
1	Fully computerized scheduling and dispatching	68	26
2	Trip eligibility check (for ADA trips)	66	35
3	Vehicle location on layered maps	66	8
4	Allows "what if" questions	65	12
5	Simulation training capability	65	13
6	Choice of performance criteria (ride/wait times, etc.)	64	30
7	Trips displayed on layered maps	64	17
8	On-line time (pickup, etc.) estimates	63	36
9	Redundant reservation warning	62	35
10	Problem passenger warning	61	28
11	Pop-up menus/multiple windows	61	28
12	Performance data calculations	60	38
13	Variable vehicle parameters (number, seating, etc.)	59	35
14	Automatic rider eligibility check	58	49
15	Personalized passenger loading times	58	30
16	Validity checks on all inputs (completeness, legitimacy, etc.)	58	23
17	Geocoded addresses	57	46
18	Manual override of computer-generated schedule	57	44
19	Computerized vehicle route selection	57	26
20	Flagging of costly trips	57	9
21	Import/export to spreadsheet	57	24
22	Automatic purge of inactive registrants	56	26
23	Automatic vehicle selection for passenger special needs	56	28
24	On-line address verification	56	36
25	Frequent destination list	55	45
26	Immediate (real-time, like taxis) reservations & scheduling	55	28
27	Automatic call-back confirmation and change of schedule	55	7
28	On-line "help" available	55	29
29	Automatic in-vehicle data capture	55	4
30	Keyword search and sort capability	54	46
31	Tracks recent ride history	54	56
32	Name recognition of common places	54	43
33	Batch scheduling/dispatching	54	34
34	Partial name/address entry	53	49
35	Support for brokering (several operators)	53	15
36	Vehicle speed as a function of traffic, time, geography	51	28
37	Call-back list generated	51	17
38	Automatic retrieval of passenger data	50	65

service in a specified length of time, eliminating those users from the file.

Automatic retrieval of passenger data—Entering a passenger's name on the reservation form may cause the passenger record to be retrieved from the passenger database and, in some cases, inserted into the reservation form.

Automatic rider eligibility check—Entering the passenger's name on the reservation screen causes the software to check to determine if the person is eligible. This may be a check to determine if he or she is registered or a more sophisticated procedure of determining if the person and this trip are eligible for ADA service.

Automatic vehicle selection for passenger special needs—Entering the passenger's name limits the selection of potential vehicles to only those which have the capability of meeting the passenger's special needs. For a fully automated system, this would be done automatically; for a computer-aided system, only feasible vehicles would be offered to the scheduler.

Batch billing—Allows for organizing and totaling the costs of riders according to their sponsors, to bill the sponsors for all trips taken in some time period with one invoice.

Batch scheduling/dispatching—Determining schedules for a set of many trips all at one time, as opposed to scheduling individual trip requests as they are received.

Billing codes—Codes may be assigned to trips or to passengers so that summaries of costs, trip frequencies, and the like may be calculated.

Call-back list generated—A list of future riders, together with their telephone numbers, is generated so that confirmation calls can be expeditiously made on the day of the trip to reduce no-shows.

Choice of performance criteria (ride/wait times, etc.)—Allows the user the flexibility to specify various statistics or measures to be captured and calculated, describing the performance of the system.

Computerized vehicle route selection—Selection of the routes—the street-by-street path between two points—by the computer program.

Electronic Document Interchange—Has provision for transmitting to other computers over telephone wires or other connectors data accumulated concerning service, passengers, and status of the software.

Federal HHS reports—Produces reports required of DRT services funded under programs of the U.S. Department of Health and Human Services.

Fixed route transfers—Includes in the trip planning the meeting of fixed route bus schedules to facilitate transfers between DRT service and fixed route buses.

Flagging of costly trips—The identification of trips that are costly to serve because they cannot be served by a vehicle serving other trips or because they are unusually long.

Flexible invoice formats—The ability to tailor the content and format of invoices for DRT service to meet the needs of the providers or the paying agency.

Frequent destination list—A list for each passenger of his or her most frequent destinations. This information aids the telephone communication and, if the information can be automatically transferred to the trip order, speeds up the reservation process.

Fully computerized scheduling and dispatching—The computer software determines the schedule and the trip assignments to vehicles with no human intervention.

Geocoded addresses—Addresses identified with specific map location codes are necessary for some scheduling algorithms and are useful for trip planning in a manual system.

Group trips—Vehicle trips consisting of several passengers traveling from the same origin to the same destination.

Immediate (real-time, like taxis) reservations and scheduling—DRT service that responds quickly to requests for service, for instance in 20 minutes to 1 hour from the time of the request.

Import/export ASCII files—The ability of a software package to read and write in a standard format called American Standard Code for Information Interchange (ASCII), pronounced *ask-ee*.

Import/export to spreadsheet—The ability of the software to read and use information from spreadsheet software and to write information so that it can be used by spreadsheet software.

Import/export to word processor—The ability of the software to read and use information from word processing software and to write information so that it can be used by word processing software.

Keyword search and sort capability—The ability to search for any and all passengers who have a common characteristic, such as mobility aids or destinations; can be useful for grouping trips or helping passengers.

Manual override of computer-generated schedule—The ability to manually change schedules/dispatches generated automatically by DRT scheduling/dispatching software.

Multi-tiered security—A method of restricting user access to selected portions of the software and databases, ranging from allowing access to use and change the entire computerized system to allowing access to only one function or database.

Multi-user reservation processing—Reservation taking and scheduling/dispatching can be accepted by more than one human reservationist, without conflicting with one another, to create compatible schedules.

Name recognition of common places—Beginning to type a place name causes the software to call up a list of candidate names with similar spelling. Some software may actually enter the alternatives in the place name field. May be redundant with most frequent destination list stored in passenger database.

On-line address verification—Verifies each address entered by checking to see if the street exists, is unambiguously identified (asking for Avenue, Street suffix when needed), and the number is valid for the street. Cannot discover all errors but will flag many mistakes.

On-line "help" available—Assistance is available on the screen while using the software.

On-line time (pickup, etc.) estimates—Estimates of passenger pickup times are calculated by the software at the time a reservation is taken. In low-end software, the estimate will not be based on an actual vehicle assignment. In high-end software, a vehicle assignment may be made at the time a reservation is taken.

Paratransit transfers—The software has the capability of scheduling two paratransit vehicles so that a transfer can be made between the two when it is required to complete a trip, as in a system in which vehicles are constrained to particular zones. It is also possible that transfers may be scheduled when it is advantageous from an operating efficiency point of view, although it is not known if any software packages contain this capability.

Partial name/address entry—Entering part of a name or address causes the software to suggest completed names to speed up the processing. This is a feature that exists in some generic packages.

Passenger prioritization possible—Passengers are assigned a priority level so that those with a higher priority would receive more favorable pickup and ride times. This feature is probably not allowed in a purely ADA service, but ADA patrons could be assigned a higher level of service in systems that service both ADA patrons and others.

Performance data collection—Collects and calculates a variety of the most common performance measures used to monitor and evaluate DRT service.

Personalized passenger loading times—Accounts for the actual historical loading time for each known passenger when estimating the trip times for scheduling purposes.

Pop-up menus/multiple windows—A menu of activities from which the user can choose appears when the user selects a heading with a mouse or a function key. A feature of user-friendly software found in software with a graphical user interface, as in Apple Macintosh and DOS Windows.

Problem-passenger warning—Entering passenger's name causes the software to indicate that the passenger is a problem passenger, perhaps because of special needs or on-board behavior. This allows the scheduler to notify the driver, limit the types and numbers of other riders, or the like.

Recent ride history maintained—A record of recent rides is kept that may be useful to speed up making trip reservations, auditing performance, or planning group trips.

Redundant reservation warnings—An indication is provided if a duplicate trip reservation is made at a time which is close to an existing reservation.

Remote terminal access—Access to the computer over telephone lines or other connections is possible from terminals or computers located elsewhere.

Section 15 reports—Software that collects and calculates the information that is required to be reported by transit systems that receive federal government funding.

Simulation training capability—Software that can simulate operations of a DRT service, for training reservationists or schedulers/dispatchers or for evaluating different operating procedures; the same idea as an airplane flight simulator.

Split billing—Allocation of the cost of a trip to several passengers sharing the trip so that different sponsoring agencies can be billed for their clients. The allocation should be based on some logical methodology, such as trip miles.

Support for brokering (several operators)—The ability to dispatch trips to different vehicle operators by considering allocation criteria that are a function of the operators.

TIGER file compatibility—The ability of the software to read and use information from TIGER files and to write information in TIGER file format.

Tracks recent ride history—See *Recent ride history maintained.*

Trip eligibility check (for ADA trips)—Verifies that a patron making a trip request has been certified as eligible for the service and that the trip is an eligible trip.

Trips displayed on layered maps—Trips are displayed graphically on the computer screen on a background map showing street networks; various levels of magnification and detail (layers) of maps can be called up at the user's discretion.

User-defined fields available—The ability to add discretionary information to the passenger files to tailor service or perform special analysis.

User name and date stamping—Information entered into the software is labeled with the name of the computer user and the time and day it is entered, to enable auditing for errors, identifying the need for training, and rectifying unauthorized users.

Variable checks on all inputs (completeness, legitimacy, etc.)—Information entered into the software is checked for completeness, accuracy (when it can be compared to information already stored), and legitimacy (when it can be tested against logical norms, e.g., a 200-mile trip is questionable).

Variable vehicle parameters (number, seating, etc.)—The ability to distinguish differences among vehicles so that the specific capacity and capability of vehicles can be accounted for when dispatching.

Vehicle location on layered maps—The locations of vehicles are displayed graphically on the computer screen on a background map showing street networks; various levels of magnification and detail (layers) of maps can be called up at the user's discretion. Location can either be estimated by the software, reported by the driver, or measured by a technology called Automatic Vehicle Location (AVL).

Vehicle speed as a function of traffic, time, geography—Vehicle speeds used by the software for scheduling/dispatching are calculated based on other factors rather than taken as a system-wide constant. Various levels of sophistication are possible, from simply assigning a speed to a particular road link to changing the speed based on weather, time of day, etc.

Zonal system—An operating procedure which assigns vehicles to operate in designated zones.

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CHAPTER **4**

COMPUTER HARDWARE

AUDIENCE

The first section of this chapter can be skipped by readers who have experience with computer hardware. If the following description makes sense to you, you may wish to skip Section 4.1.

> *Requires a 386/25 computer, math coprocessor, MS-DOS 3.3, 8Mb RAM, 20Mb disk space, VGA, and a mouse.*

The remainder of the chapter describes the results of the survey of DRT users and experts concerning hardware used currently and planned for the future.

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"Everybody needs candy. Everybody needs stationery. Everybody needs microcomputers."

> The processor's solid state switches don't click,
> No gears, cogs or levers to rattle or tick.
> The screen output is silent and still;
> No movement betrays this numerical mill.
> The machine without motion must finally demand,
> As it grows more aware that it lacks arm and hand,
> An effector to give its thoughts body and force,
> And what will it choose? Why, a person, of course!
>
> —*Sing a Song of Software,*
> Leonard J. Soltzberg, 1984 (*1*)

4.1 HARDWARE PRIMER

This section contains a brief description of computer hardware terms and concepts. The decision concerning what hardware to buy is usually dictated by the software so that you, the buyer, do not need a separate evaluation of hardware and may take the vendor's advice if you are buying a software/hardware package. If you already have a machine, the vendor will advise you concerning its adequacy and whether you need to upgrade or replace it. Hardware know-how is useful, however, so that you are not totally at the mercy of the vendor or if you want hardware with capability beyond that required by the DRT application so that you can apply it to other functions.

4.1.1 Classification of Computers by Size

Historically, computers are discussed in at least four sizes which, in order of cost, speed, computational precision, and storage capacity, are: mainframes, mini-computers, work stations, and personal computers (PCs). Rapid development of technology has lifted the capabilities of all computers so that the PC of today is equivalent to the mainframe of a decade ago, obscuring the dividing lines among these classes. Accompanying the leaps in technology have been plunges in cost so that PCs and work stations, communicating over networks of wires, together satisfy the demands of the bulk of the market.

4.1.2 Types of PCs

As the survey results cited in Section 4.2 will show, PCs are adequate to control and manage the vast majority of DRT systems. There are two main types of PCs—those that are compatible with a standard created by IBM, called compatibles or IBM-compatibles, and those that are not compatible. The noncompatibles are now mainly those machines having the brand name of Macintosh, until 1995 made only by Apple Computer, Inc., which now allows other manufacturers to make Macintosh-compatibles. To confuse identification somewhat, the abbreviation PC is sometimes used to distinguish IBM-compatibles from other personal computers. Since there is no DRT software developed for the Macintosh, we use the term PC to refer to IBM-compatible machines.

Even the term personal computer is not as accurate as it used to be. It was coined when the machine was dedicated to one user sitting at the keyboard. Now it is possible that machines on the same network may share files and computational capability, so that a user may not have total control over the PC he or she is using.

4.1.3 Operating Systems

PCs can also be classified by the operating system they use. The operating system is simply software that provides the brains of the computer, controlling all operations and the flow of information. We discuss operating systems in this hardware chapter because, without them, the computer is just a pile of metal and plastic.

The operating system called DOS dominates the IBM-compatible market so much so that IBM-compatible machines are sometimes referred to as DOS machines. IBM also markets a competing operating system called OS/2. When you buy an IBM-compatible PC, it is likely that it will come with a DOS operating system, although other operating systems will also operate it. Most notable is a system called UNIX, which was developed by AT&T. UNIX is intended to be a universal operating system that can be used on computers of all sizes. Currently available from the software giant Microsoft is an augmentation of the DOS operating system called Windows. Windows provides DOS with a graphical capability, whereby the user chooses commands, starts programs, lists files, and the like by pointing to pictorial representations (called icons), rather than the user-unfriendly written commands inherent to DOS. Windows is the DOS-based machine manufacturer's competitive response to the Macintosh operating system, which has used a graphical user interface for 15 years or more. Now a new Windows version is available called Windows 95. It is likely that DRT software vendors will begin to make their programs available in Windows 95 in the near future.

Macintoshes come with an operating system developed by Apple that is referred to as Macintosh OS. The Mac OS runs only on Macintoshes, and other operating systems do not run on Macs because Apple uses a unique combination of software and hardware to perform the operating system functions.

4.1.4 Components of a Computer

Computers consist of a number of physical components, each with a specific function (Figure 4.1). The complete description of a particular computer consists of the listing of each of the components which, in turn, identify the machine's capabilities. A typical description is the following one, which is an actual requirement for a DRT software package:

> *Requires a 386/25 computer, math coprocessor, MS-DOS 3.3, 8Mb RAM, 20Mb disk space, VGA, and a mouse.*

Usually the first component described is the name of the microprocessor, in this case a 386. The microprocessor is the electronic circuitry that performs computation and controls data flow—the primary operations of the computer. Other microprocessors that are currently being marketed in PCs are named 286, 486 and Pentium, in increasing order of computational power. The number after the slash signifies the speed of the microprocessor, in this case 25 megahertz. You don't need to understand the meaning of that designation but only that you would need a computer with a microprocessor speed of 25 megahertz or greater. Microprocessors are currently available that run at well over 100 megahertz, and they get faster regularly. The "math coprocessor" indicates that the

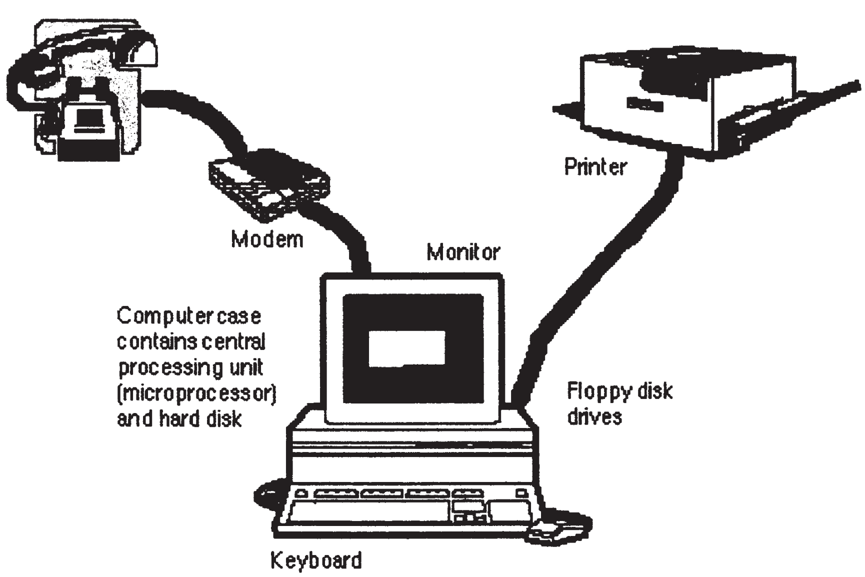

Figure 4.1 Hardware Components of a Personal Computer.

computer has a second microprocessor, this one specially designed to assist the main microprocessor by performing certain mathematical functions faster than the main microprocessor can alone. Microprocessors are often called "chips."

"MS-DOS" indicates the operating system is the version of DOS produced by the Microsoft company. As software is improved, vendors append a version number to their brand names, in this case version 3.3. Minor modifications are indicated by the number after the decimal; major new releases are indicated by the number before the decimal.

The next component is the RAM (random access memory), a fast, temporary storage used for storing software programs and data while the computer is running. RAM sizes are indicated in megabytes of capacity, in this case 8. A megabyte is about 500 pages of text data. As software becomes more powerful, it also requires larger RAM. All but the smallest packages require 4 megabytes of RAM, 8 megabytes is usually suggested currently, and up to 128 megabytes is possible.

Permanent storage, the next component of interest, serves as a file cabinet storing the programs and data that may be used over time. As the computer is running, the data and programs required for that session are shifted from the permanent storage to the RAM. Permanent storage is most often a hard disk, so called because the information is stored on a rigid metal disk that is coated with a magnetic substance. The user cannot see the disk (or disks) as it is permanently enclosed in a case. In the example of the specifications given above, it is a hard disk (not explicitly stated) with a 20-megabyte capacity, a low capacity by today's usage. Hard disks of 1,000 megabytes (called a gigabyte) are common. Another type of permanent storage is magnetic tape which is something like audio or video tapes. When used in PC systems, tape storage is usually a secondary or backup storage rather than the primary permanent storage, because data retrieval is much slower from tape than from disk.

There are several types of disks that are transportable and are inserted into PCs to read programs into and data into and out of PCs. Floppy disks, which are inserted into the computer, have been the most common means of buying programs or transferring data among computers. They are called floppy because they are flexible, a characteristic that distinguishes them from hard disks. The current standard is a 3.5-inch disk encased in a rigid case. The previous standard was a 5.25-inch disk encased in a flexible case so that it was truly "floppy." The new standard for inputting program and prerecorded standard data sets has become the CD, the optical disk system that also serves as a medium for recorded music. As of this writing, CDs are primarily input devices for reading data into the computer. As CD systems are advanced so that systems which write on the disk can be included in PCs, they will no doubt become the standard means of input and output. A floppy drive is an essential part of a DRT computer system. A CD drive for use in DRT systems now is a bit of a luxury unless you also want to use various databases or other programs that are distributed on CDs. But we advise that you either acquire or be able to add a CD for the time when it will be the standard.

Drawing by Sidney Harris: reprinted by permission.

"No wonder he never forgets. He has a bubble memory with a storage capacity of 360 megabytes."

The next designator is the monitor or computer screen. "VGA" indicates a high-resolution monitor standard developed by IBM. If DRT software uses monitor-displayed maps, a high-resolution monitor may be required.

"Mouse" refers to the device moved by hand that moves a cursor around the screen to select commands or files when an operating system using a graphical user interface is used.

Other hardware units that may be required include a modem, a device for translating the signals on a telephone line (analog) to a signal a computer uses (digital), which enables computers to share data sent over telephone lines. Modems are used to connect to on-line information services and networks, of which the Internet is the giant. In the case of DRT systems, modems are used to connect your computer to the software vendor's computer so that the vendor can troubleshoot quickly and remotely. Vendors may also distribute program upgrades and bulletins by modem.

Some means of backing up, i.e., duplicating all databases and files in case the original is destroyed, is essential both for legal and efficiency reasons. If the loss of a database would impede operations or replacement would be costly, then it should be backed up. Usually backup storage devices should have high-storage capacity so that entire days of operations can be conveniently stored. Backup data can be stored on floppy disks, hard disks, magnetic tapes, or other devices. Several types of storage devices with removable cartridges specially designed for backup storage are on the market. Portable backup devices are useful because they can be stored securely away from the system so that fire, earthquake, or other calamities would not cause the loss of all data.

Some of the hardware described above may be built into the computer, and some may be attached. Any additional piece of equipment attached to the PC is called a peripheral. The most common peripheral is the printer. Printers vary greatly in the quality of the product, but usually any printer will suffice for a DRT system, and you are free to select the quality you desire. Sometimes the designation "120 characters" is indicated, meaning a printer able to print a line containing 120 characters, which was considered a wide carriage in the days when printers were like typewriters. With modern laser and inkjet printers, the print size can be scaled at will, so the carriage width is not applicable.

PCs have a nasty habit of occasionally expressing their personalities by destroying your data, much like an unhappy child who throws your dishes. Therefore, anything stored permanently on hard disk and anything being operated upon which is held in RAM must be duplicated on some other storage medium. The most common method is to use the hard disk to back up RAM and to use floppy disks or tape media to back up the hard disk. Additionally, a printed hard copy of the data is also a backup, but it is not as convenient to use to correct errors since it is not directly machine-readable.

Another example of a hardware requirement specified by a software vendor is:

> *IBM-PC or compatible, MS-DOS/Windows, hard disk, FoxPro for Windows.*

The new element in this description is the specification of FoxPro, which is a generic database application program. This indicates that this DRT package is an example of one written in or using a generic program.

4.2 DRT HARDWARE USE

4.2.1 Microprocessors

Respondents were asked which computer they currently use (the first bar in the graph in Figure 4.2) and what their likely future hardware will be (the second and third bars). The answers indicate that the most popular computers are personal computers using the 486 microprocessor, followed by personal computers containing the 386 microprocessor. However, the use of the 386 machines will decline as they are replaced by the computers using the Pentium microprocessor, few of which were in use at the time of the survey. Present 486 users plan to keep those machines, but new users will probably opt for a machine with the Pentium chip unless they are on tight budgets, because 486-based machines are less expensive. Work stations, which are the third-most-used computers today, will also decline in use, as will mainframe computers.

It is clear that today's users expect personal computers to be the workhorses of DRT computation in the future. The microprocessor of choice may change, since the state of the microprocessor art changes constantly, leading to rapid obsolescence. However, DRT vendors have expressed the opinion that the 486 and the Pentium are sufficiently powerful for the software they are contemplating in the near future. This

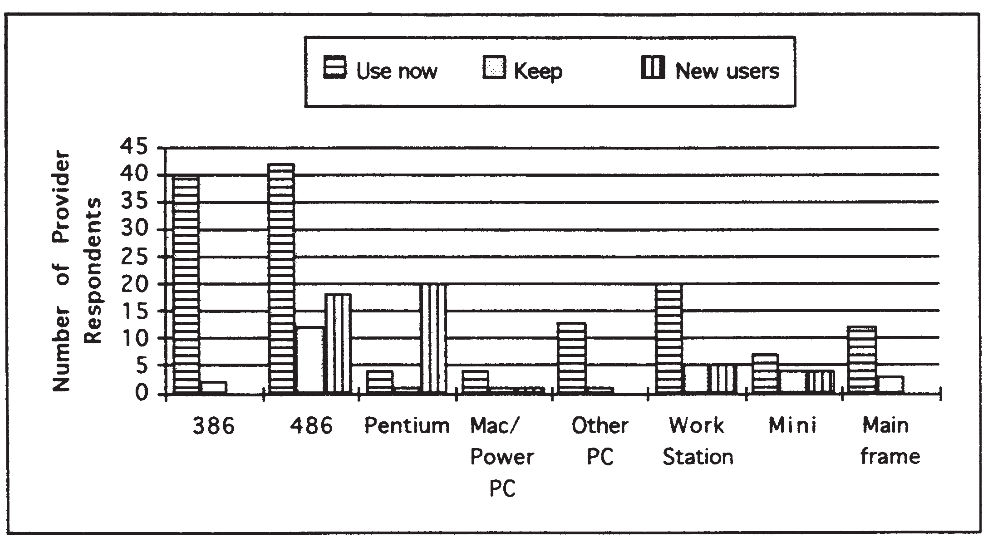

Figure 4.2 Computer Hardware Used and Planned.

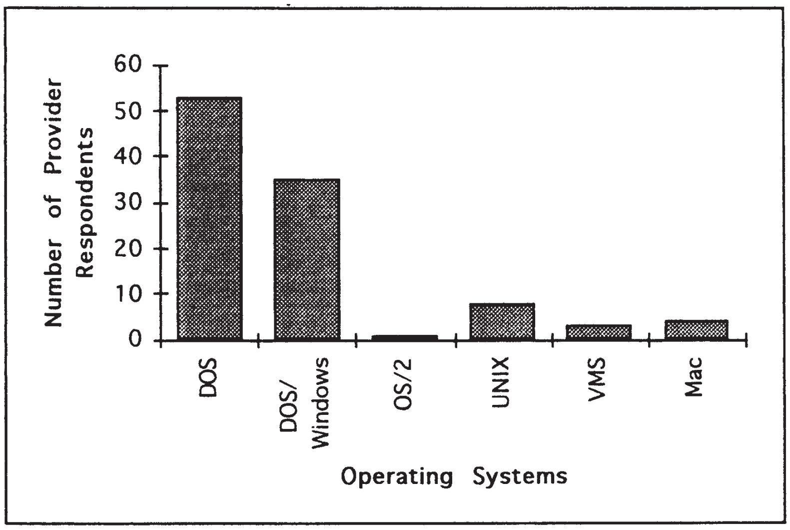

Figure 4.3 Operating Systems Used.

too may change as both available technology and the demands of the DRT market evolve.

4.2.2 Operating Systems

The survey of DRT providers (Figure 4.3) demonstrates that the most common operating system is DOS, followed by DOS/Windows. DOS/Windows will probably become the most common system in the near future as more vendors prepare software to take advantage of Windows. Four other operating systems—OS/2, UNIX, VMS (the system used by machines manufactured by DEC Corporation), and Mac OS—are used by a few providers.

4.2.3 Networks

Local area networks (LANs) are combinations of hardware and software that allow sharing of programs and data among personal computers, either at the same or at remote locations. About 62 percent of the respondents use networks and three-quarters of those indicate that they use a network called Novell. The next most popular network is Lantastic, a distant second with just over 7 percent of respondents reporting its use. Twenty-three of the 31 operators who contract for service use a network shared with the contractors that provide their services.

4.3 ACQUIRING HARDWARE

Your selection of DRT software will probably dictate the minimum hardware needed. Therefore, the microprocessor type and the operating system will be determined by the DRT software you select as the best for your needs. Some software may even dictate the brand of computer but it is more likely that you will have the choice of many brands. If an IBM-compatible is required, you are free to select the brand. While there may be differences in quality among different brands, or the vendors would like you to believe there are, computer hardware is like other commodities. Different brand names will have the same components such as microprocessors, disk drives, etc. You need to specify memory size, speed, and other peripheral hardware. You also have the flexibility to specify a greater capability in the hardware than is required by the software if you have other uses for the hardware, or you determine that a greater speed may be economically justified for your application.

Because of the commodity-like nature of hardware, it can be purchased by competitive bid or, unlike DRT software, can be purchased off the shelf. Some software vendors will sell the combined package of hardware and software and turn over an operating system to you. This is called a turn-key acquisition. This option has the advantage of making the vendor responsible for proper operation of the entire system and avoids finger-pointing between the software and hardware vendors if the system does not work.

> Make the contractor responsible for all aspects of the installation. This avoids potential conflicts if problems arise.
>
> —*Brad Christian, Assistant Transit Manager*
> Stanislaus County Transit (*2*)

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CHAPTER **5**

HOW MUCH AUTOMATION?

CONTENT AND AUDIENCE

Computers are useful for tasks requiring rapid, accurate calculations on large amounts of data. These capabilities are needed to perform the functions required of DRT operations. This chapter deals with the issue of whether or not to computerize, and if computerization is worthwhile, what level of computerization is warranted. It is intended for all readers.

5.1 THE CASE FOR AUTOMATION OF DRT SERVICE

In a paper written early in the development of ideas about the automation of DRT systems, Professor Nigel Wilson (*1*) made the following case for automation of DRT service:

> Principal factors arguing for computer control are as follows:
>
> 1. Decisions are more effective,
> 2. Larger systems are feasible, and
> 3. Features can be extended.
>
> The basic argument is that "better" decisions can be made by a good computer control procedure than by a good dispatcher, particularly in large systems. Specifically, service attributes desired by passengers can be provided more consistently and at improved levels by computer dispatching for a given number of passengers and vehicles (hence, productivity). The superior performance could be translated into a more attractive service resulting presumably in increased ridership or into a reduced vehicle fleet size with the quality of service preserved. In either case, higher productivities should be achieved by a computer-dispatcher system than by a similar manually dispatched system. This advantage increases with system size as the limit of a single manual dispatcher is approached. Effectively this manual-dispatcher limit bounds the economies of scale that may be achieved as the manual system expands. Further economies of scale may be achieved through computer dispatching. Extended features that computer control may make feasible include automatic billing, simultaneous provision of distinct services, automated interfaces with customer, and vehicle communication system.

The argument for automation today is the same one. Professor Wilson also saw the role of automation with respect to the use of complementary technologies 20 years ago, a promise that is only being realized today (see Chapter 7).

5.2 DECIDING WHETHER AND HOW MUCH COMPUTERIZATION IS WORTHWHILE

There are several bases for the decision concerning whether or not to computerize your DRT administration and operations. The decision can be made without specific and detailed analysis, based on the experience of others and on faith that computers will help. For agencies having large fleets, the no-analysis decision is probably correct. By the same logic, the smallest agency usually can justify the acquisition of personal computers for strictly administrative matters, maybe even only for word processing. Once a computer is in-house, relatively inexpensive software, such as databases or spreadsheets, can be applied to DRT operations. We believe that almost all agencies with several vehicles and several hundred riders can justify a computer for some DRT functions.

The difficult decision is whether the relatively expensive scheduling/dispatching software is warranted. Operators of fleets of 50 vehicles or more, offering immediate response service to 1,000 passengers daily in an unzoned service area, can safely assume that they need a software package that provides the fully automatic scheduling. However, if they assign vehicles to zones within their service area or if they run a high percentage of subscription trips, analysis may be required to determine if expensive software is warranted. For smaller agencies, specific analysis may be warranted to determine if the relatively more expensive scheduling/dispatching software is worthwhile. Usually, systems with about 10 vehicles carrying 150 trips per day will warrant at least a computer-assisted software package (see Table 3.2).

High-end specialty DRT software may cost between $50,000 and $100,000, which appears to be a high price when its value cannot be established with certainty before installation and use. However, it should be remembered that this software may become a major management and decision tool for operating a DRT system with an annual budget of several millions. Therefore, the effort to make a good decision is well worthwhile. In the words of a TCRP panelist, "It is not like buying a $100,000 parts washer in the maintenance shop."

This chapter starts by examining the experience of providers with computerization and concludes with an analytical discussion of issues for each DRT function. Several means of analyzing the decisions concerning scheduling/dispatching are discussed.

5.3 REPORTED BENEFITS OF COMPUTERIZATION

The experience of other providers who have computerized is useful in helping you make a determination of whether you should consider computerization. The results of the survey of providers concerning the impacts of computerization are presented here to aid your decision.

5.3.1 Impact on Staff

The impact on control room staff following the adoption of software was explored with a question asking for a rating of the strength of the impact in four areas, on a five-point scale defined by the terms “significant increase,” “some increase,” “no change,” “some decrease,” “significant decrease.” The tabulation of all respondents is shown in Figure 5.1.

The vast majority of respondents indicated that software had no effect on staff size. The few that indicated that software had an impact noted that increases in staff were more prevalent than decreases. These results support the hypothesis that changes in staff size usually do not accompany the adoption of software.

On the other hand, respondents indicated that staff skills necessary to operate in a computerized environment increased substantially, due to software use. None of the respondents thought that software use reduced the level of staff skills required. It is not clear if the adoption of software requires replacement of staff with persons with greater skill levels or if the very fact of using software is considered to be a more highly skilled endeavor, even if performed by the same staff. It is clear that you must take steps to ensure that your staff is equipped to use your new software.

Many respondents indicated that the use of software eased the task of management. Additionally, respondents generally cited an increase in job satisfaction due to software. These are both positive but difficult-to-quantify benefits of computerization.

5.3.2 Impact on Service

The impact of software on three service measures—productivity, quantity of service, and quality of service—is ranked on the same five-point scale used to rate the impact on staff (Figure 5.2). All three measures were deemed to increase substantially, and decreases were cited in only a few cases. Productivity was thought by the most respondents to increase, followed by quantity of service and then quality. Note that productivity and quantity are essentially the same result; that is, increases in productivity should allow the offering of either more trips with the same resources or the same number of trips with fewer resources.

In general, you can anticipate that the quantitative benefits of computerization will be productivity increases and not decreases in staff size. However, it should be observed that productivity increases can lead to decreases in the number of drivers required.

5.3.3 Summary of Survey Findings

In summary, users report that computerization raises productivity which, in turn, should lower the cost of operations. Respondents also report that computer use raises the quality of service. Concerning internal operations, users report that computerization does not impact the size of the staff, but

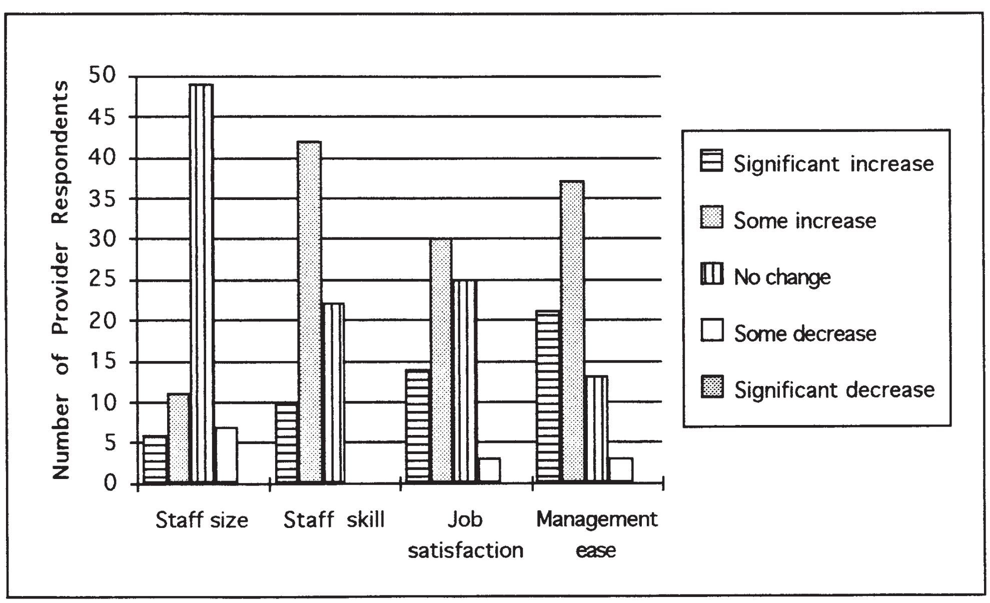

Figure 5.1 Impact of Software Use on Staff.

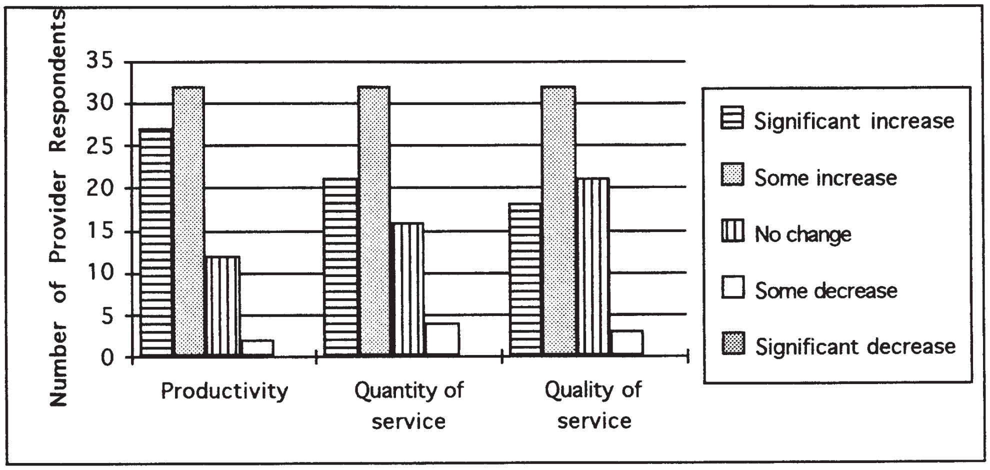

Figure 5.2 Impact of Software Use on Service.

does increase the skill level required and improves the level of job satisfaction. The survey contained no information on the acceptance or rejection of computers by the staff, but issues should be similar to the reaction of staff persons to change in any organization. Some people will resist any change, some resist computers specifically, and some will enthusiastically accept change. The advice to management is to recognize that computerization is a concept that may have to be sold to their staff.

5.4 ANALYSIS OF THE BENEFITS OF COMPUTERIZATION

5.4.1 Introduction to Benefits Analysis

In the last section, the experience of other providers was examined. In this section, we discuss how to examine the performance of your own scheduling/dispatching procedures, to ascertain if they can be improved. The intent of the analysis discussed here is to help you make an early decision on whether to further consider computerization before the effort of investigating vendors is undertaken. After examining vendors and their products, you might still decide not to proceed because you are not sold on actual products or vendors.

As a prologue to considering computerization, you should ask the question, "Can I do better without computerization or other technologies?" The first step in the search for better performance is to study the existing methods in an attempt to discover those improvements that can be implemented without capital expenditures.[1] In other words, it is first necessary to ensure that you are getting the most from your present resources. It often happens that improvements are made concurrent with computerization that, if made without computerization, would account for most of the improvements possible. Preparation for computerization requires a discipline that, if applied without the computer, would lead to improvements. It is possible that these procedural improvements are sufficient so that the additional benefits of computerization do not warrant the costs.

The analysis of present operations is done with techniques from disciplines of Industrial Engineering, Systems Engineering, and Systems and Procedures. Much of it is a common-sense application of detailed examination. Flow diagramming is also a useful tool for examining procedures. Exploring these techniques is beyond the scope of this Handbook; we suggest reference to textbooks or handbooks on any of the subjects mentioned above.

The issues involved in computerization are discussed for each DRT function in the remainder of this chapter. The emphasis is on the function of scheduling/dispatching, which presents the greatest challenge to the decision process.

5.4.2 Eligibility Determination

The determination of eligibility of a patron can be done independently of the other paratransit functions and can therefore be computerized without regard to the computerization of other functions. Database use requires listing all registered users. In a system with no computerization, this is merely a hard-copy list of registered patrons. Computerization is achieved by putting this list in a database software package, which allows retrieval of patrons' information by entering the person's name in the computer. Any of the generic database packages will serve this function.

It is sensible to computerize the eligibility function if any of the subsequent functions is also computerized. If nothing else is computerized, it is beneficial to computerize this if the

[1] A related postulate states that the greatest improvement from computerization can be achieved by ignoring the present methods and designing the computerized system from scratch. This usually is expressed as a criticism of existing software packages for not rethinking the entire process of offering DRT services and rather just computerizing the present manual systems. This may or may not be a valid criticism, but no one has yet demonstrated the radical new approach for more effective use of computerization, although some proposals have been made (*1*).

number of patrons is very large. Manipulating a lengthy hard-copy list delays the order-taking process.

5.4.3 Order Taking

As discussed previously, the use of computerized order taking depends somewhat on whether computerized scheduling/dispatching is warranted. If it is, computerization of order taking is a by-product of the scheduling/dispatching software, and essentially all scheduling/dispatching packages offer the function.

If computerized scheduling/dispatching is not warranted, computer-aided order taking may still be desirable as a recording device so that a manifest can be prepared for transmittal to the drivers. The computer plays no computational role and is used merely as a word processor.

Both generic software and specialty software can be used for order taking. Essentially any generic database software package can be adapted for order taking. Additionally, a number of vendors offer order-taking software which is relatively inexpensive, costing under $1,000.

On the other hand, if your system would benefit from computerized scheduling/dispatching, discussed in the next section, then you will probably get computerized order taking in the package, and the decision of whether to computerize depends on the value of the whole package.

5.4.4 Scheduling/Dispatching

While scheduling and dispatching can be performed separately, it does not make sense to do so in computerized systems. One of the advantages of computerization is to perform the functions jointly so that the times promised to patrons are based on dispatching, that is, the assignment of the trip to an actual vehicle. Therefore, we discuss the functions jointly as scheduling/dispatching, often referred to as scheduling, when deciding if computerization is warranted, because they will occur in a single package.

The collective experience suggests that you are a candidate for scheduling/dispatching software if you have more than 10 vehicles and deliver 100 to 200 nonsubscription trips daily. However, as the data in Figure 5.3 indicate, there are much smaller systems that use specialty paratransit software, although it is not known what level of software is used. Manual operation is the most prevalent means for small fleets, and a significant amount of generic software is used for such tasks as producing the manifests.

What are the benefits of the use of high-end scheduling/dispatching software? There is scientifically collected and analyzed empirical evidence identifying the quantitative benefits of computerized scheduling/dispatching. One large vendor reports that in its experience, computerized scheduling/dispatching will improve productivity by 0.2 to 1.0 passenger per vehicle hour, depending on all other factors. Taking the lower number in a 10-vehicle fleet suggests that, on the average, computerization would add one passenger per hour to the productivity. Cost savings accrue when the number of vehicles in service can be reduced. An average of one passenger per hour may or may not save one vehicle, depending on whether there is substantial peaking of demand. On the other hand, if the high range of an increase of one passenger per vehicle hour is achieved in a 10-vehicle fleet, then an additional 10 trips per hour are possible. Ten trips an hour usually suggests a two-vehicle saving or more, which can be substantial. For example, using some back-of-the-envelope calculations, if it costs $40,000 a year to operate a vehicle, a two-vehicle saving is an annual saving of $80,000, which may pay back the cost of a high-end scheduling/dispatching software package in 1 to 2 years or better. Bear in mind that this analysis is done using estimates and averages and does not apply to any given application. If the rules of thumb suggest that computerization may

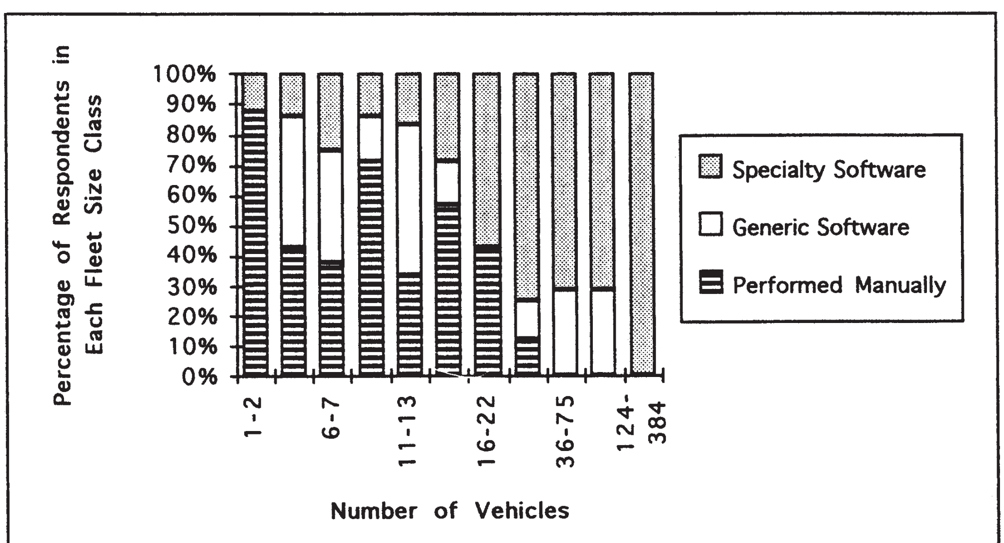

Figure 5.3 Relationship of Fleet Size and Software Use.

be beneficial to you, then you should undertake analysis of your own experience.

To analyze your operations, collect statistics on performance for a number of days of operation. Try rearranging the tours actually used to find out if they can be improved. While finding the best tours during operation may not be possible because of time constraints, in an analysis with no pressures, it is possible to examine many alternative tours. One useful way of performing this analysis would be to ask vendors to run a number of days using the data you have recorded so you can compare their tours to your actual data to answer the question concerning how much improvement you might achieve from actual software. This is not a perfect test as the probabilistic nature of paratransit operations allows for uncertainty in the analysis. However, you can have some confidence in the results if one scheduling/dispatching method continually outperforms the other.

You can also analyze your tours manually by searching in a trial-and-error fashion for better trip assignments, although the computations will be very tedious. You should use some means of randomly generating actual trip times. (A random number table will work.) If you have good computer modeling skills within your staff, you might consider developing a computerized simulation of your system to determine better tours. Some consultants also perform this analysis, although it may be sufficiently costly that only large systems can justify it. The paradox is that those who can afford the analysis need it the least, since the decision to computerize in large systems is easier to justify because the potential benefits can be so large.

The use of scheduling/dispatching procedures in an immediate-response mode is greatly enhanced by a precise knowledge of the location of vehicles. This has led some professionals to conclude that the real benefits of immediate-response DRT service will occur when scheduling/dispatching is integrated with Automatic Vehicle Location (AVL) technologies. Since AVL is a relatively expensive technology at the time of this writing, full benefits of this combination may only be available to large systems now or when the cost of AVL technology declines. However, more will be known about the benefits and costs of AVL soon because several agencies are installing systems integrating AVL and automated scheduling/dispatching (see Table 7.1).

Another issue pertaining to automated scheduling/dispatching is the problem of selecting software that performs the function well. The procedures that perform scheduling/dispatching and routing are complex mathematical ones that seek not just an acceptable course of action but an optimal course of action. Unfortunately, the quest for the optimal course of action consumes too much time, even when computerized, to be practical under the time constraints of DRT operations. Therefore, the procedures in current use settle for near-optimal solutions. Given all the other uncertainties and inaccuracies in real-world operations, the differences between the optimal and the near-optimal should be insignificant. On the other hand, the differences in the procedures used by different vendors to find the near-optimal may be significant, as may be the time required to apply their procedures. The problem for you, the buyer, is to discern what is worthwhile and which vendor can best provide it. The objective, comparative research necessary to analyze the procedures of different vendors has not yet been done by any appropriate organization.

5.4.5 Routing

Remember that the routing function prescribes the best path between points in terms of the actual roads taken (accounting for one-way streets, congestion, and the like), not merely the sequence of points. The routing task is performed by finding the best vehicle routes among drop-offs and pickups, where "best" can be defined as the lowest cost or the fastest. The best route is found by mathematical procedures that are sufficiently complex so that computerization is the only practical way to perform the function. So if you want to find the best routes, you will need a computerized procedure to do so.

Theoretically, the best vehicle routes are by-products of the scheduling/dispatching function if it is performed in a fully automated mode. Therefore, if scheduling/dispatching is fully automated, you will likely get routing for no additional cost. The question then is whether you actually use the routing information by conveying it to drivers or not. You may choose not to use computer-generated routes and instead let the drivers choose routes, for several reasons. It takes communication time and capacity to transmit this information to the drivers. Moreover, you may feel that the drivers can do as good a job or nearly as good a job as the computer because they may have more timely information on road conditions. Even if you think the computer routes may be better, you may consider route selection a prerogative of the driver, on the theory that route selection makes the driving job more meaningful.

If the schedule/dispatch function is performed manually or in a computer-assisted mode, routes will not be generated, and finding them would require a separate software package. It seems unlikely that routing performed without fully automated scheduling/dispatching would be warranted. The normal vendors of demand-responsive transit software may not even make a stand-alone routing package available, but other vendors may. Specifically, school bus scheduling software vendors would have routing-only packages.

5.4.6 Management Reporting and Statistical Analysis

One of the great advantages of computerization is that the information concerning performance can, in most cases, be easily captured and transformed to any reporting format that is desired. This is not a free by-product because it requires input of some information, but once computerized, the production of statistics and reports should become routine. Compared to the sophistication required of the scheduling/dispatching and routing task, reporting may be considered to be a mundane function. However, every DRT provider needs management information and almost all must submit reports for legal or contractual reasons, whether it be to a board of directors or to meet federal Section 15 requirements. For these reasons, reporting is an extremely important function.

In the earlier days of computerization of the DRT functions, providers appreciated the reporting capabilities even when the software did not perform the other functions very well. This suggests that automation of reporting, even if no other function is computerized, may still be worthwhile and should be considered.

Given the importance of reporting and the relatively straightforward nature of the function, it is surprising that at the time of this writing, providers using specialty software are complaining about the inadequacy of the reporting capabilities of some packages. This is a matter that will likely be improved, as is indicated in the projections of the future improvements described in the next section.

5.4.7 Other Functions

Other functions that can be performed with software assistance include accounting, invoicing, maintenance, purchasing and inventory control, and project management. These are not uniquely DRT functions as are the ones discussed above, and they are functions that many businesses perform. Therefore, greater varieties of generic software that perform these functions are available from many vendors at relatively low costs. In addition, some specialty DRT vendors market packages for these functions, and some of them may be integrated with the DRT operational software discussed above. Finally, vendors that sell to the transit industry but do not have DRT specialty software also offer packages performing these functions.

If you opt for a generic package and also use DRT specialty software, you will want to be able to use the relevant data from the specialty package without reentering it into a different computerized form. For this reason, you want a specialty package that will produce the data in standard formats that can be read by generic packages.

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