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Foreword

Most of the papers in this Record are from the 13th National Conference on Accessible Transportation and Mobility held October 23–28, 1992, in Tampa, Florida. Several papers focus on the implications of the Americans with Disabilities Act of 1990 (ADA), which mandates significant changes in the way that transportation services are provided for persons with disabilities. Papers discuss the service-route concept, which has the potential of satisfying ADA requirements with a small capital investment; a demonstration project to teach persons with disabilities to train other disabled persons to use fixed-route transit and to train transit operators to be more aware of the needs of those with disabilities. Strategies used in helping severely mentally ill persons with transportation handicaps convert from institutional settings to community-based living are presented, as is the development of transportation service options to help persons with disabilities overcome barriers that limit employment opportunities.

Two papers come from the United Kingdom: one focuses on past and current experience in accessible transportation, and the other discusses strategic management in specialized transportation, notably, the strategies of individual organizations to provide effective specialized transportation services.

Papers also focus on computerized reservations and scheduling in the paratransit industry, the institutional framework for coordination between agencies in the aging and transportation domains, and transportation technologies for improving independence based on experience in Canada.

Three papers address the mechanics of securement and restraint of wheeled mobility aids in public transportation vehicles, the engineering appraisal of wheelchair lifts, and procedures for assessing the reliability of wheelchair lifts.

Assessment of Software for Computerized Paratransit Operations

JOHN R. STONE, ANNA NALEVANKO, AND JEFFREY TSAI

The background and current issues regarding computerized reservations, scheduling, and dispatch in the paratransit industry are developed. After an overview of the scheduling process, which is the critical function of automated paratransit operations, features of selected software products are reviewed. The major considerations for selecting alternative software products are discussed. This comparative assessment of software is particularly useful for paratransit operators who plan to buy new software systems.

Nowhere is the promise of intelligent vehicle highway systems (IVHS) more tantalizing than in public transit. The promise of IVHS in the transit sector is so appealing that both FTA and IVHS America have placed a special emphasis on its development. Advanced Public Transportation Systems (APTS) is one of five program areas within IVHS America, the private nonprofit organization that the U.S. Department of Transportation has made responsible for promoting advanced transportation technology. It is also a top research and development program within FTA.

The advent of APTS is very timely for the transit sector. In urban and rural areas the transit industry continues to be pressured to meet the critical societal goal of mobility for elderly and disabled citizens as well as the general public. The Americans with Disabilities Act of 1990 (ADA) requires fixed-route transit systems to provide complementary paratransit services for persons within ¾-mi of a transit route who are unable to board conventional transit vehicles. ADA also requires systems to respond to previous-day reservations and to strive for real-time response. It stipulates that passengers can be on board no longer than an hour.

Operational pressures also exist in the realm of human service transportation. Vehicles often operate at a capacity of 25 percent or lower. The subsidized cost of carrying passengers may be twice the fare of comparable taxi service—or more if state and federal capital subsidies are included in the cost calculation. APTS, however, offers hope for improving efficiency and lowering costs, given the willingness to commit to change and to invest in the future.

The operations process starts when passengers reserve trips; at that time their eligibility to receive service is verified. They may reserve one or more trips up to 14 days in advance. Often they overbook to ensure their seats but later cancel 25 percent or more of their reservations. Ideally, ride confirmation occurs at the time of request; however, cancellations complicate the picture, as does the need to have sufficient time to build a schedule. Thus, most rides are confirmed the night or morning before service. APTS is already improving the bookkeeping of reservations and cancellations, but immediate ride confirmation depends on improved automated scheduling and dispatch.

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Once a trip reservation is taken it must be scheduled into a shared-ride sequence of other reservations and perhaps timed to meet a fixed-route transfer. The scheduling process is difficult in that passenger disabilities and vehicle capability must be matched, special passenger groups identified, the origins and destinations of passengers sequenced, and the vehicle route optimized. Thus, scheduling is a daunting technical and human problem. APTS technology has only recently had modest success in automating the process.

Closely associated with scheduling is dispatching. A previously scheduled, unmodified route is easy to dispatch (just hand a driver a trip sheet to follow), but real-time reservations and cancellations can change the schedule quickly. APTS technology, both hardware and software, must be applied more effectively so that it can accommodate requests for new or modified service immediately.

Such operations problems add to the already-difficult challenges that public transit operators face in retaining patronage and attracting new riders. APTS applications promise to aid transit operators in meeting these challenges while helping transit users access and pay for transit use.

In response to the important record keeping, reservations, scheduling, and dispatching needs for shared-ride paratransit operations, many new software and hardware products are appearing on the market. During late 1991 and early 1992 the authors surveyed the market and reported comparative features of different products. Since then many innovations have occurred. This paper updates earlier work (*1*). First, we develop computer dispatch issues relevant to shared-ride paratransit. We briefly explain technical concepts and discuss the rapid innovation that is occurring to meet the mobility requirements of the ADA. From interviews with software vendors and paratransit operators, comparative costs and features of selected software systems are given. We address the promise, as well as the problems, of automated dispatch and scheduling and give guidelines for selecting among different products. Related technical innovations are also mentioned, including geographic information systems (GISs) for displaying the schedule and route, mobile data terminals for communicating changes to schedules, smart cards and readers that can help record passenger data and fares, and automatic vehicle locators (AVLs) for tracking vehicles in order to dispatch them in real-time.

OPPORTUNITIES FOR NEW SERVICE

By improving how vehicles are dispatched and scheduled—particularly on a shared-ride, real-time basis—three benefits will result. One is that operators will provide better service by responding more quickly, using vehicles more efficiently, and billing passengers or sponsors while maintaining complete records automatically. Second, operators will expand their services to include dynamically dispatched route-deviation transit. Simply put, better scheduling and dispatching of vehicles will allow paratransit operators to reconsider the quality and variety of services that they can offer. Third, improved vehicle dispatching will dramatically change the relationship between the passenger and the operator. Traditionally, paratransit passengers have had to contact operators directly, obtain schedule and fare information, reserve a seat, and pay the driver for the trip. Soon, improved computer dispatching will allow a passenger to contact a central reservation system directly, much like passengers do for airline travel. One no longer needs to call each airline to learn of available seats and fares. Instead, travel agents have that information available for all airlines and can completely arrange and confirm air travel. Comparable capability in public transit has been slow to occur, but it is no less possible with the currently available APTS technology.

The process of rethinking transit service in light of improved scheduling and dispatching is evident in the FTA concept for the mobility manager (*2*). An organizational and technology innovation, the mobility manager is a central agent who can not only provide information on all local public transportation but also make real-time reservations for a person while on the phone. The mobility manager can even collect fares from the passenger and process payments to operators and invoices to agencies or companies that subsidize the trips.

It is against this backdrop that paratransit agencies are evaluating their services and their computerized reservations and scheduling systems. Depending on the number and type of passengers the agency transports and the service-level objectives, APTS technology offers a wide range of hardware and software options.

PARATRANSIT SCHEDULING AND DISPATCH

Central to the ability of APTS to enhance public transit service is the effectiveness of APTS in improving the process of dispatching and scheduling demand-responsive transportation. How vehicles and trips are matched directly affects passenger service levels and system productivity. If the promise of APTS is to be fully realized, computer technology must be effective in improving the efficiency of scheduling and dispatching shared-ride vehicles in real time.

Matching vehicles and trips is a formidable operations problem. It requires the operations staff to perform three functions: accept requests for trips, assign those trips in a logical manner to specific vehicles, and document the completion of the trip. Each of these functions is challenging. Accepting trip requests requires the operations staff to take trip data accurately, efficiently, and pleasantly. Documenting trips is challenging because agencies and companies that subsidize trips may require much record keeping. But it is the second function—matching trips to vehicles—that is the most intellectually formidable and that most severely affects system performance.

In general public and special paratransit systems, the matching of vehicles and trip requests is called scheduling. Scheduling paratransit trips is more complex than dispatching single-passenger taxis because of the shared-ride nature of the paratransit trips. The shared-ride scheduling problem, however, can be mitigated by preparing the routes and passenger pickup sequence in advance, typically the night before trips are needed.

The nonscheduling functions of paratransit operations were the first to be computerized: client certification, records, and agency billing. A variety of software vendors offer systems to handle these functions as well as scheduling.

Scheduling, however, is automated less easily. Most paratransit operators, particularly those of smaller systems, use manual scheduling procedures. But manual scheduling becomes an unbearable task for large systems. Depending on the degree of automation, the computer may provide a set of schedules for a fleet of vehicles given "batch" reservation data the night before service. Or the computer may keep an up-to-the-minute schedule prepared (or at least a skeleton schedule) as each reservation or cancellation is called in. A fully automated scheduling system can handle real-time trip requests and simultaneously update schedules while requesting a vehicle to deviate from the earlier schedule and pick up the new passenger. In each case a human scheduler has oversight authority on the schedule, which in contemporary software is displayed as a map on the computer screen. The location of each passenger origin and destination is available for display, as are the changing locations of the vehicles if AVL technology is used.

Figure 1 illustrates computerized scheduling including grouping, sequencing, and optimization (D. Young, personal communication, Jan. 1992). Incoming trip requests, which are answered by the call taker, may be reservations or cancellations for the next day or week, or they may be real-time taxi-like calls. The call taker enters the caller information into the host computer, and the caller's eligibility to use paratransit is verified. The scheduling function takes over next. Passengers, vehicles, and drivers are grouped according to special passenger characteristics and transportation services offered. General sequences of vehicle trips are identified depending on time of day, day of week, and location for which the transportation is needed. The vehicle path is optimized for minimum time or distance with respect to such schedule constraints as vehicle capacity and the ADA limit of 1 hr in the vehicle for any passenger. As additional requests come into the system, the path is reoptimized until a schedule of pickups and destinations is built.

At the beginning of a typical paratransit tour, a prearranged schedule (or trip sheet) is given to each driver. It lists the sequence, pickup times, addresses, and destinations of the passengers. It also gives directions for the minimum time or distance path to follow. To this point, the scheduling process parallels traditional manual paratransit scheduling. However, since the computer "remembers" the exact schedule and can predict the approximate location of the vehicle at any time during the schedule, in concept it can accommodate real-time trip requests as Figure 1 indicates. AVL technology may also be used to identify the precise location of the vehicle. Any new real-time request is inserted into the prearranged sched-

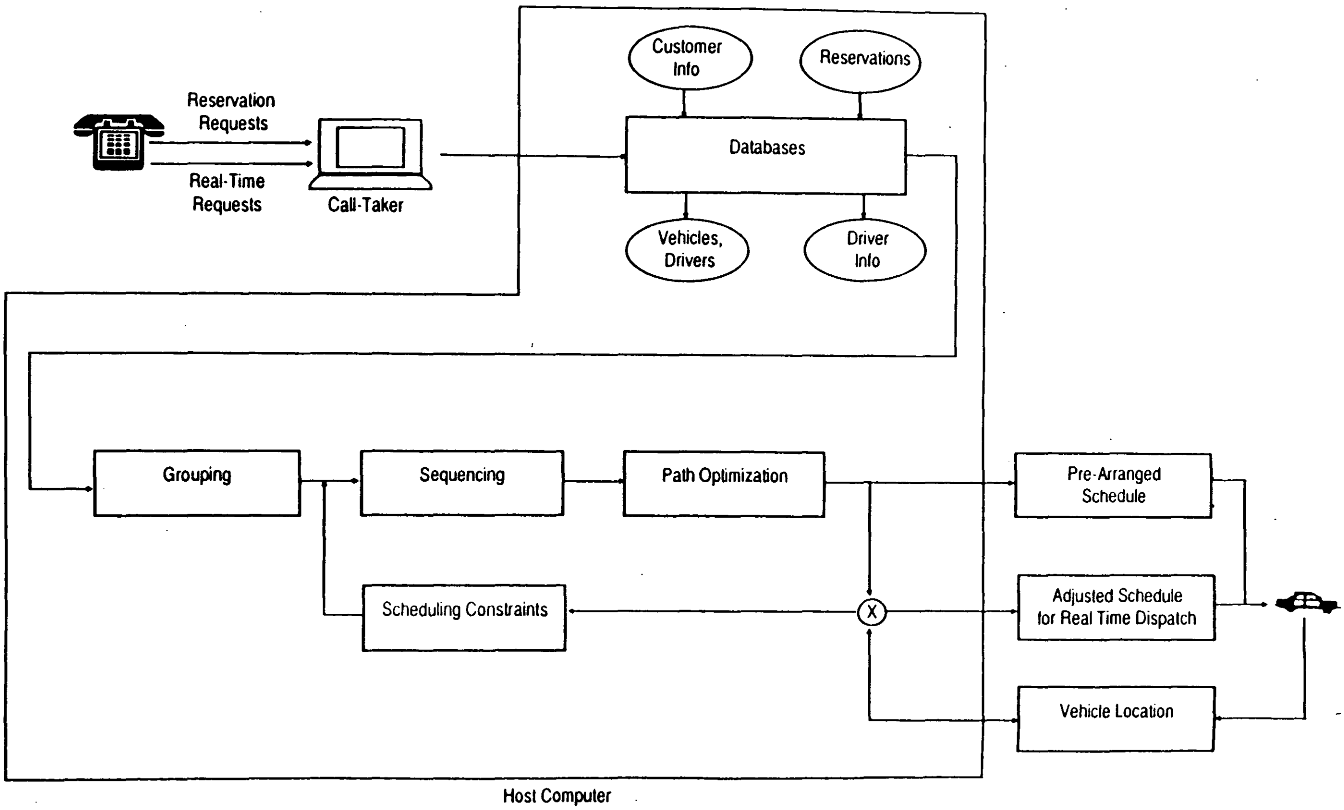

FIGURE 1 Paratransit computer scheduling.

ule at an appropriate point depending on the results of the grouping, sequencing, and optimizing functions. The new schedule is transmitted by voice or digital radio to the driver, who deviates from the scheduled route and picks up the new passenger. With appropriate in-vehicle display capabilities, the trip sheet can be replaced by digitally displayed information. Real-time, shared-ride scheduling and dispatching are not, however, a widespread operational reality for paratransit.

FEATURES OF AUTOMATED PARATRANSIT SOFTWARE

Several vendors provide software and hardware for paratransit management and service. Depending on the needs of the paratransit operator, various degrees of sophistication can be bought. For example, a small operator with 10 vehicles can buy a starter kit that includes one or more personal computers and a straightforward data base for reservations, record keeping, and billing. A larger system with 30 or more vehicles would most likely move up to a networked system of personal computers or workstations that call takers, schedulers, and dispatchers could access simultaneously. The functions of such a system would include not only automated reservations, record keeping, and billing, but also automated scheduling in at least batch mode. Larger systems, or those that have special service requirements such as timed transfers with fixed-route buses, would need options such as automated real-time dispatch, GIS route and map displays, mobile data terminals, smart card readers, and AVL devices. Tables 1 and 2 give the names of 13 major vendors, their software products, and various features. The table entries are not meant to be exhaustive. Other vendors need examination, including ATE-Ryder, Comsis (CTPS), Paratransit Systems International (Rides Unlimited), Navigation Data Systems (Fleet Track), Gandalf, State of the Art Systems, and KLD Associates (TransCad).

Paratransit software averages about $25,000, depending on available functions. Hardware costs depend on the products purchased and the number of vehicles and personnel locations that the items serve. Reduced personnel costs can often offset equipment and software costs in a year or two for the typical operator; so can improved system capacity and productivity. Nearly all the products claim demand-response scheduling, but there has been no wide independent verification of the acceptability of these products operating in an automatic scheduling or demand-response scheduling mode. In recognition of the growing importance of GIS, mobile data terminals, smart cards, and AVL, several vendors have incorporated these features into their products.

Tables 3 and 4 display comparative features for reservation, dispatch, and scheduling. Table 5 summarizes GIS features for the different software products.

SELECTION GUIDELINES

The selection of an automated paratransit management system must begin with a detailed definition of operational needs.

TABLE 1 Paratransit Software Vendor Information

Vendor Name	Software Name	Operating System	Hardware Requirement	Base Price (S) = single user (M) = multi-user	# Training Days (included in base cost)	Cost for Training
Aleph Computer Systems *	Aleph	Amos	Alpha Mini Computer	$80,000	-	-
Automated Business Solutions	PtMS	DOS Novell Windows	PC	(S) 8,400 (M) 16,500	3-4 days	N/A
Automated Dispatch Services	EMTRACK	Novell	PC	Approx $60,000	Yes	N/A
COMSIS	CTPS/CRSS	DOS Novell Banyon Unix	PC Alto Mini Computer	CTPS: (S) $9,995, (M)$14,995 CTPS/CRSS: (M) $19,995	3 days	N/A
Decision Sciences	Quick-Route	DOS PL/MOS	PC	(S) $12,000 (M) $12,000-$24,000	1 week	N/A
Easy Street	EasyTrips	DOS Lantastic	PC	(S) $25,000 (M) $25,000	1 week	N/A
Ketron*	PARMIS	Novell	PC	$25,000	0	$400 per day + expenses
Micro Dynamics	CADMOS	Novell	PC	1-5 users $7,500 >5 users $12,500	0	$360 per day + expenses
Mobile Computer Systems	PC-Dispatch/ Paratransit	DOS Novell	PC	$20,000	0	$500 per day + expenses
Modeling System	SCOOTER	VMS UNIX	Mini-computer PC	$6,400-24,000	0	$500 per day + expenses
Multisystem	GIRO/ACCESS	VMS UNIX Novell	Mini-computer PC	2-4 users $15,000 5-10 users $20,000 11+ $25,000	0	$700 per day + expenses
On-Line Data Products	PASS	DOS Novell	PC	(S) $24,500 $250 each add'l user	3 weeks	N/A
Paratransit Software, Inc.	PARRAS	DOS Novell	PC	(S) $7,000 - $11,000 (M) $10,000 - $18,000	4 days	N/A
Scandia Transport System	PLANET	VMS	Mini-computer	$500,000 +	2 months	N/A
UMA Engineering Ltd.	Quovadis	DOS Novell	PC	-	10 days	N/A

* : information from 1991, vendor did not reply
- : insufficient data, vendor did not supply

Some of these needs are shared by passengers, drivers, staff, and management. To select the best paratransit management information system, however, the focus must be on automating reservations and cancellations, scheduling and dispatching, and data collection and reporting. The following will define high-priority needs for each of these operational tasks. Given the needs as defined, technical specifications can be written to guide the procurement process.

Reservations and Cancellations

ADA Response

New software should accept 14-day advance reservations and be able to handle open returns with real-time dispatched shared-ride vans or taxis. The software should handle previous- and same-day reservations and prioritize service to eligible passengers on the basis of need, disability, and history of not showing. Real-time ride confirmation would reduce the heavy load of follow-up telephone calls for confirmation.

Matching Service to Special Passenger Needs

Passengers want to be able to book multiple trips in advance; request special drivers or vehicles; cancel trips as necessary; request immediate service; avoid unnecessary wait and travel time; travel with friends, spouses, guide dogs, aides, and groups; be made aware of alternative service by taxi and fixed-route bus; obtain service at the time requested; and have a reasonable response time. Passengers also want to be able to call the operator and quickly determine when a late vehicle will arrive.

Cancellations

New software must cancel a significant number of trip reservations efficiently and automatically, dispatch that information to drivers in real time, schedule new passengers into the open seats, and update trip sheets. The result would be more effective use of vehicle capacity, reduced dispatcher load, and a higher quality of service to passengers.

TABLE 2 Paratransit Software Features

Software Name	Client Registration	Demand-Response Scheduling	Batch Scheduling	GIS Interface	Fleet Maintenance	Reporting/ Billing	Integrate with Mobile Display Terminal	Smart-Card	Automatic Vehicle Location
Aleph	Y	Y	Y	N	Y	Y	Y	-	-
PtMS	Y	Y	Y	Y	Y	Y	Y	N	N
EMTRACK	Y	Y	Y	Y	Y	Y	Y	Y	N
Quick-Route	Y	Y	Y	Y	Y	Y	Y	N	N
CTPS/CRSS	Y	Y	Y	Y	Y	Y	N	N	N
EasyTrips	Y	Y	Y	Y	Y	Y	Y	N	N
PARMIS	Y	N	Y	Y	Y	Y	-	-	-
CADMOS	Y	Y	N	N	N	Y	N	N	N
PC-Dispatch	Y	Y	Y	Y	N	Y	Y	N	N
SCOOTER	Y	Y	Y	Y	Y	Y	Y	N	N
GIRO/ACCESS	Y	Y	N	N	N	Y	Y	Y	N
PASS	Y	Y	Y	Y	Y	Y	N	N	N
PARRAS	Y	N	Y	N	N	Y	N	N	N
PLANET	Y	Y	Y	N	N	Y	Y	Y	N
Quovadis	Y	Y	Y	Y	N	Y	N	N	N

-: insufficient data, vendor did not supply

Integrated System

In an integrated system, reservation clerks, schedulers, and dispatchers have access to the same information. If a passenger cancels a reservation, the clerk enters the information and the schedule is updated automatically and communicated immediately to the driver. Integrated systems would also be able to double-check passenger addresses from data bases and automatically identify the address from the passenger's name or identification number.

It should be noted that new software capabilities may redefine the roles of the operations staff. With the assistance of the computer and the results of automated scheduling, the telephone reservationists will have schedule information available. They will be able to answer calls from customers wondering where their rides are as well as calls for general information and trip reservations. They will have the schedules available, and the computer can slot in new calls so that rides can be confirmed immediately. In that sense, reservations clerks will take on some of the roles of schedulers and dispatchers. Automated scheduling also will allow the current schedulers to shift to a review role of automated schedules, taking on more of a strategic planning role rather than manually planning the schedules themselves.

Scheduling and Dispatching

Automated Scheduling

The highest priority for paratransit management (in a medium-sized to large operation) is a reliable, automated scheduling function. It may be on-line and schedule shared rides in real time, or it may schedule in batch mode. Either way it must allow the schedule to be adjusted manually to reduce deadheading and eliminate overlapping routes. Manual adjustment will be greatly facilitated by a GIS display of routes as they develop.

Mapping Capabilities

A GIS mapping display helps in finding optimal route paths automatically or manually; if the AVL feature is active, it helps locate vehicles so that the one closest to a demand-response call can be dispatched to it. It is highly desirable that the major elements of the street and highway network and the locations and destinations of clients be displayed during the reservation process.

Capacity

The new software and hardware must have the capacity to meet the current volume of trips and to grow with the demands of the system. A computer-based reservations and scheduling system must be able to handle a large volume of daily trips for several types of vehicles. New software must be able to use more fully the unused capacity of the vehicles, and it must accommodate unmet demand. New software cannot place trip limits on reservations; trip limits will have to be discontinued under ADA. Demand must be managed better by identifying riders who can use fixed-route transit and by monitoring and accommodating unmet demand.

Integrated System

Automated scheduling should be able to slot in another passenger who has a standby reservation or who has just called in. That new information should be displayed automatically to drivers and reservation clerks.

TABLE 3 Paratransit Software Reservation and Dispatch Component

Software	Aleph	CADMOS	CTPS/CRSS	EasyTrips	EMTRACK	GIRO/ACCESS	PARMIS
Follows ADA guidelines	Y	Y	Y	Y	Y	Y	Y
Integrate with fixed routes	-	N	Y	Y	Y	N	-
Policy help screen	-	N	Y	Y	Y	N	-
Utilize empty seats due to cancellation	-	Y	Y	Y	N	Y	-
Standby list	-	Y	Y	Y	Y	Y	-
Multi-window display	-	Y	Y	N	N	N	-
Reserve multiple trips	Y	Y	Y	Y	Y	Y	-
Reversal for round trip	Y	Y	Y	Y	Y	Y	Y
Quick key data entry	Y	Y	Y	Y	Y	Y	Y
Cancel trip by group	Y	Y	Y	Y	Y	Y	-
Cancel selected reservations	Y	Y	Y	Y	Y	Y	-
Multiple addresses	Y	Y	Y	Y	Y	Y	-
Code for landmark destination	Y	Y	Y	Y	Y	Y	Y

Software	PARRAS	PASS	PC-Dispatch	PLANET	PtMS	Quick-Route	SCOOTER	Quovadis
Follows ADA guidelines	Y	Y	Y	Y	Y	Y	Y	Y
Integrate with fixed routes	N	Y	Y	N	Y	N	Y	Y
Policy help screen	N	N	Y	N	N	Y	Y	Y
Utilize empty seats due to cancellation	N	Y	Y	Y	Y	Y	Y	Y
Standby list	N	N	Y	Y	Y	Y	Y	Y
Multi-window display	N	Y	N	Y	Y	Y	Y	Y
Reserve multiple trips	Y	Y	Y	Y	Y	Y	Y	Y
Reversal for round trip	Y	Y	Y	Y	Y	Y	Y	Y
Quick key data entry	Y	Y	Y	Y	Y	Y	Y	Y
Cancel trip by group	Y	N	Y	Y	Y	Y	Y	Y
Cancel selected reservations	Y	Y	Y	Y	Y	Y	Y	Y
Multiple addresses	Y	Y	Y	Y	Y	N	Y	Y
Code for landmark destination	Y	Y	Y	Y	Y	Y	Y	Y

-: insufficient data, vendor did not supply

Flexibility

As the system grows and moves toward real-time, taxi-like response, radio traffic will continue to grow and multiple voice radio frequencies are unlikely to be satisfactory for long—especially if paratransit service moves toward timed transfers with fixed-route buses in response to ADA guidelines. Mobile data terminals (MDTs) represent a successful approach to rapid, high-volume communications; any new paratransit operations system should be able to incorporate MDTs. Readers for magnetic fare and identification media are another type of device that the software should accommodate. A third type of device receiving much attention in paratransit operations is the AVL. A new operations system should be able to use an AVL.

TABLE 4 Paratransit Software Scheduling Component

Software	Aleph	CADMOS	CTPS/CRSS	EasyTrips	EMTRACK	GIRO/ACCESS	PARMIS
Demand-Response Scheduling	Y	Y	Y	Y	Y	Y	N
Batch Scheduling	Y	N	Y	Y	Y	N	Y
Vehicle/client needs match	Y	Y	Y	Y	Y	Y	Y
User - defined constraints	-	N	Y	Y	Y	N	-
User - weighted constraints	-	N	Y	Y	Y	N	-
Flag routes exceed constraints	N	N	Y	Y	-	Y	-
Callback list	-	N	Y	N	N	N	N
Manual route construction	-	Y	Y	Y	Y	Y	-
Freeze routes	-	Y	Y	N	Y	Y	-
Time calculation method	zone-to-zone	zone-to-zone	triangulation zone-to-zone	crow flight arterial	triangulation	zone-to-zone	-
Consider past cancellations/ no shows	-	N	N	N	Y	N	-
Perform simulation	-	N	Y	Y	Y	N	-

Software	PARRAS	PASS	PC-Dispatch	PLANET	PtMS	Quick-Route	SCOOTER	Quovadis
Demand-Response Scheduling	N	Y	Y	Y	Y	Y	Y	Y
Batch Scheduling	Y	Y	Y	Y	Y	Y	Y	Y
Vehicle/client needs match	Y	Y	Y	Y	Y	Y	Y	Y
User - defined constraints	Y	N	Y	Y	Y	Y	Y	Y
User - weighted constraints	N	N	N	Y	Y	Y	Y	Y
Flag routes exceed constraints	N	N	Y	Y	Y	N	N	Y
Callback list	N	N	Y	Y	Y	Y	Y	Y
Manual route construction	Y	Y	Y	Y	Y	Y	Y	Y
Freeze routes	Y	Y	Y	Y	Y	Y	Y	Y
Time calculation method	zone-to-zone	triangulatio	arterial	arterial	triangulatio	crow flight triangulation	arterial	crow flight, triangulation, arterial
Consider past cancellations/ no shows	N	N	N	N	N	N	N	N
Perform simulation	N	N	Y	Y	Y	Y	Y	Y

-: insufficient data, vendor did not supply

Data Collection and Reporting

Customized Reports

Operators desire customizable report formats so that they can easily design special reports on-line and readily retrieve selected data from the data base into the report format.

Automated Billing

Some operators do not need complicated invoicing and billing functions, but such options for future use should be considered when buying software.

The authors believe that any new software product must address most of these needs to ensure efficiency and quality

TABLE 5 Paratransit Software GIS Interface

Software	Aleph	CADMOS	CTPS/CRSS	EasyTrips	EMTRACK	GIRO/ACCESS	PARMIS
GIS Software	N/A	N/A	MapInfo	MapInfo	In-house	N/A	-
Import from DIME, TIGER files	N/A	N/A	Y	Y	Y	N/A	Y
GIS data maintenance utility	N/A	N/A	N	N	N	N/A	-
Multi-monitor display	N/A	N/A	Y	Y	Y	N/A	-
Manipulate screen display	N/A	N/A	Y	Y	Y	N/A	-
Display vehicle location	N/A	N/A	Y	Y	Y	N/A	-
Display driving path	N/A	N/A	Y	Y	Y	N/A	-
Display client location	N/A	N/A	Y	Y	Y	N/A	-

Software	PARRAS	PASS	PC-DISPATCH	PLANET	PtMS	Quick-Route	SCOOTER	Quovadis
GIS Software	N/A	MapInfo	MapInfo	N/A	MapInfo	In-house	DigiMap	In-house
Import from DIME, TIGER files	N/A	Y	Y	N/A	Y	Y	Y	Y
GIS data maintenance utility	N/A	N	N	N/A	N	N	N	Y*
Multi-monitor display	N/A	on one monitor	Y	N/A	on one monitor	on one monitor	Y	Y
Manipulate screen display	N/A	Y	Y	N/A	Y	Y	Y	Y
Display vehicle location	N/A	Y	Y	N/A	Y	N	Y	Y
Display driving path	N/A	Y	Y	N/A	Y	N	Y	Y
Display client location	N/A	Y	Y	N/A	Y	N	Y	Y

-: insufficient data, vendor did not supply
* Not a true GIS data maintenance utility.

of service to the operator and passengers alike. However, new software presents new opportunities, as discussed previously. New software is not an excuse for continuing old procedures. It is an opportunity to evaluate and change operating policies in order to reach new levels of service efficiency, passenger satisfaction, and community mobility.

FUTURE PROSPECTS

The current focus of the paratransit industry is on advanced technologies—APTS. The technologies include smart cards, AVLs, real-time dispatch and scheduling for shared rides, integrated reporting and billing, minimum time and distance routing for pickup and delivery of passengers, service confirmation, automatic caller identification and eligibility validation, GIS data base maintenance, graphic displays of service areas with relative passenger and vehicle locations, synthesized voice response, and other exciting items. Such micro-level improvements are vital to improving transportation to special groups. They will not in themselves, however, improve public mobility appreciably for the community, especially compared with the mobility provided by the private automobile.

Besides technical innovation, the service delivery system and community mobility require some creative thinking. New concepts such as the mobility manager are needed to affect the way people think about their transportation choices. Such concepts can then apply the new technology to affect people's travel behavior and give them alternatives to the single-occupant automobile. Thus, for example, the mobility manager must focus on the way transportation service information is acquired, processed, and made available before people choose their mode for a trip. APTS must be used not only to improve the efficiency and effectiveness of a particular mode, but to improve the choice of modes for a trip as well.

Automated computer dispatch for paratransit service is a precursor of the mobility manager. Already passengers can quickly call for rapidly responding, real-time service. Automated dispatch also has the capability for other major functions of the mobility manager, including brokering, fares, ride validation, passenger eligibility checks, billing and reporting, and magnetic fare media processing. However, the technology must also be extended to provide shared-ride, real-time dispatch and scheduling in order to become the "brain" of a mobility manager. When real-time, shared-ride scheduling is added to existing automated computer dispatch algorithms, advances must also be made in AVLs, the key to the next major improvement in response time. Fortunately, these improvements are on the verge of becoming reality.

The pace of technological change in the paratransit industry is rapid. Such change is exciting: new products and concepts for service delivery appear every month. Such rapid change also generates concern about the longevity of innovations and their integration as systems in concepts such as the mobility manager. Will better products come along? Will they all fit together when purchased? Crucial questions remain about such issues as common design specifications, physical connections, input and output formats, communications structures, and protocols. As many new products become available, there is concern in the industry about which products are best suited for operators' needs and whether the technology will greatly change within reasonable payback periods. Indeed, selecting new hardware and software can become a formidable problem.

The authors hope that this paper is valuable to those readers who plan to evaluate their needs and acquire an automated paratransit management system.

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Transportation Service Demonstrations To Facilitate the Employment of Persons with Disabilities in Tennessee

THEODORE J. NEWSOM, DEBRA MARTIN PETTY, AND CAROLYN HENDERSON

A process to facilitate the development of alternative transportation services to help persons with disabilities overcome barriers that limit employment opportunities was implemented in two phases. Phase 1 activities concentrated on collecting information about transportation resources, work-trip problems, and potential solutions. The results of Phase 1 activities are contained in a previous report. These activities produced recommendations about transportation services for workers with disabilities and provided the basis for initiating Phase 2 transportation service demonstrations. During Phase 2, local project teams were formed in Memphis, Knoxville, and Sevierville, Tennessee, to pursue the development of demonstration projects. In Memphis, the local team developed a transportation revolving loan program and a coordinated commuter van service. In Knoxville, the team focused on increasing mobility options for workers with disabilities through private-sector service contracting and through the development of a community-based transportation business. In Sevierville, the team designed a dedicated commuter van service and expanded driver education opportunities for workers with disabilities interested in driving to and from the workplace. A statewide demonstration project involving the development and implementation of a vehicle purchase program for agency-provided transportation services was also conducted. In addition, the use of the Plans for Achieving Self-Support to finance transportation options for workers with disabilities is described.

When states such as Tennessee experience periods of economic development and growth, employment opportunities increase as existing businesses expand and new businesses open. Many persons take advantage of the opportunities to obtain new employment or experience career growth as a result of increased economic activity. However, certain segments of the population, such as persons with disabilities, cannot participate fully in the economic life of their communities. Problems such as lack of education and training, day care, and the inaccessibility of work sites are barriers that must be overcome to simplify job placement and retention. In many cases, employment opportunities are limited simply because the employees cannot drive or afford transportation. In addition, many potential work sites are in areas not served by existing transportation services, and work schedules often do not correspond to scheduled public transportation services.

Transportation is the problem most often cited by parents, staff, and persons with disabilities (*1*). This issue may be looked at from two perspectives: (a) the lack of available transportation and (b) the inability of the individual to access transportation because of either physical barriers or insufficient skills. The availability of public and private transportation is essential. Many people with severe disabilities cannot transport themselves; they must depend on a third party to get to and from employment. In areas where no public transportation exists, new services and support systems are required. Where transportation may be available, service schedules, architectural barriers, or confusing routing systems may inhibit the use of that transportation by persons with disabilities. In a national survey of staff in rehabilitation agencies, facilities, and organizations, transportation was ranked as the most significant barrier to accessing employment for persons with disabilities (*2*).

In a recent study of the National Association of Rehabilitation Facilities (*3*), the status, impediments, and best practices of supported employment were reported by 2,034 supported employment providers across the nation. The three most common methods of transporting supported employees to work were (a) transportation provided by an agency, (b) public transit without assistance, and (c) transportation provided by friends or relatives. Smaller organizations were more likely to provide transportation for their supported employees. Half of the smaller organizations provided transportation for an average of 65 percent of their supported employees. In a study on program status of supported employment in Tennessee (*4*), providers reported that transportation greatly impeded the consumer's ability to obtain and keep employment. The most frequent type of primary transportation to work was that provided by rehabilitation agencies and organizations. Other types included consumers driving their own cars, independently using public transportation, and walking or riding bikes or mopeds. Transportation was reported as the service most often provided while consumers were receiving extended support to help them maintain their jobs.

It is apparent that workers with disabilities are having substantial difficulties in using traditional transportation systems to the extent desirable for community integration. Transportation is a major barrier for persons with disabilities, especially when they are seeking work training and job placement. It remains a significant issue for public and private organizations whose mission is to design and implement strategies to facilitate employment opportunities for persons with disabilities.

PROJECT OBJECTIVES AND TASKS

The overall intent of the project was to initiate a process for developing transportation service options that would help per-

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sons with disabilities participate in the economic growth of Tennessee. The targeted client group was composed of Tennesseans with disabilities who are or will be employed in competitive job positions. Besides employees with disabilities, others involved in the project were transportation operators and community service agencies that transport employees with disabilities to work sites, employers who recruit and hire employees with disabilities, and support agencies that provide funds to facilitate the employment of persons with disabilities. Under the direction of the University of Tennessee Transportation Center's Institute for Human Mobility Systems, these groups provided input to the future development and design of transportation services to transport employees with disabilities to and from the workplace.

The activities described in this paper were a part of a larger study conducted in two phases during October 1989 through June 1992. Phase 1 activities concentrated on collecting information about transportation resources, work-trip problems, and potential solutions. The results of Phase 1 activities are contained in a previous paper (*5*). On the basis of these results, the project was continued into a second phase, which is described in this paper. The development of specific service demonstrations and selection of test sites and service financing options were begun as Phase 2 project tasks.

The intent of the second phase was to continue the development of alternative transportation service options. The work focused on developing transportation services at demonstration sites throughout the state. The major tasks accomplished during this project phase included the selection of demonstration sites, the formation of local project teams, the design of transportation services to be tested at each demonstration site, and the development of financial resources to fund the demonstration projects. A description of the demonstration projects and their developmental status is presented.

TRANSPORTATION SERVICE DEMONSTRATIONS

Local Service Demonstration Projects

Specific transportation service options recommended during Phase 1 were reviewed by the project staff for inclusion as potential service demonstration proposals developed during Phase 2. Potential project concepts were selected for development in the Knoxville, Memphis, and Sevierville areas. Local project teams were formed for each of these areas to work with the project staff during proposal development, solicitation of demonstration grant funds, and project implementation when financing was obtained. The local demonstration projects and their status as of this paper are described in the following.

Community-Based Transportation Business (Knoxville)

A local project team was formed in Knoxville to consider the development of a community-based transportation business. Team members included a representative from the Helen Ross McNabb Center, K-Trans, and the University of Tennessee. The objective of the community-based transportation business project is to develop a transportation business that trains, employs, and transports low-income and disabled people. Although the transportation business would offer a variety of trips, its primary emphasis would be on work trips and work-related trips for persons with disabilities. The transportation business would provide reliable transportation to work sites, job training opportunities to low-income and disabled people, and jobs for persons with disabilities in the community-based business.

The Phase 1 results provided background information for an initial proposal developed by the staff of the Helen Ross McNabb Center and submitted to the Tennessee Department of Vocational Rehabilitation and the Levi Strauss Foundation for funding consideration. The initial proposal did not receive funding from these sources, so it was revised and a second project proposal was prepared and reviewed by the local team members. The revisions included an emphasis on training entrepreneurs interested in starting transportation businesses to serve persons with disabilities. The objective of the demonstration project is to provide business training along with technical support and financial incentives to encourage businesspeople to develop community-based transportation businesses. The proposal has been submitted for funding consideration to FTA as part of its Entrepreneurial Services Program (ESP). Follow-up contacts with FTA staff in Region 4 and in Washington, D.C., indicated that the project is eligible for funding with some revisions, but that no decisions can be made until ESP funding receives final approval from FTA.

Private-Sector Service Contracting Project (Knoxville)

A local project team in Knoxville composed of representatives from K-Trans, the Knox County Association for Retarded Citizens, and the University of Tennessee was formed to consider private-sector service contracting as an option for expanding services to persons with disabilities. The objective of the demonstration project is to contract for transportation services with private-sector providers. Such providers in the Knoxville area will be identified and recruited to participate in the program. Through a series of meetings, interested providers will be asked to propose alternative service models and financing strategies to accommodate the work-trip needs of persons with disabilities. The results will be used to prepare service designs using contracted private-sector providers. The contracted services will be procured through appropriate bid procedures and implemented as service demonstrations for set time periods.

When the local team was preparing a project concept, a planning team of city officials and public transportation providers began to develop Knoxville's Americans with Disabilities Act (ADA) Paratransit Compliance Plan. One plan element will be to explore and evaluate privatization and alternative modes such as the design of referral services, private-sector contracting, and user-side subsidy options. The funds to conduct this assessment are provided by Tennessee Department of Transportation (TDOT) as part of the FTA Section 8 Planning process in Knoxville. To help evaluate these options, the project team worked with the Knoxville ADA Paratransit Advisory Committee to develop a Project ACTION proposal to use the Care Network computer technology to identify persons with disabilities and their transportation needs. This project was submitted to Project ACTION on May 29, 1992.

Preliminary contacts with private-sector contractors indicated that contractors were interested in providing transportation services but that they would need specific market and cost information to initiate specific service design options. The ADA paratransit planning process, along with the use of Care Network computer technology, would address this need. As a result, it was decided to incorporate this project demonstration concept and its development and implementation into the ADA paratransit planning process.

Coordinated Commuter Van Service (Memphis)

A local project team from Memphis, consisting of representatives from the Memphis Area Transit Authority, the Northeast Community Mental Health Center, and the University of Tennessee, explored the opportunities for demonstrating a coordinated commuter van service. The objective of the demonstration project is to design and operate a coordinated commuter van service to transport employees with disabilities to and from the workplace. Five area community mental health agencies that now provide job development and placement services for persons with disabilities will be asked to participate in an agency transportation consortium. Northeast Community Mental Health Center will be the lead agency for the consortium. With technical assistance from the Memphis Area Transit Authority and the University of Tennessee Transportation Center, the consortium will design and operate a coordinated commuter van service to provide dedicated work-trip transportation for individuals from all five agencies. The consortium will make decisions about organizational responsibilities of its members and the operations of the commuter van service. It is planned to operate the coordinated commuter van service for a limited demonstration period. Employees, employers, and the consortium members will evaluate the service to assess its costs and benefits. On the basis of the lessons learned from the demonstration, the consortium will recommend whether to modify, expand, or discontinue the service.

The local team is working closely with the Memphis Paratransit Coordinating Committee, which oversees the development of improved paratransit services in the Memphis area. The committee has several projects under way that have been given higher priority for development and implementation. These projects include the development of an ADA Paratransit Compliance Plan for Memphis as required by FTA and the implementation of a driver training program for personnel of agencies in Memphis that operate transportation services. The development of the coordinated commuter van service is ongoing. The specific focus now is the solicitation of operating funds to initiate the service.

Transportation Loan Guarantee Program (Memphis)

Another local project team in Memphis was formed to consider the development of a transportation loan guarantee program. Representatives from the Memphis Area Transit Authority, A&A Guard Service, and the University of Tennessee participated as team members. The objective of the demonstration project is to develop a transportation loan guarantee program for employees with disabilities who need financial assistance to purchase transportation items essential for acquiring and retaining employment. The program would enable qualified workers with disabilities who can drive to buy vehicles for commuting to and from work. The program would also assist workers with disabilities to rehabilitate available vehicles in need of repair and to procure items to equip vehicles for driving or transporting persons with disabilities. The initial seed capital for the loan program will be solicited from public and private agencies. These agencies will provide representatives for the formation of a loan board that will develop eligibility criteria for loan program participants and make recommendations on program administration. An agency will also be selected to administer and manage the loan program and to develop procedures for soliciting, processing, and approving loan applications. Loan guarantees will be available until the initial seed funds are depleted, and additional loans will be made as funds become available. The program will be evaluated to assess program costs and benefits.

The local project team is searching for an administrative unit to conduct the program. Partners in Placement, Inc. and the Memphis Independent Living Center have been approached to consider the administrative unit role. Although supportive of the project concept, these organizations are unable to participate in the administrative role. The local team will continue to pursue opportunities for program funding and the identification of an organization to serve as the administrative unit for the loan program.

Sevier County Commuter Van (Sevierville)

A local project team with representatives from the East Tennessee Human Resource Agency, the Douglas Cooperative, and the University of Tennessee was formed to develop a Sevier County Commuter Van service. The objective of the demonstration project is to design and operate a commuter van route dedicated to transporting employees with disabilities to and from the workplace. The origin, destination, operating schedule, and fare rate of the commuter van will be based on an assessment of employee transportation needs and employer labor needs in selected areas of Sevier County. The commuter van route will be operated for a limited demonstration period. During the demonstration period, the route will be promoted to increase ridership among workers with disabilities. User evaluations will also be conducted periodically to assess employee and employer satisfaction with the service and to modify the route as needed. Continuation beyond the demonstration period will be contingent on the level of use and financial viability of operating the commuter van route.

A draft project proposal was prepared and submitted to TDOT for review and funding consideration. Follow-up contacts with TDOT staff to assess the proposal status indicated that the project was still under review and remains under consideration for funding as a demonstration project when funds are available.

Driver Education Program (Sevierville)

A local project team from the Sevierville area pursued the development of a driver education program for persons with disabilities. Team members included representatives from the Tennessee Department of Vocational Rehabilitation, the Tennessee Department of Mental Health and Mental Retardation, and the University of Tennessee. The objective of the demonstration project is to increase the opportunities for workers with disabilities to drive to work by obtaining a driver's license through expanded driver education programs. Current driver education programs will be identified and program activities directed to meet the special requirements, and needs of workers with disabilities will be documented. Follow-up evaluations are planned to assess the project's effects on helping such workers obtain driver's licenses and the degree to which the ability to drive to work increases job placement and retention.

A vocational rehabilitation student at the University of Tennessee is identifying and documenting the activities of agencies that conduct driver education programs for their clients. The Tennessee Vocational Training Center, in Maryville, has volunteered to assist with the project. The center has provided case study information about the local driver education program for its clients. Its participation has encouraged the team to go beyond the local area to identify and document similar programs in other regions of Tennessee. This information will be summarized and disseminated to agencies in the state that are interested in initiating driver education programs for their clients.

Statewide Vehicle Purchase Demonstration Project

Many agencies throughout Tennessee are charged with developing community-based employment opportunities for their clients to facilitate community integration and independent living among persons with disabilities. As discussed earlier, these agencies must overcome transportation barriers that inhibit job training and job placement opportunities for persons with disabilities. To meet their employment program objectives and to ensure job placements, these agencies sometimes provide direct transportation services to accommodate the work-trip needs of their clients. In an effort to provide transportation resources to these agencies, the project staff participated in the development of a statewide vehicle purchase program.

A vehicle purchase program has been designed to assist agencies that provide supported employment opportunities for persons with disabilities and that desire to buy vehicles to transport individuals to work and work-related activities. The project is a statewide transportation demonstration project developed by the University of Tennessee Transportation Center as part of a research grant from the Developmental Disabilities Planning Council. The demonstration project is a cooperative effort of the university, the Tennessee Initiative on Employment, TDOT, and the Tennessee Department of Mental Health and Mental Retardation.

The vehicle purchase program is a service option provided through Tennessee Vans, the statewide commuter vanpool service sponsored and operated by the University of Tennessee Transportation Center and TDOT. Tennessee Vans was initiated in 1990 with funds of approximately $1 million in capital and operating grants from TDOT. The vehicle lease and purchase options are designed as revolving fund programs to recover program expenses and subsequently expand services with program revenues collected from consumers and participating agencies. The vehicle purchase option enables public and private nonprofit organizations to buy vehicles for work-trip and work-trip–related purposes on a "pay as you go" financing plan. Major features of the program follow:

- Program participants include public and private nonprofit organizations that provide, or would like to provide, transportation services for commuters in Tennessee. Commuter transportation services include transporting employees to and from work or to and from job training sites or events and activities that facilitate the employment of persons served by the organization.
- Vehicles are purchased by the University of Tennessee Transportation Center and assigned to participating organizations through a simple purchase agreement. The vehicles are equipped especially for commuter transportation and include items such as cloth seats, carpeting, privacy glass, front and rear air conditioning and heat, side and rear swing-out doors, cruise control, tilt wheel, and AM/FM radio. Vehicles available during the 1991 model year are Ford 15-passenger vans and Ford 7-passenger minivans.
- Vehicle financing is provided on a "pay as you go" basis without requiring any cash down payment. The participating organization agrees to pay mileage fees to the University of Tennessee on a quarterly basis until the vehicle replacement cost is paid in full. The replacement cost must be paid in full within 60 months of the vehicle assignment date. Current fees for the 1991 vehicles are as follows:
  - –Ford 15-passenger van: Replacement cost is $19,000; mileage fee is $0.19/vehicle-mi.
  - –Ford 7-passenger minivan: Replacement cost is $15,000; mileage fee is $0.15/vehicle-mi.
  - –Administrative fee: Mileage fee of $0.02/vehicle-mi is added to cover incurred administrative costs.
- Upon payment of the vehicle replacement cost, the title to the vehicle is fully transferred to the participating organization. The organization may then use the vehicle for any organization purpose for the rest of its useful life.
- Vehicle insurance and maintenance are provided by the participating organization throughout the duration of the purchase agreement period. Basic insurance coverage levels and routine vehicle maintenance procedures are outlined in the purchase agreement.
- Drivers that operate these vehicles are provided by the participating organization. Drivers are expected to possess appropriate, valid Tennessee operator's licenses and to operate the vehicles safely, in accordance with all applicable laws and regulations.

The program for supported employment agencies was initiated with the assistance of the Douglas Cooperative in Sevierville. Douglas Cooperative agreed to participate as the first agency to develop a vehicle purchase contract and to field test the program with two vehicles. The program was subsequently field tested in Knoxville in cooperation with the Knox County Association for Retarded Citizens. The association agreed to contract for one vehicle. After successful efforts to execute contracts with these two agencies, program information was sent to similar organizations throughout the state by a mailing conducted by the Tennessee Initiative on Employment (TIE) and Department of Mental Health and

Mental Retardation. Many requests for further information about the program have been received; in response to these requests, general program information and sample purchase contracts were sent to these agencies.

Participation in the statewide vehicle purchase program has been substantial. Agencies that have procured vans to transport clients in their supported employment programs include the Douglas Cooperative; Knox County Association for Retarded Citizens; Comcare, Inc.; Greene County Skills; Emory Valley Center; Regional Education and Community Health Services, Inc.; Rhea of Sunshine; Franklin County Adult Activity Center; Lakeway Center; Gateway House, Inc.; Progress, Inc.; and Volunteer Blind Industries. Interest in the program continues, and a waiting list is being kept to assign vehicles to agencies when more vans become available. The substantial growth in the number of vans already procured and the demand for additional vehicles by agencies under the Tennessee Vans Vehicle Purchase Program was unexpected. However, this occurrence is a solid indicator that the program is a tangible benefit that is filling a mobility gap for agency-provided transportation services.

Application of PASS Program To Finance Transportation Costs

Plans for Achieving Self-Support (PASS) is a concept that enables individuals who receive Social Security disability benefits to develop a written plan for their future. Employees with disabilities who qualify for supplemental security income (SSI) may develop a PASS to set aside income or other resources to be used to achieve a specific, individualized vocational goal. A PASS can be established for education, vocational training, business startup, or job coach and job support services that enable a person to work. The purpose of a PASS is to increase an individual's capacity to produce income, thus reducing the reliance on government support in the long run. PASS makes it financially feasible for employees with disabilities to set aside or save income or resources to be used in achieving their goal by enabling them to become eligible for SSI, to continue to be eligible, or to receive higher SSI payments as they work toward self-support.

Anyone who is currently receiving or applying for SSI or Social Security disability insurance, has a disability, and does not have the capability for self-support may develop a PASS. Given these criteria, people who could develop a PASS include public school students participating in transition programs, persons receiving rehabilitation services from state or private rehabilitation agencies, and persons with disabilities who are participating in vocational or educational training programs. Persons with disabilities who otherwise would not have access to training or vocational programs can also develop their own PASSs to fund their own programs. Individuals must decide what occupational goal is going to be pursued and how. Then, the individual may choose anyone to help develop a PASS (i.e., parents, vocational counselors, job coaches, social workers, teachers, and employers), or the individual can write it alone.

The income or resources used to pay for goods and services under a PASS are counted in determining a person's eligibility for SSI or in calculating the amount of the SSI benefit that a person will receive. As stated earlier, for individuals to qualify for SSI, they must have limited income and resources enabling them to pass the SSI income and resource test. If their income and resources are too high, they will not qualify for SSI benefits. However, by excluding this income or resources in a PASS, the individual would then meet the income and resources test, thus qualifying for SSI. Likewise, an individual who already receives SSI can maintain that SSI in the same amount or even receive a larger SSI benefit by setting aside income or resources in a PASS.

The use of the PASS appears to be a viable option for some to finance transportation services. In June 1992, TIE project staff conducted a telephone survey to determine how PASSs were being used in Tennessee. The respondents for the survey were identified via the TIE Supported Employment Consumer Tracking System. The system enabled staff to select consumers for whom PASSs had been developed.

Local Social Security Administration offices were asked for information on PASS approvals; it was found that Social Security approved 19 PASSs for transportation services. PASSs were written to set aside money for various items that would allow the consumer to go to work. These items included payments for cars, car insurance, drivers, agency-provided transportation, taxis, mopeds, carpooling, car mileage, driver education, and bus passes. One PASS was approved to pay for carpooling expenses for transportation to work while the consumer participated in driver education and set aside savings to buy a car. Once the car was obtained, the consumer would use the PASS for car payments, insurance, mileage, and shoes to wear to work. Four PASSs were under review and had not received approval at the time of the survey.

The transportation services provided through the PASS have had a positive impact on the quality of life of consumers. Overall, the respondents indicated that the consumers acquired more independence and work opportunities. The PASS program enabled consumers to go to work and depend less on the family or a public agency for transportation. It provided the capability to replace and repair unreliable cars. For some, the PASS allowed individuals to go out on weekends by using the bus pass system and purchasing taxi services when no other transportation was available. Without the PASS program, long-term job security for some of the individuals would have been in jeopardy.

CONCLUSIONS AND FUTURE ACTIVITIES

The overall intent of the project described in this paper was to initiate a process for developing alternative transportation service options that would assist persons with disabilities to overcome barriers that limit access to employment opportunities and inhibit participation in the economic growth of Tennessee. Specific transportation service options were selected, and service demonstration and financing plans for implementing and field testing selected transportation services were developed. This objective is still being pursued; several projects have been selected for development. The projects are a mixture of group transportation options (e.g., Sevier County Commuter Van) and personal mobility options (e.g., driver education). This mixture was developed in response to study findings that indicated that workers with disabilities preferred options that promoted independence rather than dependence on public transportation. The major impediment to this goal has been the difficulty in locating funding for the projects. TDOT has been most responsive to the development of group transportation options, such as the Tennessee Vans Vehicle Purchase Program and the Sevier County Commuter Van. Funding "streams" for the personal mobility options, such as the Transportation Loan Guarantee Program, are not readily identifiable. In addition, the general economic environment has made it difficult to secure resources. However, the project staff will continue to submit proposals to selected funding agencies that express interest in the projects.

The overall project has actually developed beyond its original intent. The project staff envisioned the design of an optimal service that would meet the needs of all workers with disabilities. The primary goal was to develop a model centralized system that could be tailored to fit all mobility needs. As the result of project activities that created a dialogue with the consumers and agencies responsible for job training and placement, it was discovered that a centralized service concept would not meet all needs. There was a desire for diversified group and personal mobility options. Therefore, the project staff pursued a variety of decentralized services and developed a mixture of group and personal mobility options. It is hoped that these options can be financed, implemented, and evaluated to assess the benefits of this approach.

The project staff will continue to focus on developing transportation services at selected demonstration sites in local areas. The growth in the number of vans procured by agencies under the Tennessee Vans Vehicle Purchase Program is encouraging and indicates that the program is filling a mobility gap for agency-provided transportation services. The development of specific project proposals by the project staff and local teams is also encouraging. The project staff will continue to prepare and follow up requests for financial assistance to implement the projects.

The project staff will also continue to pursue the development of mobility options for workers with disabilities. Several proposals have been submitted for funding and will be conducted when funds are allocated. The Tennessee Vans Vehicle Purchase Program will continue, and vans will be made available as capital recovery funds are collected and additional capital grants are received. Although group transportation options will be developed, attention will be directed toward personal mobility options—which are what workers with disabilities desire. The results of implementing various projects will be documented and disseminated to interested individuals, groups, and communities actively pursuing the development of mobility options for workers with disabilities.

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Accessible Passenger Transportation 10 Years On: A Fresh Approach to Policy

TREVOR MEADOWS AND HARRY WRIGHT

The International Year of the Disabled Person heightened the awareness of the need for people with reduced mobility to have access to the public transportation system, yet significant inroads have not been made into this underdeveloped sector of the market. There is clearly an enormous potential for creating a fully integrated public transportation network, but what little has been done has taken a simplistic approach to vehicle design rather than address systems design. A radical change in the philosophy behind public transportation is necessary if the quality of life for people with reduced mobility is to be maintained.

One of the key issues raised during the International Year of the Disabled Person (1981) was that of transportation. The possibility arose to study immobility and to translate the findings into action. A public transportation committee in Reading, Berkshire, England, became the first public transportation agency to sponsor an application to the Department of the Environment to fund an experimental service, called ReadiBus. The task was to discover how to provide cost-effectively for the need revealed by the research, as well as to validate or refute the research. The terms "disabled" and "elderly" proved inappropriate. Mobility problems extended well beyond people described as, or associated with, being disabled. More than 10 percent of the population was found to have what we called a mobility handicap. Under the terms of the experiment, the mobility handicap had to be directly or indirectly due to any physical, mental, or sensory impairment, permanent or temporary. Thus, although substantially wider than most approaches, it did not apply to everyone who considers himself or herself to be suffering from a lack of mobility. This restriction was necessary because of the conditions of the grant, the legislation under which the service operated, and resources that were limited in relation to projected need.

Much was learned during the first year of this experiment. The large and varied nature of the market was revealed, as were the nature of appropriate services, the complexity of the factors causing barriers to movement, the need for thoroughness and attention to detail if every aspect of service design was to be optimized, and the management style and environment that involved all employees in research and development. A large team designed and developed the experiment: people from the University of Reading, consultancies, the U.K. Transport and Road Research Laboratory, the Transport Policy Review Unit of the U.K. Department of Transport, and the staff of ReadiBus. Keen interest was shown by Peter Baldwin, the permanent secretary at the Department of Transport, and by Lynda Chalker, then the minister responsible for public transportation.

The result was an enormous amount of information that could be used anywhere and relate to any mode. The information from research and operation clearly showed that the need was for short trips of a dispersed nature for individuals, low cost (lower than the cost of provision), and the image of a public transportation service. Approximately 90 percent of users would be over retirement age (50 percent were older than 75), and the main purposes of travel would be for leisure, recreation, visits to friends, and shopping (approximately 20 percent per category). This profile could be changed easily by insensitive and inappropriate design.

In 1982 the U.K. Department of Transport set up a National Advisory Unit to disseminate the information on accessible services and other types of community-based transportation. What has happened since then?

TWO APPROACHES

Since 1981 two approaches have developed, each having the same objective: transportation for all who need it. The approaches are, however, radically different.

Approach 1: Transportation for Disabled and Elderly

We believe that the first approach, transportation for the disabled and elderly, sets no realistic objectives and shows a poor appreciation of the market that it is to serve. For various reasons, it results in a concentration of issues of physical access for people in wheelchairs. The approach appears to be ad hoc, addressing any issue related to the movement of the disabled and elderly. It focuses on the symptoms rather than the causes of immobility, and it has no effective measures of progress. Approach 1 has sent the wrong message to the transportation industry.

Approach 2: Development of Accessible Public Transportation System

Approach 2—developing an accessible public transportation system—depends on understanding the individual. Which personal, environmental, and trip-related factors are barriers to movement and cause a mobility handicap? Why are the prevailing passenger transportation planning techniques fail-

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ing to eliminate these barriers? Why is there no intersectoral appraisal of the role of public transportation?

The second approach identifies people's patterns of movement (once the people are mobilized) and sets out a service design and development approach that will eventually reach all people with a mobility handicap and develop a public transportation system that is appropriate to the changing needs of a changing society.

Approach 2 has been developed empirically, notably in the West Midlands; it shows how development should occur in a gradual and progressive way. However, Approach 1 is comparatively simple and is therefore more attractive to those who underrate this area of work. There is increasing dissatisfaction with Approach 1 and frustration with its lack of progress. Approach 1, although it aims at the whole market, tends to concentrate on a small part of latent demand, and to do so ineffectively. The hopes of this approach center on the introduction of accessible buses (perhaps with low floors) on existing mainline routes. We believe that most latent demand will be catered for in this way. However, there is no hard evidence to support this hope or to show that it is true. Approach 2 is aimed at the whole market via a staged business planning approach—that is, a 20-year strategy against an overall objective within which is based a 3-year rolling tactical objective; the tactical objective is geared to the current availability of resources and current knowledge, and it seeks to gain and use knowledge to compete for additional resources.

The prevalence of Approach 1 represents the triumph of hope over experience.

INFORMATION

Information on the market is still comparatively new. Knowledge, skills, and experience are still rare. Hence, there are many pitfalls to be avoided when acquiring and interpreting data.

After 10 years, there is a great deal of operational information from many initiatives. A common trap is that of simply summarizing operational data and using the results normatively. So, if a service shows that x percent of people are women and y percent are men, it might be considered representative. If s percent of journeys are for shopping and y percent for social visits, it is interpreted as the norm.

There is little awareness that service design acts as a filter on the population. Operators and planners with limited knowledge of the market produce services that may appeal to a small proportion of people with reduced mobility (PRM)—and, even for them, the services meet only a few journey purposes. Very few services have had the skill, knowledge, and opportunities to optimize every aspect of service design and produce operating data that truly reflect the nature of latent demand. Even these services have been degraded over time, through staff changes or changes in local authority personnel (so that knowledge is not passed to the new players) or through limited resources and pressure to concentrate only on the type of demand that maximizes the number of trips made. Hence, using operational data is a mine field for the unwary.

We are not saying that the data produced by Approach 2 are perfect; we will always have more to learn. But the second approach developed unique skills and knowledge. The impetus was on turning research into practice.

When people have not been schooled in Approach 2 but operate from Approach 1, misinterpretation of information is common—and misinterpretation leads to bad policy. When things go wrong, it is often because false assumptions have been made somewhere along the line. Approach 1 does not put its work into context and allow one to see what is not being done. It is assumed that the data produced are representative and that the average view reveals the norm; the norm equates with what should be done.

In any new area, development does not advance uniformly. Usually some people demonstrate greater ability than others to grasp the fundamental nature of the issue and turn it into good practice. Policy makers should identify these "top 2 percent," the people with the knowledge and ability for development. If the average is taken rather than the best, the tendency is to level down. Policy should not be based on bad practice.

If the average always represents something less than the best that can be achieved, then in reviewing the performance of the average we should not come to conclusions about the potential for different types of service. The average performance of paratransit systems in the United Kingdom leads many people to believe such services are inefficient, expensive, or intended for the severely disabled. What should be done is to look closely at what the top 2 percent can do with paratransit and see the potential role of paratransit rather than its existing (average) role or even its worst cases.

Hence, by lacking vision or the potential knowledge required to turn paratransit into a cost-effective multimodal operating system, many have pigeonholed it as a special service. We then begin with categorizations, which themselves impede progress. That is, we have "mainstream" public transportation (routed systems creaming off volume flows in big buses, and continuing to decline) and special services. We have described elsewhere this approach as part of a precategorization approach (i.e., one reaches the conclusions before one even begins). It is an output of Approach 1. We believe that policy should be more neutral and encourage developments that reveal the relevant role of services and the nature of the market; then categorizations may be made more accurately (postcategorization).

CONSULTATION

To be effective, consultation must be proactive. People must know what they are looking for; they must test volunteered information to see whether it is sensible, representative, and practicable. There must be ways of penetrating this "silent majority." In the United Kingdom the people with the most comprehensive knowledge are

- Too busy with operational responsibilities or welfare support to come forward.
- Unsure about whom to brief with what they know. Some who have tried are disillusioned by what has been understood or made of their efforts.
- Devalued, because quite often in this area those with the knowledge do not come from a conventional career but have

progressed through unconventional means. They may have no formal academic or professional qualifications.

- Not necessarily good at writing reports or communicating what they know to policy makers. They need help through regular debriefing by those who can formalize what they know. They may be substantively excellent, but their work is dismissed simply because they lack writing and presentation skills, which are not prime requirements in their day-to-day activities.

Proactive consultation means getting out in the field and contacting friends, relatives, and carers of PRM; social workers; and other welfare officers who treat the symptoms of immobility. It also means being accepted by people on their terms so that they are relaxed and get to know you. There is an overreliance on conventional surveys, which at best summarize what experienced operators already know.

Consultation should represent a thirst for information, an ability to draw information out of people, a talent for listening. It is a never-ending task: the policy maker's ear should never be turned away.

LEADERSHIP

People have different abilities. One key ability in an area of work as large and as challenging as this is leadership. The ability to assemble the requisite knowledge and skill is important for a leader, but especially so is the vision that inspires leaders to chase the ultimate objective. Leaders have a vital role in motivating others, pulling people forward, asking the next awkward question, questioning what has been done and achieved, and destroying complacency. Such a role, although thankless and exhausting, is indispensable to progress.

Leaders themselves, however, need support to prevent burnout, disillusionment, and demotivation. Policy makers should identify such people and spend time with them, making it clear that they must say what they need to say and that saying merely what people want to hear is not their function. It is difficult to give this reassurance. Often the policy maker at the regional or national level is paying, either directly or indirectly, the wages of people with leadership abilities. The policy maker should be aware that the natural assumption, particularly where the developers are finding flaws in the current policies, is that censorship is implicit in patronage—that it is too easy to not speak the truth for fear that the patronage will cease. When this happens, the policy makers are starved of what may be their most vital input: constructive criticism.

OVERVIEW

To get policy right, it is essential that the people at the top take a holistic view of the area. In transportation this is especially difficult because the product is an intermediary good and its impact extends across the spectrum of modern economic and social life. Certainly it would be good to have many people, at all levels of involvement, who can take the holistic view and see where what they do fits with what others do. However, because of an education system that segregates information and creates single-discipline hierarchies, it is difficult to find enough people with eclectic skills to occupy even the top positions.

COMPLICATED INFORMATION

Is the approach to this area getting too complicated? There are large differences in the demands for information. At the policy level, general statements may be adequate if they are based on a sound synthesis and can be trusted. At the academic level, sufficient information is needed to allow certain types of statistical or mathematical analysis and to allow correlation to be tested and the researchers to say something interesting. The output does not have to be true, and the interpretation may still not be sensible.

At the level of service operation, very detailed information is needed about all aspects of PRM, and all the factors that may be barriers to movement must be understood. It is the operator's job to mobilize all people in need, so they build up awareness—of how to eliminate barriers by design, of who finds their service easy to use, of who still has difficulties, and so on.

This detailed knowledge is necessary to build up detailed specifications for premises, work practices, information design, computer systems, vehicles, and so forth. If the senior staff involved in operations (managers and planners) do not have this detailed understanding, they will lose credibility in the eyes of the rest of the staff and the customers.

Policy makers should realize that operators have this detailed knowledge and work with them to assess progress and the direction that development should take. In reality (in the United Kingdom), this would require senior civil servants to work closely with people from voluntary organizations. Attention to detail and a thorough knowledge of the market are parallel requirements for anyone launching a commercially viable product. Bank managers will not fund commercial enterprises based solely on meritable principles, rights, and hope. They require the display of detailed and well-researched facts and a precise knowledge of the market.

SUPPLY SIDE

Over the past 15 to 20 years almost every part of developed economies has seen product diversification. Separate market niches have been identified and provided for in products ranging from stereos to clothes, foodstuffs to vacations. The motive has been to sell and make a profit. However, as mentioned, the same market analysis methods, product diversification techniques, and marketing and management systems apply to services requiring subsidies. The methods ensure that all segments of the market are identified, that the product of passenger transportation is diversified to cater for different types of need, and that potential consumers get to know about the product, which is delivered efficiently. The knowledge of the market also identifies the role of the product and accumulates information about users to show how mobility can change their lifestyles and give them autonomy. Such information is needed to justify subsidies and prove that value is being obtained.

The commercial sector attracts capable people by offering job interest, financial reward, and occasionally some security.

In the noncommercial field the work environment must be right to attract, encourage, and retain visionaries capable of transformational management. What is the "right environment" for sustained development? Is any policy maker examining this factor?

The supply side must be proactive. Its job must be to identify what is not being done and then argue that it should be done. There is a tendency to accept the resources that one has and to reconfigure supply to provide a little more for some of the people that are already mobilized. Any improvement in service delivery within existing resources is a marginal addition to supply compared with the vast market of people with unmet needs that remains. Such rationalization can destroy the development impetus, demotivate operating staff, and result in a position that loses some users, ceases market penetration, puts the operator on the defensive, and begins the downward spiral of decay. Nothing stands still. Advances are made only through great effort, and ground already won can be easily lost. As Napoleon said, "He who stays within his own defenses will lose the campaign."

COMMUNICATION

If the transformationalists can be given their head, then what they find in practice must be communicated to policy makers. They must thirst for the constant challenge of breaking new ground, making progress, and identifying the next questions to answer, but they must also play a role in passing on and demonstrating their findings. The skills and working practice they have developed must be passed on to others, the majority of whom will be transactionalists—that is, those whose skill it is to continue what has already been developed, who can put an operation into effect in another area and make sure that all is managed well on a day-to-day basis. Transactionalists must be able to implement specifications developed, tried, and tested by the transformationalists, but there must be dialogue between the two. Transactionalists can identify problems; they recognize where there is ignorance and where new questions should be asked.

No value judgments should be made about the two roles—one is neither superior nor inferior to the other; managers have different aptitudes, abilities, and interests. Relatively few transformationalists are needed, and their work needs coordination. Very many transactionalists are needed, however, to make sure that the buses get out there and the job is done, that the development effort is put into effect and not wasted.

TEAMWORK

There is a pressing need to bring together a "critical mass" of people who have the knowledge needed to tackle this work. It is critical in that the individuals are isolated (nothing brings them together) and are worn down by trying to make progress in an unreceptive and unsupportive environment. They are becoming disillusioned and in some cases taking their skills away from this area of work. A critical mass is large enough to support its members and contains expertise from all the disparate areas of knowledge: economics, sociology, psychology, systems design, mechanical engineering, management, policy development, education and training, and so on. It is large enough to have influence and to create momentum.

If transportation is seen as interdisciplinary, then boundaries between local departments of authority and between subject areas in education need to be broken down. Perhaps central government should take the first step by creating the first interdisciplinary team to attack the problem and show that cooperation can be effective.

We must not grind down those with vision; we must recognize what they can offer and support and encourage them.

A BUSINESS PLAN

Strategic Objective

Clear long-run practical objectives should be evaluated. Is the long-run objective simply to make existing systems physically accessible? Should people in certain income groups be the focus of attention? Should delivery cater primarily to a limited range of journey purposes? Or should we be aiming for mobility for all who need it? If so, what level of mobility? If the emphasis is on ensuring people access to facilities and activities, should nontransportation solutions be priority ranked so that the problems of congestion and pollution are not compounded? Many complex issues are to be addressed before clear guidelines for long-term goals can be set. When the strategic objective is sorted out, it is a constant point of reference for tactical objectives.

Tactical Objectives

Tactical objectives concentrate on what we do *this* year. However, they must be set in relation to the strategic objective so that they are consistent with it and allow development toward it. Of course, it should be recognized that the strategic objective will never be reached; it is a moving target. Social, environmental, and economic conditions are changing all the time, so the strategic objective that may take 20 years to attain should not be rigid; it should be reevaluated as time goes by.

One form of tactical objectives may be to allow as many people as possible to live independently within existing resources; that is, to accent service development. There may be a requirement that services should be provided on an equity basis or to categories of people who are given preference.

Monitoring

Monitoring should be regarded as devising a simple system of gathering information about the operation as it develops. Ideally it should be an automatic process (i.e., it should involve no work practices beyond those needed to operate the service safely and efficiently).

Evaluation

The effectiveness of the operations should be questioned. The first step of evaluation is to make sure that the right questions are being asked. It is not uncommon in research to ask either shotgun questions (every question one can think of) or random questions (questions that are interesting but that have no specific objective). The questions must be probing and must refer to the strategic objective.

Evaluation should be analytic, not descriptive; it is of limited interest to know the number of people who are wheelchair users, who go shopping, who are under retirement age, who travel certain distances, and so on. What must be asked is, Why are we getting these results? Are they as expected for the area of operation, or are they somehow strange? If so, why? Has the design gone wrong, or has the implementation gone wrong?

A vital part of evaluation is to identify who still needs to be mobilized: this includes other types of service provision and their specifications and costs.

Monitoring and evaluation are extremely good in some places and extremely crude in others. The average situation is an ignorance of the basic questions to be asked. Above all, evaluation should be honest and relevant, that is, in human terms, not simply an inventory of accessible vehicles.

SYSTEMS APPROACH

Wherever discussion begins in transportation, it tends to lead toward a concentration on technical issues and mechanical or civil engineering. Developing a transportation system is not purely or primarily an engineering task; it is a systems problem. No element of design should be looked at alone. For example, one reason that accessible services are underused is a lack of publicity. Better publicity can usually increase the use of a service. However, there is usually great consistency between the different aspects of design. People who have a great understanding of the market can design a service that is appropriate and for which there is great demand. Because of the thoroughness of their knowledge, they also know how to market the product.

Conversely, where understanding is poor, design, delivery, and marketing of the service are poor, although better marketing does little to improve the service design and delivery or make the service more appropriate. Policy makers who take a holistic view soon become aware of this consistency attribute.

EFFECTING A CULTURE CHANGE

The changes needed to enable PRM to live independently are major. Over the past 10 years the issue has been marginalized through inappropriate terminology and a concentration on physical modifications rather than on the nature of barriers to travel, the reasons for travel, and the destinations of travel. There is an urgent need to bring the issue of reduced mobility from the margins of passenger transportation planning and make it the focus of the discipline. The passenger transportation industry should be about understanding current and potential passengers, not about technology. Several key changes are needed for policy to progress constructively.

After 10 years, we need to return to basics and find a conceptually sound starting point that is based on people and their needs. Two basic elements should be recognized: barriers to movement and the patterns of movement once the barriers are removed. Subsequently, cost-effective delivery of service needs organizing on the basis of logistics.

A major (and ongoing) debate should take place concerning the role of public transportation. Once the role is identified, the nature can be defined.

Transportation should always be thought of as an intermediary good. This principle is often taught in transportation courses but usually only in the introduction. It is not emphasized and is often forgotten. Gaining access to an activity is the objective, and transportation is the bridge between people and activities. It should be remembered that (in the United Kingdom at least) this bridge is that of walking for 40 percent of journeys made by mobile people.

Evaluation of progress should be not an inventory of engineering feats, but an assessment of the impact of new initiatives on people. It should be honest, not a public relations exercise, and should seek to identify the people using services and the people who are still immobile.

Unambiguous terminology should be developed and used. It should be determined not by policy makers and politicians but by those with functional responsibility who have shown a capability to address the whole problem of reduced mobility. If one takes definitions from those addressing only part of the problem, the terminology will not fit the entire market. Hence, when politicians and policy makers use limited terminology, they are spreading the results of bad practice and limited experience; they are discredited in the eyes of, and demoralize, the top 2 percent.

Solving the problem of reduced mobility will take great financial support. The issue needs to find allied causes so that a stronger case can be made to prove the worth of the expenditure. The most promising allied causes now are those evaluating the effects of traffic congestion and vehicle exhaust emissions. Each of these issues points toward the need for a common solution: a diversified and flexible public transportation system.

Services should be encouraged that help to reveal the nature of demand. Demand should not be determined by a supply provided through unsubstantiated opinion instead of an analysis of the needs of people, or the outcome will be that a few people gain mobility and the needs of most will go unmet.

Developments—whether of policy, finance, legislation, technological, systems design, or other—should be put in context. A holistic view is needed, and progress must be balanced and take place on all fronts. Policy makers must seek out those with knowledge based on experience and spend time listening and digesting what is said.

To achieve changes in service delivery there must be changes in

- Management style and environment,
- Organizational structure, and
- Legislative structure and environment.

Because of the scale of demand and the scale of the task of providing for all of this demand, a strategic perspective is necessary.

There have been many welcome developments in the built environment and in bus design, but as Ann Frye, of the U.K. Department of Transport, summarized at the 6th World Conference for the Mobility and Transportation of Elderly and Disabled Persons, held in Lyon, France, "Whether we have also succeeded in giving people the confidence and the means to travel, by whatever mode is most appropriate, remains to be seen."

Implementation of Service Routes in the United States

JAMES J. MCLARY, AGNETA STAHL, AND SHARON PERSICH

The passage of the Americans with Disabilities Act of 1990 (ADA) signified a new era of mobility for elderly and disabled passengers. There have been many debates about fixed-route versus door-to-door demand-responsive services. While the United States has been discussing the issue, Sweden has been experimenting since 1983 with a concept called service routes. Madison Metro (in Wisconsin) is very close (April 1992) to implementing the first two service routes in the United States. The planning activities leading up to implementation and, subject to availability, preliminary results are discussed. The service-route concept and the unique planning consideration necessary to design successful routes is reviewed, as are the process used in defining desirable origins and destinations, the public participation process, the development of alternatives, the refinement of alternatives, and the selection of routing details. In addition, the discussion will include detailing of operating guidelines (i.e., driver selection/training and fares), the integration with other Metro service including Metro+Plus, the estimation of demand, the development of costs and revenues, and finally the establishment of a monitoring and evaluation plan. This concept when applied to small cities or selected small communities within a larger urban area has the potential to satisfy ADA requirements with a small capital investment and potentially lower operating costs. The addition of minivans with low floors and ramps could provide the door-to-door service needed by a minority of users. Most important, this design can provide significantly better mobility and flexibility for the transportation-disadvantaged residents of our communities.

The Swedish government has adopted goals and policies that enable elderly and persons with disabilities to live in their home environment. These policies initially created a separate transportation system for the elderly and persons with disabilities. During the late 1970s this thinking changed, and today's Swedish policy can be summarized in two words: integration and normalization.

The United States government has followed somewhat the same path as far as transportation is required. The passage of the Americans with Disabilities Act of 1990 (ADA) has required that most services and facilities—including transportation—be accessible to persons with disabilities. All transportation systems must be fully accessible, and complementary paratransit services must be provided.

The general manager of Madison Metro in Madison, Wisconsin, saw a presentation by Agneta Stahl, who originated the service-route design, on the Swedish Service Routes and thought that such a service could improve mobility and control some of the escalating costs of Metro+Plus, a service for the elderly and disabled. This paper discusses the concept, the first design effort, and the results of the Madison implementation.

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SWEDISH SERVICE ROUTES

Sweden's goals emerged during the 1970s and 1980s in national discussions about the situation of persons with disabilities. Extensive research and development efforts were also made to arrive at practical solutions to facilitate travel for people with disabilities. Sweden, like most other countries in the Western world, offered special transportation services (STSs) as an initial approach to solving the transportation problems of persons with disabilities. STSs were introduced in Sweden at the end of the 1960s. Initially, STSs were conducted on a volunteer basis, but municipalities gradually assumed responsibility for providing them. The concept spread rapidly during the 1970s, and since 1979 all Swedish municipalities have offered STSs. In 1974 parliament decided to introduce national subsidization, which today reimburses a maximum of 35 percent of a municipality's total costs.

The purpose of STS is to make transportation available to people who have difficulties using conventional public transit. Thus, at the outset Swedish policy created a separate transportation system for the elderly and persons with disabilities. During the late 1970s, however, this thinking changed. Today the goal of the Swedish policy can be summarized in two words: integration and normalization.

On the basis of experience gained from research into public transportation as well as from various local initiatives during the past decade, a new philosophy has been developed in Sweden for providing overall public transportation in urban areas. Today transit authorities believe that public transportation must be adapted to the market. Applying this concept means that the bus company cannot offer the same route network to all consumer groups. Different groups make such different demands on public transportation that a differentiation of the route is necessary. The transportation service must be adapted to each individual community, with specific attention paid to a passenger's physical limitations, origin and destination, and required care and attention.

This recognition resulted in, among other things, the development of service-route traffic. The service-route network places priority on bringing bus service as close as possible to the residents, whereas the conventional basic-route network is usually constructed in the form of straight radical lines that quickly connect different residential areas with downtown centers. This means that the service routes wind through different residential areas, so the same distance to the bus stop (and hence the bus) is rather short. In addition, the bus drives to the entrance of service centers and various health facilities. Thus, service routes become an attractive means of transportation for people with various disabilities and constitute an important part of a differentiated, and community-responsive, public transportation route network.

As far as the elderly and persons with disabilities, the developments during the past decade have produced a Swedish policy that assumes that no community can be fully served with a single transportation mode. Two important assertions can be made. First, some people are so seriously handicapped that they require special services. Second, people with less serious disabilities can travel by public transportation if equipment and facilities are adapted to their needs.

Therefore, Swedish policy today also recognizes that adapting the existing 40-ft buses with lifts and other facilities is not the best and only solution for all persons with disabilities. The difficulties encountered by people with a mobility handicap vary so much that different solutions are necessary: it is not enough to adapt the public transportation system solely by making technical improvements in vehicles. Easing the problems faced by people with mobility handicaps requires being aware of what it means to grow older or suffer disabilities, difficulties that create the need for a little extra time for coping with the system. In other words, besides technical improvements, better service is needed. It is also important to consider all the problems that one might encounter along the entire route when using public transportation: on the way to and from and at the bus stop, boarding and alighting from the vehicle, and during the ride.

Such recognition has resulted in a new design, a community-responsive public transportation for urban areas, in which specific attention is paid to the needs of the elderly and persons with disabilities; it consists of the following:

1. Traditional fixed-route service: The service, using standard 40-ft buses designed according to Swedish law, supports the needs of mass transportation for people with little or no mobility limitation. To facilitate getting on and off, these vehicles, under Swedish law, are relatively accessible if some service-oriented measures are introduced.
2. Service routes: A regular transportation system is operated with smaller 20- to 26-ft buses fully accessible with a low floor of 12 to 14 in. This system serves mainly the elderly and persons with disabilities who cannot cope with public transportation involving large vehicles, long distances to the bus stop, and the stresses encountered during the trip. These people either do not use public transportation or can use it only with great difficulty.
3. Special transportation services: STSs will be available for people who are so seriously handicapped that they require door-to-door transportation services and more personal assistance. This service is operated with taxis or vans (low-floor vehicles) fully accessible to wheelchair passengers.

A community-responsive public transportation system means that each system can better meet the varying needs of individuals with impaired physical strength or mental capacity. It also makes it possible for people to be integrated in the public transportation system to a larger extent and to a greater age. This paper describes the Swedish service-route concept as it is being introduced in the United States.

SERVICE-ROUTE TRAFFIC

The second level of the community-responsive public transportation system implies an introduction of new regular public transportation network: service routes. It should be pointed out that service-route traffic is one regular route network among others in a market-adapted public transportation system and thus is not a separate STS wherein one must meet eligibility requirements and prebook trips.

The service-route concept appeared in 1983 when the Boras Transportation Company introduced a public transportation called service routes. Planning a service-route network requires particular care because it should bring the buses near the residents.

The service routes usually operate from 8:00 or 9:00 a.m. to 6:00 or 7:00 p.m. daily. There is hourly service on weekdays, which is often reduced to one departure every hour on Sundays. The planning of a service route must include route layout, operating times, trip intervals, vehicles, and service to meet the conditions and needs of the elderly and persons with disabilities. The following is a brief characterization and description of important parts of service-route traffic:

- Service-route traffic implies a compatible public transportation system that fulfills the requirement of integrating and accommodating the elderly and persons with disabilities. Service-route traffic is available to all presumptive bus passengers and is accessible to all people with functional impairments.
- Service-route traffic is a regular transportation system with fixed trip intervals. It is a flexible transportation system wherein one does not need to plan or book a trip in advance. The timetables are adjusted to allow the traveler the time required for boarding and alighting, finding a seat, and so forth.
- Service-route traffic uses a route layout that assigns particular consideration to the locations of the homes of elderly and disabled persons and of important destinations such as care centers, clinics, hospitals, and shops.
- Service-route traffic features easy-access bus stops. Buses stop at the entrances to hospitals and care centers. The distance to bus stops in residential areas is minimized. One may even hail the bus outside one's door.
- Service-route traffic uses thoroughfares that other traffic does not serve, such as pedestrian malls, broad bicycle paths, and even market squares.
- Service-route traffic incorporates small and fully accessible vehicles with a capacity of about 20 seated passengers. The vehicle must be a low-floor bus without any height deviations inside, such as steps or platforms. The bus must also be able to kneel down to 8 or 9 in. and have a ramp (not a lift) to accommodate wheelchair passengers. According to evaluations and tests on various bus types, the Orion II basically fulfills such requirements and is also the vehicle most used for this traffic in Sweden.

Experiences from service-route transit in Sweden indicate that service routes can be introduced to complement regular traffic and to provide an opportunity for many more people to use public transportation. Service-route traffic thus creates conditions that generally improve the public transportation network for all inhabitants. By late 1991 more than 50 cities in Sweden had introduced service-route traffic.

The achievements of service-route traffic have also been recognized internationally and, by late 1991, implemented in other European countries (Denmark, Finland, Norway, and Holland) and in Canada (Toronto, Oakville, Welland, and Calgary).

For the transportation company, new customers start to use public transportation, and the number of passengers increases continuously. During a 2- to 3-year period the number of travelers on a service route usually more than doubles.

In Boras, where service-route traffic was introduced 7 years ago, the number of passengers per vehicle hour has increased from about 8 during the introduction period to more than 22 in 1991 (the average of the 10 routes covering the whole city). The service routes operate from about 8:00 a.m. to 5:00–7:00 p.m.

Service-route traffic has turned out to be a cost-effective form of public transportation in Sweden: general cost-recovery for traditional mainstream public transit service is between 45 and 50 percent. The rest is paid with tax money from the municipality and the county (each normally pays half of the required subsidy). Again, figures from Boras show that the cost-recovery for service-route traffic is 60 to 65 percent. The main reason is the high number of travelers per hour on the service routes, a number that increases over time.

On the regular fixed-route service, the large average number of passengers per mile traveled is 2.9 to 3.1, compared with 3.8 to 4.0 passengers per mile for the service-route traffic. So in Boras, service-route traffic appears to be about 25 percent more cost-efficient than the regular fixed-route service.

For the municipality and government, the establishment of a service route in an area substantially reduces dependence on STS; it also reduces the costs for this special service by up to 40 percent. The experiences from service-route traffic are positive in most places where it has been introduced. Service routes are now operating in cities of different sizes in Sweden. In Boras (population 85,000), where the whole city now is covered by service routes, 25 percent of the passengers are registered to use STS. In Stockholm—Sweden's largest city (population 1.2 million)—two service routes have been running for 2 years and six others have been introduced. On one of the Stockholm routes, 50 percent of the passengers are registered to use STS; on the other, more than 30 percent.

Service-route traffic is a profitable form of public transportation—which is even more remarkable when considering that this system has also

- Increased travel opportunities and improved comfort not only for those entitled to STS, but even for others who find traveling difficult;
- Given people entitled to STS better transportation alternatives (by their own accounts) with greater freedom of choice than STS; and
- Contributed to increasing activity levels and breaking down the isolation of many elderly people.

The experiences from service routes clearly imply that the Swedish goals of integration and normalization in public transportation have become a reality for more people in the society and for the elderly up to a greater age than before.

MADISON SERVICE ROUTES

The development of service routes in Madison was based on the process used in Sweden. This market-oriented process required the team members to rethink some traditional transit planning procedures. In summary, the process included the following steps:

1. Identify and plot major origin and destination points,
2. Locate concentrations of elderly and disabled residents,
3. Analyze Metro+Plus and Group Access Service travel patterns,
4. Develop corridors of concentrations,
5. Develop design parameters (policies, service, and operation),
6. Conduct ridership estimates,
7. Develop cost estimates,
8. Refine alternatives, and
9. Develop implementation guidelines.

Many decisions were made as the process continued; as a group, these decisions are called design parameters. The discussion that follows includes primarily the decision process, not the manner in which the city arrived at it.

Operating Guidelines

Five operating guidelines were developed: form of service, vehicle stops, fare level, driver assistance, and eligibility. These guidelines were instrumental in designing the service.

1. Form of service: The form of service is primarily fixed route, although both routes enter parking lots and drives that full-sized fixed-route buses can not enter. Route deviation by calling ahead to the driver was not included.
2. Vehicle stops: Vehicles stop in designated areas where the density and congestion are high. Flag stops are permitted in low-density residential areas.
3. Fare level: The fare level was set as the same cost as a senior Metro fare, which is 50 percent of the full fare. If the passenger wants to transfer to a Metro route, full fare is required.
4. Driver assistance: The service is curb-to-curb, not door-to-door. This will vary by driver, location, and passenger, but the general policy is curb-to-curb.
5. Eligibility: Madison will require all Metro+Plus users that live on a service route and have designations on a service route to use the service and not be eligible for Metro+Plus.

Service Parameters

Two routes will operate Monday through Friday from 9:00 a.m. to 5:00 p.m. Round trip will be 30 route-mi with 60-min headways.

An important consideration in the design of the service routes was the integration with Metro/Metro+Plus service. The West service route was designed to coordinate with the planned Metro transfer centers. This facilitated a smooth transfer with fixed routes for when the Metro becomes fully accessible. No mainline routes were eliminated, but service planning for the new service might enable Metro to become more direct and less circuitous. It was also part of the design to reduce Metro+Plus trips and move some trips to service routes at a much lower cost.

Once all of the design issues were identified, demand and cost estimates were developed. Using Metro's cost-allocation model and a complete line-by-line budget analysis, the cost per trip was estimated to be between $3.70 and $7.40/passenger, depending on ridership. Because the service is fixed, the more riders, the lower the cost per trip. Metro+Plus costs approximately $12.00/trip.

The biggest issue that Madison Metro faced in implementing service routes was to redefine the role of the transit operator. The routes will be operated by the fixed-route transit operators of Madison Metro. This will be the first time that the fixed-route operators transport elderly and disabled passengers with mobility impairments. As a result, the operators who drive service routes will require extensive training. The labor union, the local affiliate of the International Brotherhood of Teamsters, will be a major participant in operator training and selection. Transit system management will develop the operational procedures, requirements, and work rules for the service routes, but the labor union must be extensively involved in determining which operators are best qualified to serve the targeted clientele.

Marketing is essential to the success of Madison's service-route project. Because this is a new routing concept, potential users must be taught how the route will operate and how to use it. There is a great difference between the service route and paratransit and fixed-route transit. Marketing efforts must remove passenger fears about the service. Most important, marketing efforts must recognize that the target user group generally has the greatest difficulty accepting and understanding change. This calls for clear, concise, and understandable marketing materials. Such efforts included using public meetings, distributing printed materials, offering fare incentives, and working with advocacy groups of the elderly and of persons with disabilities.

The last major implementation issue was the development of a monitoring system. The transit system must develop a mechanism to determine whether it is serving the needs of its target user groups. The system must develop a customer feedback system to measure whether users want more or less service, whether the service goes where the people want to go, whether the people understand the service, and whether the transit system is providing a high-quality service that is responsive to customer needs. From the perspective of the transit system, the monitoring system must measure the productivity and effectiveness of the service routes.

Above all, the transit system must be flexible in its approach to providing service routes. If information received from marketing and monitoring calls for change, the change should be made. To be successful, the routes must serve the needs of the elderly and persons with disabilities.

The ADA will require a major shift in Madison's approach to providing transportation to the elderly and persons with disabilities. Because capital and operating resources are strained, passenger use of accessible fixed-route transit must be maximized. The highly desirable Metro+Plus service will no longer be available in large quantity to a broad spectrum of elderly and disabled people because some paratransit resources will be used to provide accessible fixed-route service. Although the ADA addresses accessibility, it is silent on mobility. The city of Madison has always sought to provide the highest level of mobility for its residents. The ADA presents a dilemma in achieving this goal.

The service routes, however, give the city a way to bridge the gap between accessibility and mobility. The growing demand for paratransit service can be addressed with service routes while neighborhood circulators are provided for the first time. Through the use of service routes, the city can meet special transportation needs in a cost-effective and efficient manner. The first two routes are seen as the start of a complete service-route network.

The concept of improving mobility for the elderly and persons with disabilities should be foremost in the minds of transportation planners and operators. Unfortunately, many transportation providers serve single purposes (e.g., large transit authorities, human service agencies, and taxi companies) and miss the need for full-service integration. The need for full-service integration requires a vehicle mix, including small taxi-type accessible vehicles, and cooperation between all agencies. The ultimate goal of all transportation companies is to move people in an efficient and effective manner. It is imperative that all providers work to that end.

IMPLEMENTATION RESULTS

On April 20, 1992, Madison Metro implemented two service routes, the first of their kind to be implemented in the United States. Madison's interest in this new service concept has two aspects: to supply an alternative that provides a high degree of accessibility and mobility for persons no longer eligible for paratransit under ADA guidelines, and to shift as many paratransit trips as possible to service routes in order to increase operating efficiency.

Since the mid-1970s, Madison Metro has provided paratransit service to the elderly and persons with disabilities. Popularity of the service grew rapidly during the 1980s, but so did its cost. In recent years, ridership and cost growth have exceeded budgetary projections, causing concerns about how to continue meeting the travel needs of elderly and disabled persons while finding a more cost-effective means to do so. At the same time, the ADA was passed, mandating that accessible fixed-route transportation be the primary means of service for all individuals. Service routes, which combine the scheduling efficiency of fixed routes and enhanced accessibility features of paratransit, appeared to be one way to achieve lower service costs while bridging the gap between accessibility and mobility for the elderly and persons with disabilities.

Metro's service routes have been in operation for 6 months. Experience to date is that passengers who use the service do so frequently and are very pleased with the service. However, ridership potential is not being achieved, mainly because of service areas that are much smaller than the urban area and therefore do not encompass all destinations and travel patterns. This finding has implications for service-route design in American cities. Madison Metro is currently modifying the design to address this situation.

Operating Features

Route and Schedule Design

Madison Metro operates two service routes in areas of the city that have the greatest concentrations of residential complexes for the elderly and disabled, medical facilities, activity centers, and shopping centers. One of the areas is in the central city; the other is more decentralized and has been characterized as a naturally developing retirement neighborhood. The routes operate similarly to a circulator, connecting the major residential complexes with the primary destinations in the service area. The routes were not connected initially.

The operating characteristics of the routes are as follows:

- Length of Route 1: 7.5 mi;
- Length of Route 2: 7.75 mi;
- Average operating speed: 8.8 mph;
- Average stop time: variable (for planning purposes, an average stop time of 45 to 60 sec was used. Metro refined this method by incorporating factors estimating a stop's potential use rate, the likelihood of wheelchair loadings, and delay related to ease of access to a bus stop);
- Headways: 1 hr;
- Service hours: 8:30 a.m. to 4:30 p.m., Monday through Friday;
- Fare: $0.25 for seniors and persons with disabilities and $0.50 for adults and students. A transfer fee amounting to the difference between the service-route fare and fixed-route cash fare is charged; and
- Vehicles: Orion II buses (capacity for 22 ambulatory passengers and 3 wheelchairs).

In designing the service routes, several features have been particularly important:

- Picking up and dropping off passengers on the same side of the street. This means inbound and outbound route patterns will be different.
- Transporting passengers between origins and destinations in both directions. This is especially important for minor and major destinations; otherwise, trips lengths will be excessive.
- Operating headways at intervals of 30 or 60 min for schedule simplicity.

Bus Stop Policies

Door-to-door service is an important aspect of service routes, so one major design objective was that of maximizing the number of bus stops close to accessible building entrances. Because this would entail establishing bus stops on private property, easements were obtained from property owners. All property owners who were approached about being a bus stop location agreed to the on-site bus access despite concerns about already-congested drive aisles and parking areas. In some cases, owners were willing to discuss adapting the facility to improve the connection between buses and buildings. Bus stops on private property are identified by a decal placed in a window near the accessible entrance. In total, Metro's service routes have 82 bus stops, including 22 on-site stops. The average distance between stops is 0.36 mi.

Driver Selection and Training

Recognizing that driver interaction with passengers is a major part of service-route success, Madison Metro requires that drivers undergo special training on passenger assistance and customer relations. The training module includes instruction on appropriate terminology, communication guidelines, and instruction about symptoms associated with different disabilities and passenger assistance.

Integration with Mainline Service

Madison's service routes were implemented in areas of the city that have high levels of fixed-route service. Because of the potential for transfer, coordinating the schedules between service routes and fixed routes was one of the objectives recommended in the original plan. The plan also recommended possibly reducing fixed-route service where routes overlap with service routes. These objectives have not been realized, primarily because of service-level incompatibilities.

Schedule Coordination

Schedules between the service routes and fixed routes are not coordinated because the 1-hr headways on the service routes will not enable bidirectional coordination of transfers, especially with multiple lines converging at major timepoints. In many cases, transfers would have required crossing major streets.

Also, without mainline accessibility, the potential for transfers was deemed to be low. A recent on-board survey found that about 25 percent of existing riders are transferring to mainline routes. The most commonly cited reason for the majority who are not transferring are the steps onto fixed-route buses. Not explored as possible reasons were lack of schedule coordination, eligibility to use paratransit for trips beyond the service-route area, or barriers such as crossing streets.

Duplication of Service

Metro has not attempted to restructure fixed routes to either reduce the level of service or consolidate (or eliminate) mainlines in the service-route areas. The primary difficulty with restructuring fixed-route service to reduce duplication is related to the linear nature of Madison and the through-routing concept used by Metro. Routes begin at either end of the city and operate through the other end. Thus, reducing or eliminating service along fixed-route segments covered by service routes would force transferring and increase travel time for fixed-route passengers, a situation viewed as having a high potential for losing riders.

Six-Month Evaluation

After 6 months, ridership growth has been lower than expected, mainly because the service routes serve only a few destinations within the overall transit service area. Route design is being altered to improve this situation; the changes include connecting the routes and adding a shuttle service to destinations beyond the service areas of the routes.

Ridership Trends

Weekly ridership on the service routes since implementation on April 20, 1992, through September 11, 1992, has fluctuated within a range of 262 to 412 passengers. This compares to a "low" ridership projection of about 1,000 weekly trips. Average weekly ridership on Route 1 is 145; on Route 2 the average ridership is 181. Productivity per vehicle hour is 1.81 for Route 1 and 2.26 for Route 2. Paratransit productivity is about 2.1 passengers per hour.

Weekly Ridership

Weekly ridership for the same period is shown in the following table:

Ridership	*Route 1*	*Route 2*
High	201	245
Low	96	122
Average	145	181
Passengers per vehicle hour	1.81	2.26

One major reason for lower-than-anticipated growth is a low capture rate for potential riders and trips. Only a quarter of the paratransit riders who can use service routes do so, and then for only a small portion of total trip making. The most common reason that riders and nonriders cite for not using service routes is a lack of desired destination.

Another reason is that fixed-route riders, particularly the elderly, are not switching to service routes as initially predicted. Interviews with several elderly persons using the fixed routes found that they are continuing to use them because of greater convenience.

Trip Purposes

A survey of current riders found that trip purposes tend to be split equally between medical appointments and shopping (Figure 1). Driver observations, however, support a prevalence of shopping trips. Drivers have also observed that some passengers do not ride for specific trip purposes but often ride for the entire day, an indication of the social function that transit often provides.

Consumer Reactions

Figure 2 shows the results of passenger ratings for various aspects of service. Overall, passengers have rated the service highly, with 66 percent of those surveyed giving the highest rating to driver courtesy. A large majority (62 percent) also gave very high ratings to destinations served and quality of printed schedules. Response was more mixed regarding schedule times and vehicle comfort. Comments on survey forms indicate that passengers find the bench seats in the Orion IIs uncomfortable. In terms of schedule times, the lower ratings correlate with many suggestions for service on Saturday.

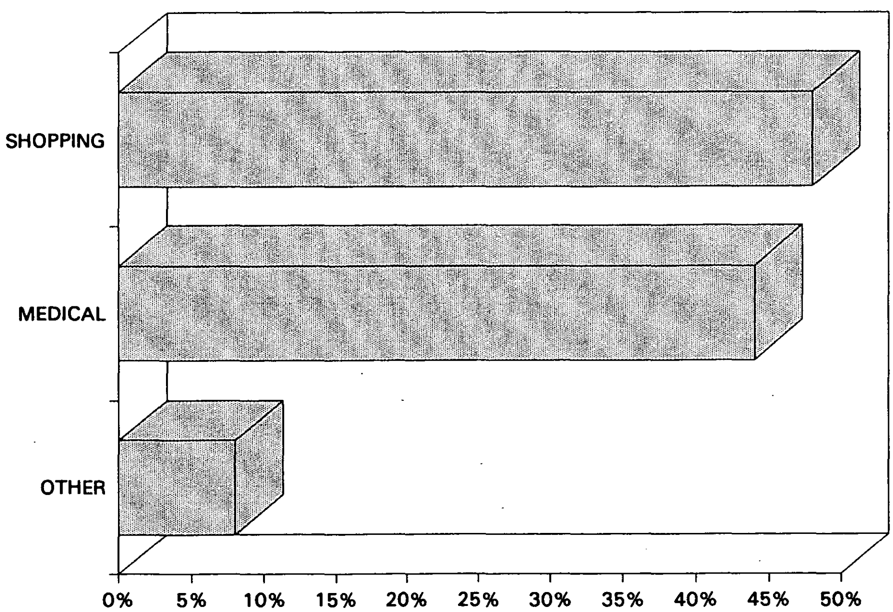

FIGURE 1 Trip purposes.

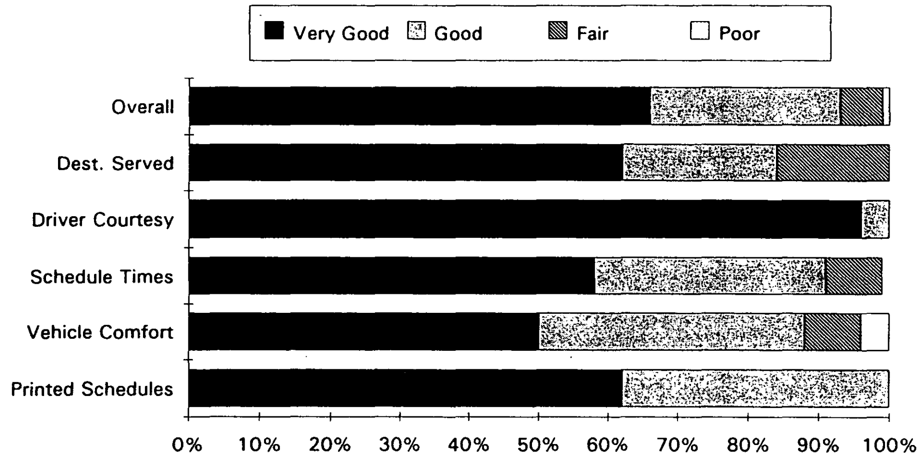

FIGURE 2 Service ratings.

Effects on Paratransit

Because of the low capture rate for potential riders and trips along the service routes, a noticeable reduction in paratransit rides has not been experienced. Moreover, if trips being taken on service routes resulted in a proportional decrease in paratransit trips, a decrease of 12 percent would have occurred. However, since this has not happened, it appears that trips on the service routes are mostly new trips generated by the availability and convenience of a new service.

In an effort to determine why more potential riders are not using the service, a mail-out survey was conducted. The most commonly cited reason was that routes do not go to desired destinations. The next major reason was difficulty in reaching the bus stop.

Service Changes

The slow ridership growth and low capture rate of potential users along the service routes has led Metro planners to conclude that most travel patterns of elderly and disabled persons tend to be broader than the "neighborhood" service-route areas, a phenomenon related to the more dispersed development patterns of our cities. As a result, Metro is changing the service routes to increase the number of destinations served.

One of the major changes is to link the two routes. During implementation, several hospitals and clinics, which tend to be concentrated along one of the routes, expressed concern about the lack of connectivity between routes since many clients reside along the other route. This deficiency has been borne out in surveys and suggestions from passengers who not only want service to destinations on the "other" route, but also access to destinations not currently being served, primarily other major shopping areas. The routes will be connected in the central business district and interlined in order to minimize transferring. Doing so will increase travel time to some destinations, but minimizing transfers was considered to be more important.

Another major change will be an expansion in service area to include more destinations identified by passengers. This will be accomplished by adding several "shuttle" trips to other major shopping centers and grocery stores with an available paratransit vehicle. These trips will be coordinated from a major activity center on one of the service routes.

SUMMARY

The Madison experience has helped define the service-route concept in the United States. Although it is too early to draw many conclusions, there do appear to be some cultural and environmental differences between Sweden and the United States that will require refinement of the Swedish service-route concept for it to work in the United States. The intermediate level of service between fixed-route mainline buses and curb-to-curb paratransit vehicles does have attractive features. More research and experimentation is necessary to better define and determine the applicability of the service-route concept in the United States.

Wayfinding Crisis Intervention: Theory and Practice for Mentally Ill Persons with Transportation Handicaps

BRENNEN TAYLOR AND ANN TAYLOR

Wayfinding crisis intervention has proven to be an effective intervention with severely mentally ill persons who often enter a crisis state upon becoming lost when traveling to community health services. A crisis service delivery model used with this population is presented in the context of a problem-solving process.

The passage of the Americans with Disabilities Act of 1990 (ADA) symbolizes a renewed national effort to serve people afflicted with handicapping conditions (*1*). This law converges with the national and international rehabilitation movements. In a mental health context, America's deinstitutional movement is changing radically to bridge gaps in service needs. Recently, the helping professions assessed several dimensions of mental health services. Their investigation of mental health care and its organizing and financing suggests that further rigorous research is warranted for enhanced service delivery. Several national mental health plans have been devised to improve services to persons with severe mental disorders and developmental disabilities (*2–4*).

The national mental health plans are responses to advancing community mental health services with greater specificity on behalf of existing and newly identified psychiatric populations. Over the past 30 years the helping professions have extended their expertise into other disciplines to assist increasingly diverse mental populations. This extension has made available the merits of orientation and mobility training, or wayfinding training, to the deinstitutional movement (*5*). The training is used by severely mentally ill persons with transportation handicaps who travel to community mental health services by public bus transit. The general characteristics of this population indicate that they confront immense psychosocial and architectural barriers in daily travel to urban mental health services. Most of them have inadequate wayfinding and public bus riding skills largely because of their mental condition. These clients also experience other difficulties that result in high noncompliance with outpatient services. Salient factors such as travel distance, the demands of implementing a travel plan, medical illness coupled with a psychiatric condition, and visuospatial disorders influence their use of community-based services with few exceptions (*6–13*).

Transportation-handicapped mentally ill persons require expertise and planning far beyond the standard treatment available to severely mentally ill persons who have been deinstitutionalized, because the mental operations required for traveling are not easily mastered by psychiatric or nonpsychiatric populations (*14–20*). In essence, wayfinding training programs that include selection criteria and travel training procedures and use public bus transit systems put into effect deinstitutionalization with greater specificity. They ensure greater compliance with community-based services (*21,22*). The wayfinding training selection criteria follow (they are not mutually exclusive per population):

- Exceptional populations (mentally retarded)
  - –Not overly resistive
  - –Not severely impaired by cerebral palsy
  - –No severe loss of hearing or vision
  - –Able to associate time and events
  - –Does not damage property
  - –Does not run away
  - –Has not caused serious physical injury to self or others within the past year
  - –Can walk or move independently in wheelchair
  - –Not profoundly retarded
- Transportation-handicapped mentally ill
  - –Not dually diagnosed (schizophrenia with mental retardation)
  - –Expresses an interest in learning independent travel
  - –Develops a travel route based on a cognitive map
  - –Executes public bus riding skills as instructed
  - –Receptive to the process of normalization
  - –Does not have a severe health condition
  - –Has either rote or associational learning ability
  - –Has long-term memory for route learning
  - –Has been stabilized on psychotropic medication (if necessary)

Although advances have been made in serving mentally ill persons who have transportation handicaps, the successful transfer of these clients from institutional to community-based settings remains a problem. Clients frequently become geographically lost when traveling alone to urban community mental health centers. Technically, a person is geographically lost if he or she does not associate current community location with an understanding of the destination that is out of immediate perceptual range (*23*). Becoming lost tends to move a client into a crisis state because of the correlation among stress, coping, and a vulnerable mental condition. Currently, the helping professions have not proposed a treatment model that addresses such a situation.

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This paper builds on earlier research conducted with transportation-handicapped persons of Barney Neighborhood House in Washington, D.C. Three interrelated mental health components are presented from a social work perspective. First, an overview of crisis intervention with psychiatric populations is presented. Second, a wayfinding crisis intervention model used with this population to regain geographical orientation is briefly discussed. Last, the problem-solving process of crisis intervention is outlined. Implications of wayfinding training are related to the transportation component of ADA.

CRISIS INTERVENTION OVERVIEW

Lindemann's pioneering research on managing acute grief remains the foundation for developing crisis intervention theory and practice (*24*). In his brief casework with the relatives of victims of the Coconut Grove fire, he found that the time frame for acute grief varies: it can occur immediately or be delayed. Acute grief is accompanied by psychosomatic symptoms. Victims also rely on defense mechanisms to cope with the trauma. Lindemann's work established that grief was a natural reaction to trauma and that people develop a new state of equilibrium by working through the crisis. Later, Caplan designed a community mental health approach to prevent crises through programs. The helping professions have universally accepted his concept of prevention. Prevention is a vital method to reduce the impact of crises (*25,26*). These contributions paved the way for scholars to advance crisis intervention theory and practice in diverse settings with special populations. Crisis intervention can be discussed in four parts: definition, type, theory, and principles. A composite definition of a crisis embodies several ideas. Generally speaking, a crisis is the perception of an event or situation as an intolerable difficulty that exceeds the resources and coping mechanisms of a person (*27*). During disequilibrium, a crisis can result in an extremely negative or an extremely positive outcome, depending on how a person handles the difficulty. The inability to function effectively as a consequence of emotional turmoil is an undesirable outcome. A positive outcome, however, enhances problem-solving and coping skills (*28–31*).

Either outcome can occur with each of the three types of crisis:

- Developmental crises are normal yet unique events that mark a dramatic shift in a person's life.
- Structural crises tend to occur with unanticipated events that are beyond an individual's control.
- Existential crises direct a person to assess and take further action toward achieving self-actualization.

These crises commonly interact, which influences the transfer of psychiatric clients into community life (*24,32,33*). It accounts for crisis theory, drawing on human behavior and environmental psychology theories to help people work through crises. Those theories assert that human beings are biologically endowed to function independently because of adaptive ability. One's ability to recall experiences and organize emotions and intellect into specific habitual patterns of social functioning allows one to carry out the activities necessary for daily living. Successful adaptation to crises involves having the capacity to act or react to environmental demands. It helps to maintain psychological equilibrium for directing energies and executing skills to meet life's tasks (*34–38*).

Inadequate response to environmental demands does not automatically move a person into a crisis state. Three factors are associated with a crisis. A hazardous precipitating event occurs that threatens one's survival. This threat makes a person more vulnerable by limiting his or her problem-solving and coping skills. The person then moves into a state of disequilibrium that warrants professional assistance (*39*).

Crisis theory further posits that a crisis is caused by the perceived significance of the hazardous event. The event can induce pathological or nonpathological responses based on environmental and situational variables. The degree of life threat, duration and severity of the stressor, level of displacement or disorganization of a person from his or her community, and the location of the crisis are relevant variables (*40*). A crisis becomes a life-threatening experience for psychiatric clients who possess diminished independent living skills (*41*). In summary, crisis theory establishes a set of ideas that help in solving people's difficulties through various types of intervention. The basic principles of crisis theory follow (*24–41*):

- Crises occur across the life span.
- Hazardous events tend to create emotional disequilibrium and disorganization.
- Crises represent opportunities for growth and development.
- A crisis is neither an illness nor a pathological experience.
- Specific types of crises follow stages that can be charged.
- Crises are limited (4 to 6 weeks) depending on the type.
- Crises are complex and difficult to resolve.
- People in crises are open to help.
- Quick fixes do not apply to crisis intervention.
- Resolution of the crisis enhances practitioner and client personhoods.
- The principles of crisis intervention stem from its theory.

Crisis intervention is a shortened yet specialized intense problem-solving process. A synthesis of its core principles follow (*42–45*).

- Provide immediate help that involves ensuring client safety.
- Define the crisis through a psychosocial assessment.
- Focus on the crisis by letting clients ventilate their feelings.
- Reduce tension through supportive techniques.
- Intervene to help client gain cognitive and behavioral problem mastery.
- Develop a problem-solving stepwise plan with the client.
- Implement the plan by drawing on various resources.
- Evaluate the plan for its effectiveness.
- Terminate yet follow up the crisis resolution.

The crisis worker action continuum of Gilliland and James should be deployed during crisis resolution. It can guide the degree to which a worker becomes directly involved to help a client solve a crisis (*24*). In summary, crisis intervention theory and practice has developed into a sound clinical method.

It is effective with a wide array of people who suffer psychiatric emergencies. The revolving-door syndrome has been curtailed by mentally ill clients who resolve their psychiatric emergencies in the community rather than in the hospital (*41*).

WAYFINDING CRISIS INTERVENTION MODEL

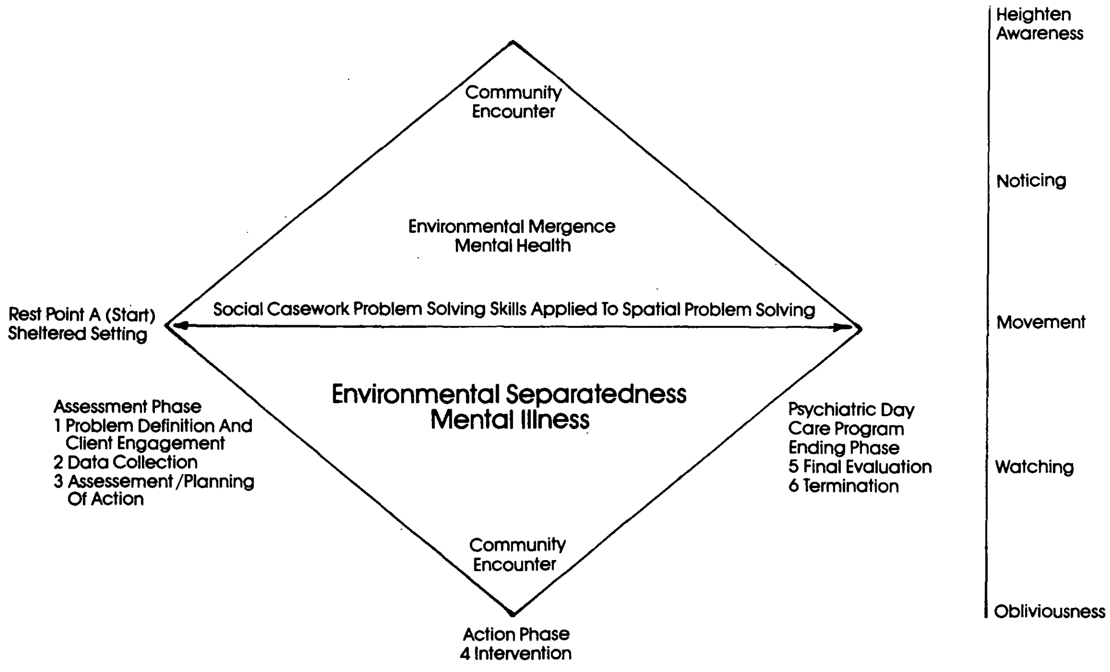
Crisis intervention with persons who are geographically lost is a situational crisis. An integral part of wayfinding training—the cognitive and behavioral ability or skill to reach destinations in the environment—requires that a client test independent travel to demonstrate route mastery under the supervision of a trainer (*46*). It requires that clients determine the direction of a familiar goal across unfamiliar terrain by monitoring the outward journey on the basis of visual landmarks (*47*). The deinstitutional literature is filled with tales of psychiatric clients found wandering in the community because they could not find outpatient facilities. By and large, these clients are mentally ill persons whose psychosocial decompensation comes from being in a crisis state (*13,41,48–50*). Their successful transfer into community life necessitates at least a service delivery system with affordable and available housing, support networks, adequate resources, a mass transit system, and effective case management. Crisis counseling by telephone should be a core component of case management with deinstitutional clients. This service bridges geographical and psychosocial barriers of lost clients with community mental health practitioners for crisis resolution (*51*).

Few data exist for theories about the mechanisms associated with psychiatric clients' moving into a crisis state because they are lost (*52*). However, two interrelated wayfinding theories provide a possible explanation. Ley conceptualizes wayfinding as a frontier outpost. He suggests that four human responses to persistent uncertainty occur in a new environment: during navigation a traveler processes information, consolidates new ties within the environment while dissolving bonds with the old environment, and forms a social network; the new environment serves as a point of reference for future activity (*53*). Seamon says that the frontier outpost experience is solidified into a geography of the life world through a traveler's movement, rest, and encounter within the environment. Movement helps a traveler to assimilate unfamiliar places into a world of familiarity, rest anchors a traveler in his or her personal travel knowledge, and encounter involves learning routes. A traveler who demonstrates the tendency toward environmental merger acquires independent travel skills. His or her noticing and heightened contact with the environment allows the travel plan to be executed on the basis of the dynamics of the social casework wayfinding model.

On the other hand, environmental separateness is characterized by a traveler's watching and obliviousness during a journey before learning travel routes. These two variables tend to correlate with psychiatric conditions of severely mentally ill persons with transportation handicaps undergoing community travel (*54*) (Figure 1).

The following list displays some relevant dynamics that result in psychiatric clients' becoming lost:

- Poor environmental orientation
- Poor episodic and semantic memory
- Attentional overload
- Resistance to normalization
- Inadequate treatment team support
- Lack of public transit knowledge
- Disadvantages of public bus seating



The upper triad of the diagram represents environmental learning that develops independent travel skills. The lower triad represents non environmental learning. The upper triad must be mastered in order that the lower triad becomes routine.

FIGURE 1 Social casework wayfinding model.

- Independent travel without route mastery
- Switch from specialized to public mass transit
- Overdependence on travel trainer
- Confusion, distance, and lack of motivation (objective and cognitive)
- Noncompliance with travel instructions
- Resistance to requesting help
- Change of urban landmarks during stay in institution
- Misdiagnosis of psychiatric condition
- Use of mobile landmarks for travel

This continuum lists factors associated with moving into a crisis state:

- Mobility (equilibrium)
  - Normal activities
  - Normal vital signs
  - Reasonable sociability
  - Coherent mental functioning
- Partial mobility (precrisis)
  - Increased anxiety
  - Increased vital signs
  - Perspiration
  - Tense muscles
  - Loosening cognition
  - Doubting own travel competence
  - Heightened awareness of survival needs
  - Decreased concept of self
  - Interested in being helped
- Immobility (crisis)
  - Rapid vital signs
  - Sweating, headaches, shortness of breath, fatigue
  - Disoriented thinking
  - Physical illness (nausea, diarrhea)
  - Urgency for help
  - Regression

Theoretically, a client begins a trip in a state of equilibrium. This is predicated on having a travel trainer accompany the client throughout the trip. It may result in a client's immediate mastery of a particular travel route, but such mastery would be the exception. The norm suggests that during travel the client processes spatial information, interacts with the public, and implements travel instructions. A cognitive map of the primary travel route is formed; it places landmarks in sequential order. The map permits mastery of the primary travel route. Mastery demands that the destiny be learned from the sheltered setting to the community-based program, its inverse, and the integration of landmarks from both directions (*55*). Gaps in the cognitive map due to memory deficits result in inaccurate travel decisions.

A client's anxiety increases the farther that he or she travels toward a destination by public bus or walking without seeing familiar landmarks. Anxiety is a psychological reaction to a dangerous situation that reduces the efficiency of performing tasks (*56*). Heightening anxiety contributes to noticing landmarks not seen earlier. Unfamiliar landmarks generate cognitive dissonance that moves a client into the precrisis stage. Clients then begin to question the reliability of their own travel knowledge and cognitive map for competent travel because of these unfamiliar landmarks. This tends to move a client into the crisis state that paralyzes problem-solving and coping skills. When trying to become reoriented, a client must compile satisfaction data on (a) knowing where one is, (b) visualizing what is likely to happen next, (c) considering whether it will be good or bad, and (d) developing an alternative course of action; creating subgoals to gain mastery within the environment will be attempted by trial and error (*57*). These travel decisions are often too demanding for psychiatric clients in the crisis situation.

Psychiatric clients are empowered to resolve the crisis through trial and error. This consists of a combination of location- and route-based navigation or resourcefulness. For example, a client can rely on the public bus driver or the public for appropriate wayfinding help (*58*). If a client is able to identify familiar landmarks through a search process, the cognitive map will be triggered and the sociophysical surroundings will become structured to produce environmental orientation. A client's recognition of landmarks substantially reduces stress and allows the cognitive restructuring of the mental map. As unfamiliar landmarks are replaced by familiar landmarks within the cognitive map, clients begin to gain a new state of equilibrium. The crisis state is reversed as clients recognize landmarks that serve as travel guides. The more landmarks that the client can recall in sequential order, the more the client becomes competent and moves out of the crisis state.

Later, the meaning of the crisis must still be worked through to enhance the client's psychosocial functioning. This also provides additional information for community mental health practitioners to assess a client's problem-solving and coping skills for future situations.

Some psychiatric clients will not be able to resolve their geographical crises. Outreach crisis intervention will be required; it is predicated on a client's psychological functioning, help-seeking behavior in strange environments, and the clinical expertise of helping professionals. The following crisis intervention approach is implemented with the mentally ill who become lost in the community (*59,60*):

1. Data collection (telephone)
   - Worker assesses client's psychosocial functioning by telephone counseling.
   - Worker provides supportive therapy.
   - Worker requires client to describe landmarks in the environment.
   - Worker determines client's geographical location.
   - Worker determines client's efforts to solve the problem.
   - Worker directs client to stay at current location.
   - Other professionals provide support while help is on the way.
2. Intervention (in the community)
   - Worker travels by private vehicle to client's location.
   - Worker finds client.
   - Worker makes sure that client is safe.
   - Client tells worker how he or she got lost.
   - Worker and client backtrack the primary travel route.
   - Worker and client return to the sheltered setting or community program.
   - Treatment team determines a time frame for continued training.
   - Individual travel plan is revised on the basis of specific factors contributing to becoming lost.

–Action-oriented group therapy is implemented to help client work through the crisis (psychodrama, assertion training).

3. Evaluation

–Implement client's wayfinding training on the basis of the revised plan.

–Monitor client's travel of route with client.

–Correct and reinforce client's travel decisions.

–Monitor client's travel of route unobtrusively (weaning).

4. Termination

–Reinforce client's mastery of a primary route.

–Work through client's reactions to terminating the training.

–Provide wayfinding training as needed.

–Encourage client to master a secondary travel route.

–Link clients with other clients who travel the same route to community-based programs.

IMPLICATIONS

This paper has conceptualized wayfinding crisis intervention with transportation-handicapped mentally ill persons who ride public buses to use urban community mental health services. This service is a way to foster normalization of physically or mentally impaired persons in accordance with the ADA. There are at least two major implications derived from the research. America is becoming an increasingly mobile society for all populations (*61*). The national mental health plans and the international mobility movement place transportation central to development of future mental health services. The helping professions must expand the concept of treatment teams to serve transportation-handicapped psychiatric populations. The services of public bus drivers must be included as an informal part of treatment. Frequently, bus drivers are the primary source of accurate travel information for psychiatric clients. Bus drivers can influence whether a client moves into a crisis state by providing needed data. Moreover, bus drivers can ensure a client's safety who is in crisis before the helping practitioner arrives. Further training of bus drivers about deinstitutionalization would prove invaluable to people with diverse disabilities.

There is also a need to investigate thoroughly the psychological dimensions of wayfinding with psychiatric populations. Certain factors are associated with becoming geographically lost. For example, clients sometimes use mobile landmarks as stationary environmental reference points for travel. On face value this appears contradictory, but there is a rational explanation. People's activities occur in a given place and time. Some events that happen in a place change from time to time, occur in repeated and predictable patterns, and range from beneficial to dangerous. These temporally changing patterns of events can help a client be in the right place at the right time (*62,63*). Specifically, during a client's travel, some parts of the city are more populated with roadside vendors than others. Psychiatric clients traveling the same route may recognize vendors as stationary landmarks. The same vendor may decide not to work on a given day or to change location. This alters a psychiatric client's cognitive map. If a client relies on a number of vendors as stationary landmarks but cannot find them, the crisis continuum may be catalyzed. Further investigation of such wayfinding crisis intervention will prepare helping professionals to service this population effectively.

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Evaluation of Interagency Coordination and Cooperation Between Transportation and Aging Networks in Harris County, Texas

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Interagency coordination and cooperation are considered effective tools of management in an era of fiscal crisis in the public sector. The degree of coordination and cooperation between the transportation and aging networks in Harris County, Texas, was examined and evaluated. Data were collected from agencies on such cooperation and coordination. Results show that little coordination is taking place; primary interaction occurs between the main funding agency and individual transportation or service providers.

Coordination and cooperation between agencies have been major issues from the late 1980s because of anticipated and actual federal funding cuts and because of the need to be more efficient and reduce administrative and overhead expenses (*1*). The needs of the growing group of the elderly and the differences in services between rural and urban areas are highlighted in federal reports. Although agreements between the Administration on Aging and the U.S. Department of Transportation indicate that the emphasis on coordination and interagency cooperation at the federal level is a recent development, coordinate services have been implemented since the early 1970s (*2*). Some coordinated transportation services have been subsidized by the local human resource agencies' Title III Grant and UMTA; their size of operation has increased from a few passengers to a large operation of thousands of daily trips. Some of these services are primarily in rural areas, but other examples are strictly urban (*3*). Other relevant research includes earlier work in examining and evaluating different management concepts for consolidating specialized transportation (*4*). Perhaps the best published document in the area of coordination is that by the Center for Systems and Program Development (*5*), in which a wide range of management models—from community action agencies to brokerage models to volunteer programs—are described and discussed in detail.

Although the available literature clearly indicates that coordination was initiated in a number of areas in the 1970s, it does not appear that the lessons learned were transferred to other states or programs. For example, in Texas, there appears to be little knowledge or diffusion of the brokerage coordination concepts despite the initiation of the Bexar County brokerage plan (*6*). Close to San Antonio and Bexar County is Harris County, the largest urbanized county in Texas, where one would expect some of these innovative ideas to be promoted. Thus, this research evaluates the level of interagency coordination and cooperation between the transportation and agency networks in Harris County.

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DATA AND SAMPLE

A combination of service providers furnish transportation services for the elderly in Harris County: the Houston Metro (regular fixed-route services), Metrolift (for the handicapped only), the metropolitan subsidy taxi program, bus services provided for or by senior or multipurpose centers, and taxi services dominate. Human services agencies provide transportation for specific trips to all eligible clients including the elderly. These trips are limited to specific destinations for a single trip purpose for a wide range of clients besides the elderly, so they were excluded for this research.

To ascertain the level of interagency coordination, a list of agencies was developed from the list of service providers to the elderly, which was developed by the Houston/Harris County Area Agency on Aging (AAA). The 105 potential transportation providers included taxi companies and Metrolift. The Houston Metro was excluded because of the nature of its services and its area limitations.

Information on coordination and interagency cooperation was not readily available. As a result of the limited information, data were collected through a questionnaire that was pretested and precoded to simplify data analysis. Although 105 agencies were contacted in the initial mailing, only 25 percent of them completed and returned questionnaires in the prepaid envelopes. This response was well within the expected rate of 20 percent as defined by social science research methods; nevertheless, the authors were disappointed. Another 20 percent responded after being repeatedly contacted for telephone interviews. The overall data collection effort indicated that many agency directors or their assistants did not have the time, data, or strong interest in providing input to the survey. As a result, many questionnaires were not completed well and some responses to complementary questions were inconsistent. All these factors are reflected in the results obtained from our analysis of the data from the questionnaire and the responses from a user survey of 250 elderly people conducted a few months earlier (*7*).

FINDINGS

Harris County has about 280,340 elderly persons (those 60 years and older) on the basis of the 1990 census; the ethnic breakdown is shown in the following table:

Ethnic Group	*Total Population*
White	186,788
Black	50,452
Hispanic	30,767
Asian	6,846
Native American	596
Others (self-classified)	12,191

As a whole, the fastest-growing segment of the population is the Hispanics, who may have been undercounted during the 1990 census because of language and other factors.

Of these elderly, 4,137 unduplicated persons received transportation services during 1991–1992 that were funded primarily through the AAA (Houston/Harris County AAA, unpublished data, Sept. 1992). For the same period, 271,351 one-way trips were recorded, which yields an average of 65.6 trips per person per year, or approximately 5.4 trips per month (a little more than one trip per week per person). From the data it is safe to assume that the remaining individuals getting transportation are subsidized through other funding agencies or provide their own transportation by driving or getting a ride (*5*). Clearly, although other private foundations provide funds both for group meals and transportation to the sites, the primary service providers are funded through the AAA and appear to serve only a small percentage of the elderly in Harris County (1.5 percent for transportation and 4.1 percent for group meals). Thus, it is apparent that though there is a rapid increase in the elderly population in the county, the services are available to only a few. Service must be provided not only to keep up but also to serve an ever-increasing percentage of the elderly, many of whom are likely to become more aware of their rights to such services under the Older American Act of 1965.

Transportation is the key to the elderly's ability to access other services; hence, coordination and interagency cooperation may be the only ways to expand transportation services to meet an increased demand.

Analysis of the information collected produced the following distribution of agencies that participated in the survey:

Agency Type	*Response (%)*
Government and social service	12.2
Church/private	10.2
Senior/nutrition	44.9
Multipurpose	16.4
Nursing home/assisted living	16.3

From the data it can be seen that senior centers or nutrition centers provided the bulk of the responses and that no exclusively transportation agencies responded. Of these agencies, the provision of transportation services to their clients is shown in the following table:

Service Type	*Response (%)*
Agency vehicle/paid driver	34.7
Contract with a transport company	30.6
Voluntary driver plus others	16.3
Combination of above	14.3
Not applicable	4.1

This table indicates that most of these agencies used a combination of their own vehicles, paid drivers, and contractors. Several interrelationships between many variables were investigated, and the significant relationships are tabulated in Table 1.

From Table 1, the strong link between the agencies and their choices of providing transportation services is evident. The crosstabulation between the agency type and the transportation services shows a significant relationship. The missing cells indicate several factors, such as (a) limited transportation services provided by certain types of agencies, (b) a lack of mobility needs on the part of the clients (due to deteriorating physical health for those in nursing homes), and (c) regulatory barriers prohibiting volunteer drivers (as with government or social service agencies). The relationship between the agency and the manner in which its clients travel is also very strong. Centers that have their own vehicles or paid drivers provide most of their clients with transportation or contracted services. Centers that use volunteer drivers (or a combination with volunteers) have many clients who drive their own cars. There is also a high degree of correlation between the type of agency and its primary activity; this is expected because agencies were classified primarily by their functions.

In the preceding crosstabulation (Table 1), the cells without any value show those agencies that have organizational constraints on the kind of activities that are provided for the elderly (e.g., no health care facilities for the church or private associations, or the multipurpose centers). Likewise, these missing combinations may also reflect a lack of physical facilities or funds to provide certain types of services. Of crucial importance in the analysis were the questions on the level of information on the transportation alternatives provided by

TABLE 1 Significant Relationships

Crosstable Variable	X^2	P-Value	Degrees of Freedom
Agency type/transportation type	32.25604	.00926	16
Agency type/manner in which client travel to center	40.95711	.01684	24
Agency type/primary activity of center	28.74475	.00430	12
Agency type/type of additional trips needed	13.51558	.9530	8
Agency type/frequency of interagency communication	12.24288	.01563	4
Agency type/need for centralized computer information system	14.84738	.06128	8
Agency type/outreach program	21.49784	.04355	12

the agencies to their clients and various mechanisms for information exchange between agencies and with clients.

Only certain responses were significantly related to the type of agencies. They were as follows:

- The clients' responses on additional trip needs being mainly for shopping,
- The regularity of interagency communication,
- The need for centralized computer information systems, and
- The existence of outreach programs.

Although the findings point to the existence of regular feedback and interagency cooperation and the need for formal communication mechanisms, the effectiveness of the current exchanges and the validity of the responses to the questionnaire may be questionable.

The evidence on information available to agency clients suggests that most agencies have very little information on alternative transportation. The results of the survey are shown here.

Information	*No (%)*	*Yes (%)*
Schedules	55.1	40.8
Rates	61.2	34.7
Senior eligibility criteria	49.0	46.9
Taxi rates	64.3	28.6

Most of the agencies appear to provide little or no information to their clients, so they are unlikely to have much interaction with other agencies, especially transportation agencies. Of course, this lack of information could also reflect that the primary activity of these agencies is to provide meals. Most respondents (primarily directors) believe that the majority of their clients drive (44 percent of the agencies), probably because of their suburban or rural locations. Of those centers that keep information on their clients' transportation needs, the most frequent requests were for shopping trips, which was followed by medical trips.

These general indicators of a lack of interagency interaction are reinforced by the fact that 48 percent of the agencies do not have any mechanism for exchanging information on senior services in the county. The findings on the regularity of coordinating activities are given in the following table:

Degree of Interaction	*Percentages*
Regularly	36
Periodically	16
Occasionally	10
Rarely	24
No response	14

These figures show that only a few of these agencies have regular contact with other agencies. To reinforce the lack of interagency coordination and cooperation, 54 percent of the agencies expressed a need for coordination. Of this group, 40 percent indicated a need for a centralized computer information system.

Perhaps most useful is the response on the need for a centralized computer referral system, which was expressed by 64 percent of the agencies. It was attempted to solicit explicit ideas on ways to improve communication between agencies, but there were no useful suggestions.

Implicit questions on awareness of brokerage management systems indicated that most agency respondents had no understanding of this type of system. Detailed questions on service characteristics of a brokerage system yielded similar results. Responses to the question on the agency of primary importance with which they interact reinforced the earlier findings that each agency interacted mainly with its funding agencies, which are primarily the AAA, the United Way, and some private foundations. This appeared to be the only indication of their interaction with the aging network. Sixty percent of agencies said they had an outreach program.

A surprising finding is that most of the agencies' clients traveled less than 20 mi; a significant minority traveled more than 50 mi (probably for medical trips).

CONCLUSIONS

A summary of the findings clearly shows an awareness of the need to interact and coordinate—but a lack of agreement on method—and an awareness of the value of a computerized data base and central referral system.

Overall, interaction between the transportation and aging agencies appears to be nonexistent except for those agencies that contract with a transportation company to serve their clients. Since none of the transportation agencies initially contacted participated in the survey, all the conclusions as to their lack of interaction are speculative. It appears that the transportation agencies are not interested in interacting with the aging network and do not depend on this network for their business. For example, the Metrolift service caters to the needs of the handicapped, some of whom are elderly. However, the elderly handicapped individuals may be an insignificant group for Metrolift because few of them qualify for its service. The overwhelming feeling of the authors was that agencies were unable to keep track of information, needs, or actual use of services by their clients beyond the minimum required to comply with contractual obligations. It would be appropriate to conclude that there is limited interagency cooperation and no interagency coordination in Harris County. In addition, there is little interaction and cooperation between the transportation and the aging networks despite the existence of an extensive aging network comprising hospital, research, and service centers.

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Strategic Management in Specialized Transportation

ALAN BRYMAN, DAVID GILLINGWATER, AND IAIN MCGUINNESS

Between 1988 and 1990 a major U.K. study investigated the decision-making processes in three voluntary nonprofit organizations operating specialized transportation services. The results of the work, in collaboration with a wide range of organizations, funding agencies, and advisory bodies, suggest that the management of these organizations is in a period of transition. Each of the three case studies favored growth-oriented strategies. However, the organizations were often constrained by external factors—notably, their dependence on other bodies for financial resources. To survive as well as grow, community transportation organizations are moving from their traditional voluntary roots toward a more professional approach to providing services. The main findings of the research are presented, and directions for organizing and managing specialized transportation in the United Kingdom are outlined.

The 1980s witnessed a tremendous growth in the number and variety of specialized and nonconventional passenger transportation services in the United Kingdom. Voluntary organizations provided most of these services, although statutory providers of conventional transportation services have become more active in this area. A common trait of these organizations was a concern for the mobility and accessibility needs of those with mobility impairments and other transportation disadvantages. Bell has defined such services as being "socially provided organized vehicular services under the auspices of a voluntary organization, offering limited transportation services for disadvantaged groups in a defined geographic region" (*1*). In the United Kingdom, voluntary transportation service providers are known as community transportation (CT) organizations.

This paper focuses on strategic management in specialized transportation: the strategies of individual organizations to provide effective specialized transportation services.

METHODS

A comparative case study methodology was adopted, and an "expert choice" sample was used to select three CT organizations. The three CTs were well established; they operated services in the northeast, the Midlands, and London. They are referred to by the pseudonyms of Metro, Provincial, and Capital. Data collected included documentary evidence (such as annual reports and minutes of meetings), notes of workplace observation, and semistructured interviews with key participants (including both the coordinator of the organization and the chair of its management committee). Data analysis was informed by grounded theory, an approach that facilitated the discovery of theory from data rather than one that proceeded on the basis of hypothesis testing (*2*).

By using replication logic, the importance of four theoretical concepts was recognized: strategy, leadership, organizational culture, and resource dependence. Some of the findings have been reported in other publications (*3*). Although the intention was not to track the three organizations, 2 years after leaving the field all three coordinators were interviewed again.

At the time of fieldwork, Metro operated dial-a-ride, community group hire, furniture recycling, and vehicle maintenance services; Provincial operated dial-a-ride and community group hire; and Capital operated a voluntary car service and community group hire. Capital was also developing a service of safe transportation for women, applying the concept of brokerage to its group hire and publishing a driver training manual for CT projects throughout the United Kingdom.

Funding for the organizations came primarily from statutory bodies, including district councils, county councils, and passenger transportation authorities (PTAs). At Provincial and Metro, dial-a-ride was funded by the county council and PTA, respectively, whereas group hire was funded by their respective district councils. All external funding for Capital came from the local district council. A coordinator oversaw the operation of each CT. Policy was determined by a management committee consisting of individual users, representatives of user groups, and officials from the funding bodies.

FINDINGS

The four aspects of organizational functioning were identified as contributing significantly to the nature and quality of the provision of specialized transportation services. Together they affect the decision-making processes that surround CT provision; that is, they illuminate differences, both for policy and for practice, in the interorganizational network (*4*). Current issues within the voluntary transportation sector center on two basic but linked questions: How should specialized transportation be provided, and by whom?

Each of the CT organizations embarked on strategies intending to provide a range of services for individuals and community groups. These included dial-a-ride, dial-a-bus, voluntary car schemes, safe transportation for women, tra-

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ditional community group hire, and related services such as the provision of low-cost furniture for individuals and families with low incomes. The ability to accomplish these goals, however, became circumscribed by the multiorganizational context—more specifically, politicized environments, high levels of external control, and low levels of trust within the organization and in the relationships with other agencies concerned with service provision, particularly statutory funding bodies.

Strategy

Each of the CT organizations had clear ideas about where it wished to be in the longer term and the objectives it needed to achieve in the shorter term. We viewed strategy as a process (*5*), but one that took into account the context in which that strategy was developed (*6*). Formulating the content of any strategy in an organization often entails managing both its context and its process. According to such a view, organizations set out with strategic intentions. Some of those intentions fall by the wayside; in some cases they are replaced by new or emergent strategies. Thus, the strategy that materializes is not necessarily the strategy that the organization had intended. The realized strategy would also provide insights into the organization's success in managing both the environment and strategy processes.

Each of the three case studies was committed to expanding, in terms of staffing as well as operations. Each organization had been operating specialized transportation services since the early 1980s. Growth was to be overarching. Both group hire and dial-a-ride services were to be expanded, and new initiatives were to be considered and developed. The expansionist philosophy of the three case studies can be summarized by Capital's own view of its aims and objectives: its long-term aims were "the creation of a fully accessible public transportation of which CT was a part in terms of its role in group activity and community development." Capital's short- and medium-term objectives were to "substantially extend the activities of Capital to provide models which transportation operators could pick up." This development work would be set in the context of continuing "to provide a good service to groups and individuals with the vehicles that we currently have, to promote good standards of practice in the sector and provide good levels of training to empower groups to organize their own transport facilities."

By the time we entered the field, Capital had already begun an ambitious program of expansion. Its coordinator described it like this:

> If you look at what [Capital] is doing, it has a superb track record over the last two years in that it's growing dramatically, it's far more efficient than it was, it's got a whole range of new ideas, it's consulted widely, its role in terms of a whole range of council committees is much greater.

However, he recognized the fragility of many organizations in the voluntary transportation sector, including Capital: "It only takes one or two people to say we are never involved to feel the whole thrust of the project is in the wrong direction."

Provincial was a hybrid of two voluntary transportation projects that had operated separately since the early 1980s. The chair during 1988–1990 suggested that since the amalgamation of the city's group hire and dial-a-ride organizations in the mid-1980s, the "organization had lacked leadership ... it had been drifting. It needed taking in hand and producing a strategy for its development and growth." He added that the organization had tried to "overcome its complacency by getting people to think about the future and think about expanding the organization." By the time the chair left the organization, the group's lobbying had improved, but enhanced status through more appropriate and well-funded premises was still far off. Achieving an effective user-controlled management committee also proved difficult; this objective was to prove equally difficult at Metro and Capital.

Within Capital the coordinator and management committee agreed, as part of its strategy, to subsidize core activities by commercial ventures. The coordinator helped set up a limited liability company with a remit of becoming more involved in providing local authority transportation, particularly for social services and education. Second, Capital joined with the local authority and a private developer to discuss providing transportation for mobility-handicapped persons to a proposed retail complex.

At Metro there was very little evidence of consensus on strategy. Clearly, the organization wished to expand each of its three major activities: dial-a-ride, group hire, and furniture service. Metro was interested in computerizing dial-a-ride and in considering the brokerage concept for group hire. The management committee spent much time arguing about the dial-a-ride service and the organization's capacity for controlling its rapid growth. There was a consensus among the committee that Metro was unable to cope, that it had become overwhelmed by dial-a-ride. Metro—to a much greater extent than Provincial and in contrast to Capital—was tied to the national government's temporary employment scheme (the Community Program) for funding many of its staff, and thus it was tied to the complexities that came with it. Clearly, voluntary organizations need to fight for their survival in the wake of increasing competition for funding. Internal wrangling and personality differences exacerbated Metro's problems.

In each case, expansion could be sustained only if funding was available to support additional staff and resources. All three organizations were dependent on resources from funding agencies. Realizing an expansionist strategy, therefore, hinged on long-term financial security.

Managing Dependency

Managing the resource dependency was crucial to Metro, Provincial, and Capital. The influx of money was their lifeblood. Although they managed to generate small amounts of income, it was insufficient to offset revenue costs for premises, staff, and general expenses. It was essential that the CT organization cultivate and maintain a working relationship with the funding body. This dependence relationship clearly affected the ability of the CT organizations to accomplish their intended strategies. This not-altogether-satisfactory position is summarized by Wilson and Butler:

> In particular, [voluntary] strategy is constrained when money received from state agencies which, justifiably from their perspective, wish to see their financial support utilized in a manner congruent with their interests and which do not always coincide with the preferences of the voluntary organization. (7)

This relationship became more complex when there was more than one funding body and the funding bodies themselves differed on policy. This was evident at Metro and Provincial. In other publications we have argued that the context or environment within which the CT organizations operated was so overwhelming that it neutralized their internal strengths, which often included leadership skills of the coordinator and strong internal cultures (*3*).

We have also argued that the Metro coordinator showed clear leadership skills but that he was frustrated by a hostile environment and strong external control over the operational capabilities of his organization. This became apparent in 1988 when the PTA through its executive arm, the Passenger Transport Executive (PTE), began a wide-ranging policy review into the provision of special needs transportation service. Once its intentions were made clear, it became very difficult for Metro to respond, other than to instigate a vigorous lobbying campaign. The process revealed the workings of the interorganizational network within which the central organization has power over peripheral organizations. Benson argues that a mechanism by which a stronger organization may exert influence over a weaker one is by setting criteria that ensure poor performance in the weaker (*4*). In May 1989 a proposal to put dial-a-ride out to tender was agreed. Control over the policy, organization, and resourcing would lie with the PTE, not with Metro. For Metro, this meant the permanent loss of dial-a-ride. However, the loss allowed Metro to return to its community roots and concentrate on other services. Metro's coordinator expressed a sense of relief, having believed that the management committee had become preoccupied with dial-a-ride to the detriment of its other services.

At Provincial, the need to work effectively in a multiorganizational context was also important. With the benefit of hindsight, the control mechanisms exerted by its two funding agencies were evident, but not as rigid as those in the Metro situation. At the time of our research, Provincial's funding came from two sources: the district council and the county council. The former funded group hire; the latter, dial-a-ride. This situation exists today and is largely due to efforts to achieve main program funding. As with Metro, some of Provincial's staff were funded through the Community Program. A management committee member summed up Provincial's strategy as this: "to make itself indispensable before [the Community Program moneys ended] so one of the authorities would be required to take us on board." Although a good relationship existed with the district council, it was to the county council that Provincial looked for more permanent funding, because the county council provided the resources for nonconventional public transportation.

Problems arose when the county council became more interested in providing specialized transportation services throughout its area and finding out whether some services could be provided in-house. Provincial lobbied for its very survival and achieved further funding, but it was still temporary in nature.

Elsewhere, Metro was not so fortunate. The PTE came to recognize the need for a new package of specialized transportation measures. The PTA vice-chair commented at the time, "I think there is a need to control dial-a-ride. I think they [Metro] have worked under their own steam for a long time ... and we started looking at the options of how best to operate special needs transportation and [Metro's] carrying on was dismissed as an option." She added, "We see [dial-a-ride] as securing a service for a group of people who would have special needs, the same as we would look at securing a service where a gap had been left in the market by a commercial operator for people on a housing estate." Hatten has argued that the dominance of one or another funding source can change the character of the recipient institution (*8*).

Capital's coordinator stated that careful consideration must be given as to how and by whom specialized transportation services should be provided: "Of course people with disabilities know their needs best, but they don't always know how best to meet those needs." Implicit in his response was that CT organizations are more attuned to the needs of mobility-handicapped persons. This view was given added weight by Metro's coordinator. In the 1992 interview, he reflected upon the loss of dial-a-ride:

> I don't think the PTE understood the voluntary sector or voluntary organizations. They were much more comfortable working with their commercial friends. And I think also, having lost control of the buses [a reference to the 1985 Transport Act that divested the PTE of its powers to run bus services], they wanted to get back some form of control ... of some type of bus service.

We referred earlier to the effect of a coordinator's leadership orientation in mitigating the effects of a hostile interorganizational network. We argued that at Metro the environment was so hostile (and this was coupled with a lack of support from within) that leadership was constrained and rendered largely ineffective. At Capital, the coordinator exhibited leadership later characterized as being of a transformational style (*9,10*). However, this leadership was made all the more effective by a supportive relationship with the district council. More specifically, a contact was established with a principal officer of the council who attended and contributed to policy discussions within Capital. He provided "visionary support" to the coordinator. The two organizations and its individuals collaborated over Capital's involvement in the wider transportation environment, for example, education transportation. The funding body officer highlighted this only too well:

> When we first learnt that ILEA would be disbanded [a reference to the abolition of the Inner London Education Authority and the transfer of education back to individual London boroughs], over a lunchtime meeting in a bar here at [council offices], [he] and I were talking about and [he] said "I think we ought to see about getting involved." Those weren't his exact words, and a great deal more was said.

The coordinator himself summed up the relationship as being a mixture of a CT with a bit of vision and a council officer with a bit of commitment.

Leat has suggested that grant aid provision creates dependence on both sides: the voluntary organization is dependent on the grant to provide the services on which the authority depends (*11*). This is evident at Capital, but not at Metro. At Provincial, the county council regarded CT as a satellite organization responsible for delivering a major part of the local authority's policy obligations. However, the local authority regarded Provincial as essentially a meritorious voluntary sector initiative (although it had been operating for 9 years) that provided key services. Whereas Capital was funded appropriately, Provincial was forced to lobby continually for resources to carry out the services it had been charged with and wished to develop. Provincial is in a more stable position, but the relationship with the county council was ably described in the second interview with Provincial's coordinator: "I think they used to trust us, but we did not trust them. Now I think we're beginning to trust them slightly. ... [T]hey've still got a long way ... to go before they can actually prove themselves reliable."

DISCUSSION OF RESULTS AND CONCLUSIONS

Our research focused on strategic management within specialized transportation provision. The research has shown that each CT organization adopted a fundamental strategy based on a quest for survival in what was perceived as an increasingly hostile and contested operating environment. The need for some stability in the funding base was identified as crucial to the ability to provide services. All three CT organizations embarked on strategies with growth potential. At Capital, external funding problems left the CT with no choice but to expand. At Metro, however, the CT was perceived as being unable to manage the rapid growth of dial-a-ride. Most significant, that perception came from within as well as from the external bodies. Each CT organization at the time of our research was showing signs that it was more professionally organized and managed. As for actual service provision, there was a degree of convergence between the operations of the CT organizations themselves and those of respective local public transportation providers. The implication for the CT organizations was a movement from traditional voluntaristic roots. The shift from traditional roots is shown in Figure 1.

The voluntarism-professionalism continuum reflects the pressures for change noted earlier. It represents the opportunities open to each CT organization in the way in which it delivers transportation services. The community orientation–entrepreneurial orientation continuum reflects a CT organization's strategy for survival. For example, at the start of our research, all three CT organizations were situated in the voluntarism/community-orientation quadrant. By the end of 1990, each had move (albeit at a different pace) toward the professionalism/entrepreneurial-orientation quadrant.

Our research has shown, however, that CT organizations can embrace either greater professionalism or entrepreneurship without sacrificing their traditional voluntaristic roots. For example, they can move toward the community-professional type of service provider, reflecting the kind of social service organization favored in Sweden. They can also move to the

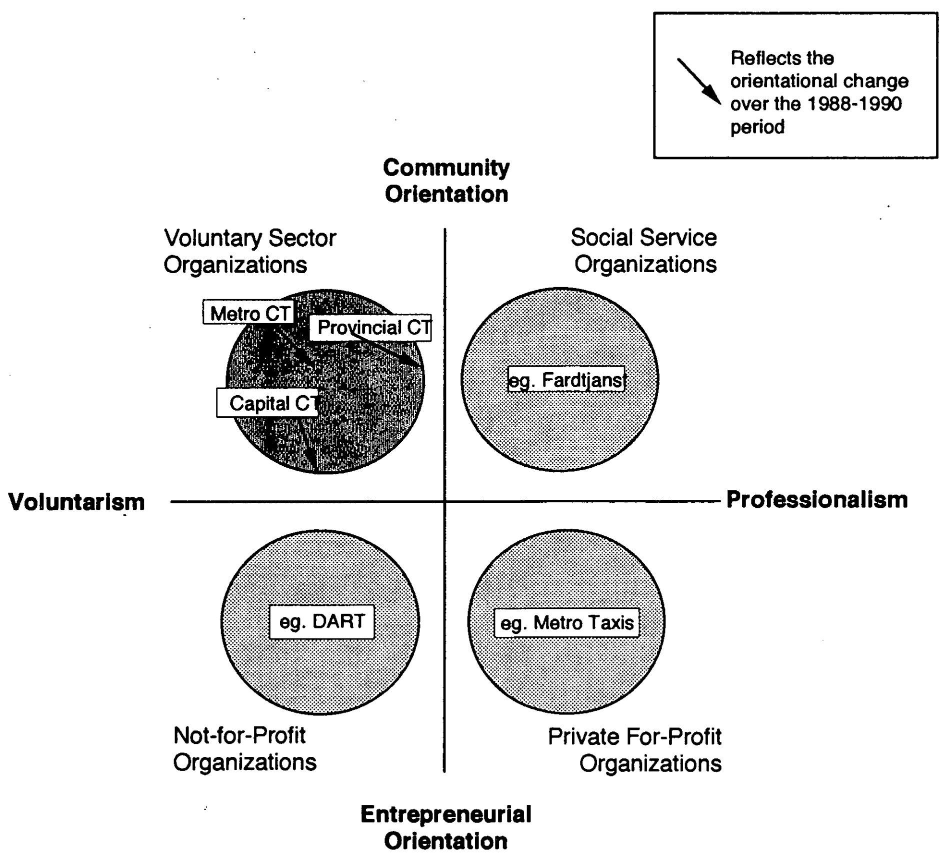

FIGURE 1 Cultural orientation.

voluntary-entrepreneurial type of service provider more typical in North America. However, the ability to move in one of these two directions, or to stand still, is limited by the multiorganizational context within which each CT must function.

Thus, it appears that the CT sector has reached a crossroads. Should it look to the Swedish model, which both provides specialized transportation and actively promotes measures to enhance accessibility to conventional public transportation? Should it encourage individual CT organizations to build on innovations such as the development of semifixed routes and expansion into social services, education, and health-related transportation? Some CT organizations would be content with small-scale community development activity. They would be seen as having served their role as transitional agents in reorganizing conventional public transportation as it affects mobility-handicapped persons. This however, would deny CT organizations growth opportunities, especially for those operating in urban areas. It would thus affect the growth of the CT sector. Standing still is therefore not an option; our evidence suggests a shift toward a voluntary-entrepreneurial orientation as a way of moving forward.

At the time we left the field, Metro's intended strategy was far from realized. In fact, the organization ceased to exist by the end of 1991. A specifically targeted furniture service and a skeleton group hire service are currently being provided by other voluntary organizations. Provincial has achieved a degree of stability, both within the organization and in its relationship with its funding bodies. In this sense it could be argued that Provincial has realized its intended strategy. Capital continues to grow, its relationship with the local authority as healthy as ever. It is clear that CT organizations have developed the professional expertise to provide specialized transportation services; many funding bodies have conceded this. Yet the increasingly competitive resourcing environment continues to constrain them in their capacity for growth and development.

ACKNOWLEDGMENTS

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Travel Training: Avenue to Public Transit

VIRGINIA CERENIO AND CONNIE SOPER

The Americans with Disabilities Act of 1990 mandates significant changes in the way transportation services for people with disabilities are provided. As in other areas of the country, fixed-route operators in the San Francisco Bay Area are now required to assume new levels of responsibility in overseeing both fixed-route and paratransit services. A basic premise guiding the regulations that interpret the law is that once a transit system becomes fully accessible, people with disabilities who are capable of using the system will use it. The law requires that each new vehicle purchased be equipped with a lift but recognizes that other factors contribute to a fully accessible system. Many people who have been unable to use public transit will now be able to do so because it will be accessible. For others, fear or lack of knowledge about the system may have prevented use of transit in the past, even though they may have been able to use it. From the operator's and the trainer's points of view, ways to tap this potential ridership and establish training programs that respond the needs of operators and to the people with disabilities that they serve will be explored.

In 1990 the Cerenio Management Group (CMG), of San Francisco, was awarded a training grant from Project ACTION (a federally funded program that sponsors demonstration projects to promote accessible transportation); recently it was successfully completed. Through the project, people with disabilities were trained to teach others with disabilities how to use fixed-route accessible service and to work with transit personnel so that transit personnel can better serve people with disabilities.

This paper will discuss the way trainers were recruited and selected, the curriculum designed for training, the goals and objectives of the program, and the results of the project. The paper will point out the effectiveness of using local resources within the disability community to provide training that may enable people with disabilities to use public transit.

BACKGROUND

Within in the nine-county San Francisco Bay Area, 23 transit operators are responsible for implementing the paratransit provisions of the Americans with Disabilities Act of 1990 (ADA). These agencies operate in rural, urban, and suburban communities and offer a variety of fixed-route bus, light rail, rapid rail, and ferryboat services to the public. The vast majority of these services are accessible, but the provision of paratransit is a new responsibility for most operators, one that is a significant additional expense.

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Currently, consistency is lacking among programs in the determination of paratransit eligibility, which has restricted interjurisdictional travel for paratransit consumers. To overcome this obstacle, the local metropolitan transportation planning organization, Metropolitan Transportation Commission, has initiated an effort with the region's operators and disability communities to establish regionwide criteria for ADA paratransit eligibility.

Efforts are under way to develop these criteria and to establish an eligibility process that will respond to the requirements of the ADA consistently throughout the region. A task force consisting of consumers with disabilities, paratransit providers, and transit operators is providing guidance for the project.

ROLE OF TRAVEL TRAINING

An overriding principle in establishing regional eligibility is the role of travel training in the eligibility process. Consumers and operators alike recognize the benefits of travel training; therefore, travel training is expected to be an integral part of the ADA paratransit eligibility system.

Unlike eligibility for some current paratransit systems, eligibility for paratransit under the ADA is not based solely on the existence of an applicant's disability. Instead, eligibility will be based on the individual's functional ability to use accessible fixed-route transit. The ADA assumes that most of those with disabilities will be able to use a public transit system once it is fully accessible.

Traditionally, an "accessible" vehicle has been one with a lift and securements to accommodate people in wheelchairs. The ADA clearly acknowledges that an accessible system is not achieved simply by adding a lift to a bus. For the first time, it is recognized that other features are necessary to achieve full accessibility. For example, transit systems are required to make public information readily available and drivers are required to call out stops. Such requirements may enable people to navigate a system that they previously could not.

In the Bay Area, as in other parts of the county, careful scrutiny and assessment will occur before paratransit eligibility is established. As part of the process, an applicant will be judged as to whether he or she is an appropriate candidate for training. In some cases, it may be determined that for at least some trips, with travel training, the applicant can use fixed-route service and is therefore not eligible for paratransit.

Even though transit vehicles and systems will be fully accessible, some people may be reluctant to use fixed-route transit—especially those who were previously able to access paratransit. Provision of training can enable a disabled person to use fixed-route transit, which is more cost-effective for the operator than providing paratransit.

NEED FOR GUIDELINES FOR TRAVEL TRAINING

In theory the merits of travel training are accepted, but most transit agencies in the region do not offer such services and are not sure how to begin a program. Furthermore, some perceive barriers (e.g., costs and liability) or are not aware of community resources that may be useful to them. Guidelines should be established for transit operators that wish to implement travel training programs and to use existing resources. In addition, there is a need to promote travel training for potential trainees.

CMG PROJECT ACTION GRANT

In 1991 Project ACTION funded CMG to conduct a two-phase training project to certify people with disabilities as sensitivity trainers for transit personnel and trainers of transit consumers with disabilities. The experiences and lessons learned from this project can serve as a model for transit properties throughout not only the Bay Area but the entire country.

The goals of the project were to develop

- A training program in which transit users with disabilities are certified as sensitivity trainers for fixed-route and paratransit personnel,
- A training program in which transit users with disabilities are certified as trainers of transit users with disabilities on how to use fixed-route and paratransit services effectively, and
- A sensitivity teachers training manual; the first section should train transit personnel and the second section should train transit users with disabilities on how to use the transportation network. The manual is entitled *TRANSFER: A Training Manual To Support Accessible Transit Systems for Persons with Disabilities*.

DESCRIPTION OF PROJECT ACTIVITIES

Key tasks were as follows:

1. Select trainees,
2. Develop sensitivity materials,
3. Develop training techniques,
4. Conduct training program,
5. Provide transportation personnel training,
6. Develop user materials,
7. Provide user training,
8. Certify trainers, and
9. Produce training manual.

Selecting trainees was an extensive process; it was based on screening applications and panel interviews. Out of 18 applicants, 15 were interviewed and 13 selected to participate by early June. The proposed goal was to have half of the trainees from San Francisco and half from other Bay Area counties. Of selected trainees, five were from San Francisco, five were from the East Bay (Oakland/Richmond), one was from the South Bay (San Mateo County), and one was from the North Bay (Marin County).

From this experience, it is recommended that a larger pool of applicants and trainees be targeted because of turnover. Of the 13 persons chosen to participate, 3 left the program during classroom training and 3 were unable to complete the field-training requirements. All of the reasons for leaving were due to disability. To plan and compensate for this attrition rate, select a larger group of trainees.

For each of the certified trainees, travel was one of many goals to be accomplished on a personal level. Independent travel was a part of a larger life plan; each person was already functioning independently in other parts of his or her life. Each person was able and willing to request assistance if needed.

More than 20 field training sessions were conducted by trainees and master trainers for transit personnel of fixed-route and paratransit providers. To implement field training, trainees were responsible for making their own travel arrangements—as well as those for other members on the training team—on accessible public transit to training sites throughout the Bay Area. Master trainers and trainees provided sensitivity training for fixed-route transit, van, and taxi operators and for social agencies that serve the disabled.

Field training was divided into levels of mastery. Each trainee had to receive a passing evaluation before proceeding to the next level. The first level consisted of observation by master trainers and peers. The second level consisted of team training with a master trainer. Then each trainee was required to team teach with their peers. The training was conducted with transit operators and, to the extent possible, under real-life conditions.

In CMG's team teaching, each trainer is responsible for knowing all aspects of the training but not necessarily for teaching all of them. In an actual training situation, someone with a disability should have a backup trainer, since his or her health condition may fluctuate daily. The trainees were trained to be prepared to provide training under "real" conditions, in which flexibility is a key part of successful training.

Finally, a training manual was produced for replication; it was based on the actual training program.

INTERACTION WITH TRANSIT AGENCIES

An important part of this project was to conduct training for transit agency personnel. When field training was scheduled, no transit companies requested travel training for customers, although it was offered. The transit agencies were not prepared; they had no program or staff to perform these functions. The transit agencies that had accessible services were not ready to cooperate in providing joint travel training or already had set travel training and trainer programs.

Despite these obstacles, travel training was provided to all Project ACTION trainees as an inherent part of their field training. Trainers arranged their own transportation using fixed-route or paratransit service to provide training sessions throughout the Bay Area. Arranging their own travel, either in groups or alone, was part of the travel training education and was encouraged by master trainers. The travel training that did occur was in excess of the two 4-hr sessions required.

To implement travel training at a transit agency, some recommendations follow:

- Transit agencies need to recognize the importance of soliciting the participation of transit consumers with disabilities in training, as trainers or as trainees.
- Transit agency representatives must be involved as part of the training process; they can be involved in many aspects: policy, procedures, funding, marketing, and so forth.
- The input of disabled transit consumers in the training process must be an integral part of the transit agency procedure.
- A suggested training manual is *TRANSFER*, which was designed for use nationwide by any person or transit agency interested in providing sensitivity or mobility training.

Some transit officials have supported the project since its inception. Both appointed and elected officials attended the graduation or sent letters of commendation and acknowledgment to trainees with disabilities when they completed their training program.

Since completion of the project, interested parties around the country have asked for information, lists of the certified trainers with disabilities for consultation, and copies of the training manual; they also want to discuss possible future projects.

For travel training to succeed in the transit agency organization, the philosophy of accessible transit for all must filter from management throughout the organization. Access must be reflected in policies, funding decisions, training programs for all personnel, marketing plans, fare structure incentives, and active community input.

POSTTRAINING ASSESSMENT

Participation in Project ACTION was a meaningful experience for the trainees. Besides the actual training, it increased a sense of self-worth and belonging in all trainees, who came from various backgrounds and levels of education. For several members, even speaking out in a group was a new and frightening experience. Tremendous gains were made and friendships nurtured during the program.

Many of the participants have returned to their respective transit providers with a determined sense of cooperative purpose and have increased their level of voluntarism as citizen participants on transit advisory committees for fixed-route, paratransit, and ADA implementation.

Graduates of the project now face some practical problems when arranging to conduct training. Because Project ACTION trainers have disabilities themselves, sometimes they do not have the personal or economic support necessary to arrange, coordinate, and conduct training sessions without help. Although team training has always been emphasized as an option, the backup support in most cases is beyond what they can provide to each other.

CMG is responsible for deciding person by person what these trainers need to enable them to function as practicable and effective trainers. An option would be to explore peer training, recruiting older adults (seniors) with transferable training skills and giving them the necessary content to coteach training sessions. These able-bodied seniors would provide the backup logistical support for the trainer. They would assist the trainer and possess sufficient knowledge to carry on the class if the trainer needed a break.

CONCLUSION

Each community is different, especially as far as its resources available to conduct training projects. Some common issues exist, however, despite different approaches to implementing the ADA and diverse geographic or cultural situations.

For the most part, transit operators now lack guidelines for establishing programs to conduct travel training for passengers with disabilities who may be capable of using fixed-route transit with appropriate training. This paper has identified some potential barriers and outlined the needs from the perspective of the transit provider and has discussed a model program that links the potential resources of trainers to the need for operators to establish training programs.

It is useful to consider transit consumers with disabilities as resources for the transit agency—in providing input to the content of any transit education program, in considering their marketing suggestions, and in working with the transit agency to sell the accessible system to their peers.

Mechanics of Mobility Aid Securement and Restraint on Public Transportation Vehicles

K. M. Hunter-Zaworski and D. G. Ullman

The Transportation Research Institute at Oregon State University is conducting a research and design project to develop a universal securement system for mobility aids in public transportation vehicles. The research team has embarked on a substantial study to determine the functional, operational, and engineering requirements of a universal securement system. As part of the study the team has developed an understanding of the mechanics of securement. As a result, the mechanics of securement and restraint systems for mobility aids will be explained. The discussion will focus on five generic classes of mobility aids and the characteristics of each class as they pertain to the securement problem. The operating conditions and dynamics of the public transportation vehicles that are relevant to securement and restraint will also be presented. The current technology in securement and restraint systems will be introduced in generic terms. The mobility aids, operating conditions, and securement and restraint systems will be discussed as an integrated system. In conclusion the future of securement and restraint systems will be examined.

There are more than 500 models and styles of mobility aids in use today. Mobility aids commonly used in the adult market will be discussed in five generic classes. These classes cover most aids, but some mobility aids bridge two classes and others are special-purpose devices that fit none of the classes.

MOBILITY AID CLASSES

Manual Wheelchairs

A manual wheelchair consists of two large wheels with two smaller castors in front. In general, the wheelchair frame can be folded. Manual or standard wheelchairs usually have detachable armrests and footrests that permit transfers in and out of the chair.

Sports or Lightweight Wheelchairs

Sport-style wheelchairs are very similar to standard wheelchairs except that they are generally much lighter and have smaller castors in the front and sometimes cambered wheels in the rear. Sports wheelchairs usually have rigid frames and do not fold, but they have quick-release wheels to ease storage. Eliminating the folding feature makes a wheelchair much lighter. Sports chairs often have much shorter wheelbases than standard chairs so they are more maneuverable, and they are stripped down to include the minimum of accessories (such as armrests).

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Electric Wheelchairs

Electric wheelchairs look like standard wheelchairs with large rear wheels and smaller front castors. Electric motors, batteries, and controllers are added to the frame. The large drive wheels are usually much wider and more robust than those on a standard wheelchair frame. There is a tremendous variety of power transmission and control systems for electric wheelchairs, but they are all essentially configured the same.

Powered-Base Wheelchairs

A powered-base wheelchair usually consists of three or four medium-sized wheels. All the motors, batteries, and controllers are underneath the seat on a powered base. Many of the powered bases are modular so that they can be broken down easily into components such as the steering column, batteries, motors and wheels, controller, and seat for transport in a personal vehicle. Powered-base mobility aids are generally robust and heavy for use outdoors and over rough terrain.

Three-Wheeled Scooters

There are many styles and models of three-wheeled scooters, which are generally much lighter and have smaller wheels than powered-base chairs. For models with rear-wheel drive, the batteries and motors are underneath the seat and the steering column is attached to the front wheel. For models with front-wheel drive, the batteries are underneath the seat and the motor and controller are attached to the front drive wheel. Several three-wheeled mobility aids are robust enough to be classified as powered bases.

MOBILITY AID WEIGHT AND CENTER OF GRAVITY

To develop the mechanics of secured mobility aids it is necessary to have information on the weight and centers of gravity of the mobility aid and of the passenger. To find this information for the mobility aid, a small project was undertaken to determine the centers of gravity of several representative models. The horizontal center of gravity was calculated from weight measurements made at each axle of the mobility aid. The vertical center of gravity of standard or sports wheelchairs was found by balancing the chair on its rear wheels; the center of gravity for battery-powered units was measured by weighing each wheel, then lifting one end of the vehicle 4 in. and reweighing the wheels. A summary of the data is given in Table 1. All values in this table have an error band of ±1 in. (25 mm) and ±2 lb (1 kg). The vertical center of gravity distance is measured from the floor. The horizontal center of gravity distance is measured forward from the center of the rear axle.

CHARACTERISTICS OF MOBILITY AID PASSENGERS

Passengers in mobility aids have a wide range of weights and weight distributions. To cover this range, data for 95th-percentile men and 5th-percentile women were studied (*1*,*2*). Lumped mass occupant models were used to determine the center of gravity. The model does not account for atrophy of the lower extremities, asymmetry, or occupant biomechanics that may be unique to paralysis or muscle weakness. Table 2 shows the center-of-gravity measurements for seated 5th-percentile female and 95th-percentile male mobility aid passengers. The horizontal distance is measured from the seat back, and the vertical distance is measured from the bottom of the feet.

OPERATING CONDITIONS

To discuss the mechanics of securement systems, it is necessary to know the conditions in which they must operate. Requirements for securement systems fall into two broad classes: the transfer of forces between the mobility aid and the vehicle carrying it, and the human factors involved in fastening and releasing the system. This discussion focuses on the transfer of forces and the mechanics of the securement systems.

The forces on a mobility aid that might make it move, bend, or break are created by the motions of the vehicle in which

TABLE 1 Summary of Measured Devices

MODEL	TYPE	VERTICAL CG in/(mm)	HORIZONTAL CG in/(mm)	WEIGHT lbs/(kg)
Invacare Rolls 1000	Standard Wheel-chair	12.0 (305)	7.0 (178)	40.0 (18)
Kuschell Champion 3000	Sport Chair	12.0 (305)	5.3 (135)	23.0 (10.4)
Rolls Arrow	Electric Wheelchair	10.0 (254)	6.2 (157)	169.0 (77)
Fortress-Scientific 655FS	Power Base	9.0 (229)	7.5 (190)	209.0 (95)
Fortress-Scientific 2000FS	Scooter	9.0 (229)	8.6 (218)	180.5 (82)
Everest & Jennings Carrette	Scooter	7.5 (190)	9.3 (236)	174.5 (79)
Invacare Tri-Rolls	Scooter	Not Available	8.2 (208)	147.5 (67)
Amigo RWD	Scooter	7.5 (190)	8.2 (208)	129.0 (59)
Average of 4 scooters tested	Scooter	8.0 (203)	8.6 (218)	158.0 (72)

NOTE: CG = center of gravity

TABLE 2 Center-of-Gravity Information for Mobility Aid Passenger

95th Percentile Male Weight	216 pounds	(97.2 kg)
Vertical Distance of Center of Gravity	26 in	(666mm)
Horizontal Distance of Center of Gravity	9 in	(230mm)
5th Percentile Female Weight	102 pounds	(46.0 kg)
Vertical Distance of Center of Gravity	20.5 in	(525mm)
Horizontal Distance of Center of Gravity	7 in	(179mm)

the mobility aid is secured; these forces are generated by accelerations of the vehicle. Accelerations are transformed into forces in accordance with a simplified version of Newton's law:

$$F = m \times A$$

where

F = force,
m = mass, and
A = acceleration.

According to this law, if the mass of the mobility aid and passenger and the amount of acceleration on the vehicle are known, the force on the securement system can be found. The mass of the mobility aid and passenger is equal to the weight in pounds divided by gravity (32.2 ft/sec^2). In SI units the mass of the mobility aid and passenger is given in kilograms.

In the previous section the weights of a sample of mobility aids and representative passengers were itemized; in this section the accelerations that can be expected to put loads on the securement system will be identified. The accelerations are summarized in Figure 1. The rest of the section explains the information in this figure. All values in Figure 1 are given in terms of *g*. Simply explained, if a vehicle containing a 250-lb combination of mobility aid and passenger accelerates at 1 *g*, the force on the securement system will be 250 lb. If it accelerates at 10 *g*, the force will be 2,500 lb.

Essentially, two types of vehicle are used to transport mobility aids: fixed-route vehicles and demand vehicles. Fixed-route vehicles, buses that run on a set schedule and circuit, are generally large (greater than 30,000 lb gross vehicle weight) and have limited acceleration capabilities; they back up rarely, corner slowly, and, except in accident conditions, put low load on the mobility aid or securement system. Demand vehicles, on the other hand, range from common passenger vans to modified truck beds. They are smaller, lighter, and more maneuverable than fixed-route vehicles.

Another classification is the operating situation of the vehicle. Specifically, each type of vehicle spends most of its time under normal operating conditions. These include all potential operations in which the vehicle does not hit another object or tip over. Generally, for normal operating conditions, the accelerations of the vehicle are low. Even though most vehicles spend their entire operating lives within the normal operating conditions, accident conditions must also be accounted for. As shown in Figure 1, accident conditions result in much higher accelerations than normal operating conditions.

The last variable in Figure 1 is the direction of the acceleration of the vehicle. Each direction of concern is defined in terms of the direction of the force placed on the securement system:

1. Forward: The securement system holds the mobility aid from moving or pitching forward. This force is caused by the vehicle's braking under normal operating conditions or hitting something head on in accident conditions. Accelerations that cause forward forces are often called decelerations.
2. Sideward: The securement system holds the mobility aid from moving or rocking side to side. This force is caused by the vehicle's turning a corner under normal operating conditions or being hit from the side in accident conditions.
3. Rearward: The securement system holds the mobility aid from moving or pitching backward. This force is caused by the vehicle's accelerating, braking while backing up under normal conditions, or being hit from the rear in accident conditions.

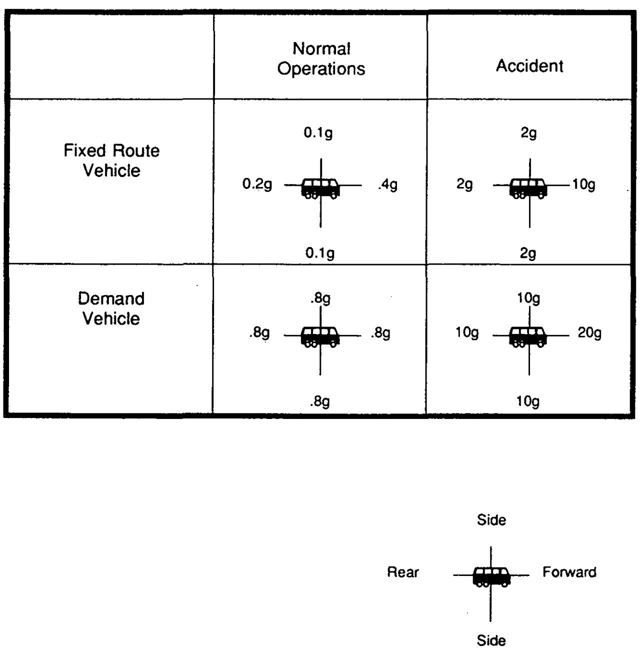

FIGURE 1 Accelerations of vehicles carrying mobility aids (*g* force loads).

Shown in the figure is the acceleration in each of the major directions for each of the two types of vehicle in each operating situation. The sources for each of the values and the limitations on them are discussed in the following paragraphs.

Fixed-Route Vehicle, Normal Operating Conditions

The values shown are estimates for the accelerations for fixed-route vehicles operating normally. The forward acceleration value of 0.4 *g* is based on standards set for the maximum braking capability of large vehicles. Specifically, according to SAE J992, vehicles of more than 10,000 lb must decelerate at least 3.7 m/sec^2. This is equivalent to 12 ft/sec^2, or 0.4 *g*. According to the U.S. Department of Transportation (DOT), tests have shown that the maximum forward deceleration experienced by a bus is 0.8 to 1.0 *g* (*3*).

The sideward value of 0.2 *g* is an estimate because there are no known standards or measurements for sideward accelerations or forces on restraint systems in fixed-route vehicles. Acceleration measurements for sideward accelerations on large transit buses were between 0.3 and 0.37 *g* for severe operating conditions.

The rearward value of 0.1 *g* is based on the limited acceleration possible with the throttle restrictors used on all buses.

It is possible for a bus to achieve a higher rate by backing up and braking hard, but this condition seldom occurs in normal operating situations.

Fixed-Route Vehicle, Accident Conditions

The values shown in the figure are estimates for the accelerations for fixed-route vehicles in accident situations. The forward acceleration value of 10 *g* is based on a number of measurements and standards. This has been confirmed by BC Transit tests in which a bus and a van were wrecked in a head-on collision (*4*). The maximum deceleration of the bus was 10 *g* with a duration of about 0.1 sec. The value of 10 *g* has been adopted by some agencies (such as DOT) as a guideline and proposed in other standards by the International Standards Organization (ISO). In some standards and guidelines this is translated into a force on the securement system. Specifically, if the mobility aid and passenger weighed 400 lb, then the force on the securement system would be 4,000 lb (10 × 400) applied horizontally at the center of gravity. This value is given elsewhere (*3*).

The sideward value of 2 *g* was developed through calculations. If a standard-sized car of 1000 kg (2,220 lb) hits a stationary light bus of 10 000 kg (22,000 lb) in the side at 50 km/hr (31 mph), the bus will experience a sideward acceleration of 1.3 *g*. If another bus of the same weight at 17 km/hr (10 mph) hits the first bus from the side, the first bus will experience an acceleration of 2.3 *g*. From these values and a lack of other published data, the value of 2.0 *g* has been selected.

The rearward value of 2 *g* is based on the same assumptions as the sideward situation.

Demand Vehicle, Normal Operating Conditions

The values shown are estimates for the accelerations for demand vehicles operating normally. All values are 0.8 *g* on the basis of the results from tests performed to find the maximum forces and displacements on a scooter restrained by a four-belt system (*5*). The vehicle used in these tests was a standard 1990 Ford chassis with a custom body designed to transport mobility aids. This vehicle was run through a series of tests including maximum acceleration at full throttle, maximum braking, constant radius turns, and swerving maneuvers. The results show that the maximum acceleration that this vehicle can produce without hitting anything or rolling over is about 0.8 *g* in any direction. This value occurs when braking either forward or backward or when swerving or otherwise turning as sharply as possible. Note that the braking performance while backing up is far more severe than the force exerted when accelerating as hard as possible.

Demand Vehicle, Accident Conditions

The values shown are estimates for the accelerations for demand vehicles operating under accident conditions. Most standards and testing of securement devices are based on the forward value of 20 *g* for this case. Experimental data for a van hitting a cement wall at 30 mph (50 km/hr) range to 30 *g* for a very short period (*4*) and to 10 *g* for a van hitting a bus. The value of 10 *g* for both rear and side impacts was based on the latter experimental value and supported by calculations. In effect, if a bus hits a stationary van at 30 mph (50 km/hr), the resulting acceleration on the van will be 10 *g* regardless of direction.

MOBILITY AID SECUREMENT AND RESTRAINT TECHNOLOGY

The discussion on securement and restraint technology will focus on the generic classes of securement systems and restraints and not on specific commercially available systems. It may be possible to draw inferences to specific brands, but this is not the intent. Securement systems refer to the technology used to immobilize the mobility aid. Restraint systems are technologies that restrain the mobility aid passenger from excessive movement.

Belts

Belt securement is generally provided in two-, three-, or four-belt systems; these are often called two-, three-, and four-point securement systems. Two-belt systems are often used on fixed-route bus systems to secure standard, sport, and electric wheelchairs. The mobility aid is backed in against a modesty panel or a flip-up seat and faces forward. The two belts are usually attached to a modesty panel, stanchions, or the floor and reach up from behind and attach to the front uprights of the mobility aid frame. This system is flexible, inexpensive, and adaptable to different models of mobility aids; some mobility aid passengers can attach the system by themselves.

Three-belt systems are similar to the two-belt systems; the third belt is used to attach to the front or cross members of the mobility aid for added stability. One three-belt system that is used on a fixed-route vehicle consists of an additional strap that is mounted on the sidewall of the bus and comes across the platform of a scooter and fastens on the floor. This third strap is often called the scooter strap and is used for scooters and powered-base mobility aids. Passengers are generally unable to fasten three-belt systems unaided.

Four-belt systems consist of two belts that attach to the front of the mobility aid and two belts that come up from behind and attach at the rear uprights of the wheelchair frame. In general, the mobility aid faces forward but it does not back in against a flip-up seat or modesty panel. These systems are generally found on demand-responsive vehicles and fasten to tracks or plates on the floor or side of a vehicle. Four-belt systems cannot be attached independently by the passenger.

Wheelclamps and Belts

Many fixed-route transit agencies provide wheelclamps and belts. Wheelclamp systems usually also have one or two additional belts. The belt secures the mobility aid on the opposite side of the wheelclamp. The orientation of the belts with respect to the side and stanchion of the vehicle usually depends on the orientation of the flip-up passenger seat in the transit vehicle. If the flip-up seat faces forward, then the belt or belts pull up from under the seat. On flip-up seats that face the side, the belt pulls out from the side of the vehicle and attaches to the front of the mobility aid.

The wheelclamp is on either the aisle side or the outside of the transit vehicle. Aisle-side placement permits the extra belts to function better but may pose a tripping hazard. Many newer models of wheelclamps accommodate both narrow and wide wheelchair wheels. Observations of these systems in service indicate that they are installed in many different configurations and often the passenger uses only the wheelclamp, even when instructions say that the belt must also be used for securement. Only the wheelclamp is used because it can be easily engaged without the help of others. When the wheelclamp is used alone it becomes a one-point securement system, which is unbalanced and asymmetrical and consequently puts unequal loading on a mobility aid frame.

Lockdown Systems

Lockdown securement systems are almost exclusively used by mobility aid passengers who drive their own vehicles. In general, lockdown systems require the attachment of additional hardware to the mobility aid frame and vehicle. Often the additional hardware is attached underneath the mobility aid, so it decreases the clearance underneath the mobility aid, which can be a problem. The advantage of this technology is that mobility aid passengers can use it independently, quickly, and easily. Lockdown systems provide fast, convenient, and independent securement. In most lockdown systems, the attachment mechanism acts through the center of gravity of the mobility aid.

Restraint Systems

Restraint systems are used to restrain the mobility aid passenger. They can be classified in terms of the number of belts or points of restraint: generally there are two-, three-, or four-point restraint systems. The use of restraint systems for fixed-route vehicles is usually voluntary, but passenger restraint systems are nearly always required for demand-responsive vehicles. There is controversy over whether the restraint system should be attached to the mobility aid, the vehicle, or the securement system. In the proposed standards ISO and SAE have taken the position that the restraint system must be attached to the transit vehicle. Typically, the mobility aid is not strong enough to take the restraint loads, but the mobility aid must be secured enough itself to avoid pinning or loading the occupant in a crash. The rationale behind placing the restraint system on the mobility aid is that the mobility aid passenger would not be pinned between the restraint and the mobility aid if there was relative movement between the mobility aid and the securement system. However, attaching the restraint system to the securement system or off the mobility aid would permit more options for personal restraint.

Two-point restraint consists of a lap belt that is attached either directly to the mobility aid or securement system or directly to the transit vehicle. The lap belt restrains the pelvis but does not prevent the torso from rotating. One of the major problems with two-point restraint is the routing of the belt given the design of the mobility aid.

Three-point restraint combines a lap belt and shoulder strap. In general, a three-point restraint system is attached directly to the securement system or the transit vehicle. A three-point system provides restraint to the pelvis and limits rotation of the torso.

Four-point restraint consists of a lap belt and shoulder harness and provides the highest level of restraint. The lap belt restrains the pelvis, and the shoulder harness provides symmetric restraint to the upper torso and prevents rotation and torsion. Four-point restraint systems are often provided with optional head restraint systems. Head restraint is a different issue, one related to back support.

MECHANICS OF SECUREMENT SYSTEMS

In this section the capabilities of the different types of securement system will be discussed. The discussion will cover the general characteristics of each system and its specific operation with the five classes of mobility aids. No matter which securement system is used, it must provide forces sufficient to hold the mobility aid in all three directions: forward, sideward, and rearward. It must also keep the mobility aid from rotating about any axis: tipping forward, rearward, or sideward, or pivoting about the vertical axis.

The securement systems shown in Figure 2 will be used to illustrate and assist with the discussion of the mechanics of securement. The figure shows four belt configurations for illustrative purposes. Specific systems will be discussed later. The examples will be for the forward forces only, when the vehicle is decelerating.

Assume that Belts A and C are being used. The passenger is restrained with a lap belt to the mobility aid, and the mobility aid is secured with a two-belt system to the floor of the vehicle. In a deceleration, the forward force on the passenger, which is centered on his or her center of gravity, pulls on Belt C. This force is transferred to the mobility aid, and thus the force on Belt A is for both the mobility aid and passenger. Because the center of gravity for the combination is above the line between the point at which Belt A attaches to the mobility aid and where it attaches to the floor, the mobility aid and passenger will tend to tip forward, making the securement system ineffective. If the passenger is unrestrained, the force on Belt A will only be that to secure the mobility aid and the passenger will fly forward out of the mobility aid during the deceleration. If the mobility aid's center of gravity is on or only slightly above Belt A, the mobility aid will have little tendency to tip.

For the second example, assume that Belt B is used instead of Belt A. Now the center of gravity is always below the line of the belt; therefore, during a deceleration the mobility aids will tend to tip back, whether the passenger is belted in or not.

If Belt D is used to both restrain the passenger and secure the mobility aid, then for deceleration, the force on the mobility aid is transferred through the passenger to be carried by Belt D. This situation can crush the passenger.

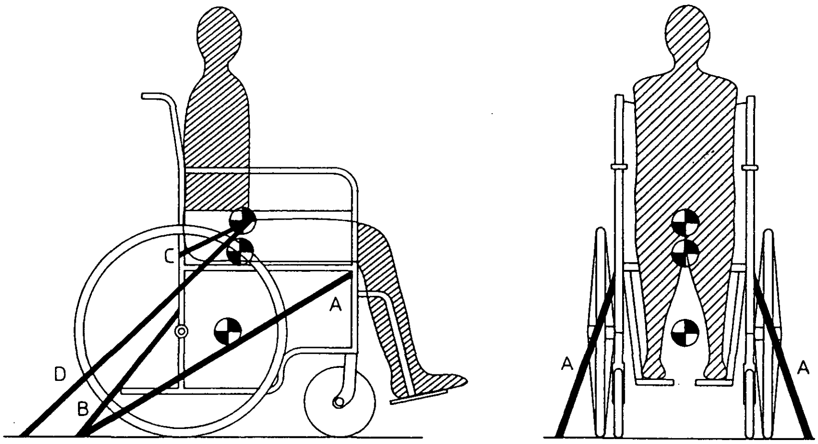

FIGURE 2 Generalized securement system.

If Belts A and D are used together, and both belts work as designed, it is assumed that Belt D carries the force on the passenger and Belt A carries the force on the mobility aid only. However, if Belt A is loose, fails, or is improperly placed, then the same situation as with only Belt D occurs.

Note that the examples focused only on forward forces and rotations that tip the mobility aid either forward or backward. The same types of motion can also occur to the side.

The discussion on the mechanics of the different securement systems will focus on describing the forces on the mobility aid and the occupant and ways the securement systems counteract those forces that result from accelerations that occur under normal and accident conditions. Each section will describe the forces that the securement systems put on the mobility aid. To secure the mobility aid adequately, the securement system must limit translation in three directions and rotation about three axes, during forward, rearward, and sideward acceleration under normal and accident conditions.

Note that securement during accident conditions is only as good as the structural integrity of the mobility aid itself. Most mobility aids were not designed to be secured and may fail under heavy loads. A few manufacturers have begun to take accident loadings into account when designing mobility aids.

Belt Securement Systems

In a two-belt system it is assumed that the belts are attached to the front portion of the mobility aid frame (Belt A in Figure 2). To limit translation and rotation of the mobility aid from side to side, the line of the belts should pass out to the side of the mobility aid as shown in Figure 2 (*right*).

Assuming that a mobility is backed against a flip-up seat, a two-belt securement system can secure a mobility aid in the forward and rearward directions and limit sideward movement. It is recommended that the belts pass down toward the floor at an angle of between 60 and 45 degrees and pass out to the side at about 15 to 30 degrees (Canadian Standards Association Z605; draft).

One of the major problems with two-belt systems is finding appropriate attachment locations on the powered-base and scooter-style mobility aids for the two belts that also meet the recommendation for angles and secure attachment points.

A three-belt securement system is a two-belt securement system with an extra strap that is provided to prevent scooters and powered-base mobility aids from tipping over sideways. A three-belt system often consists of a two-belt system with an added scooter strap. The scooter strap is mounted on the interior sidewall of the bus; it comes across the platform of a scooter and fits into a fastener on the floor of the bus. The two-belt system prevents translations and rotations that were discussed earlier, and the extra strap limits sideward motion and tipping to the side.

A four-belt securement system provides the best level of securement. Four-belt securement systems restrict translation forward, rearward, and sideward and rotation about the three perpendicular axes. It is important that the belts pass down toward the floor at about 45 degrees and pass out to the side at about 30 degrees. These angles are suggested so that there is a sufficient horizontal component to counteract forward, rearward, and sideward forces. The two belts attached at the front of the mobility aid pull forward and counteract the forces induced by rearward acceleration. If all four belts are attached at an angle to the side, they will counteract the forces induced by side-to-side acceleration.

Four-point securement systems have problems attaching to the powered-base or scooter-style mobility aids because there are not enough attachment locations to provide balanced restraining forces. Two manufacturers of mobility aids are now providing dedicated attachment points on some of the new models. One of the manufacturers provides an accessory kit to modify a mobility aid so that a securement system can attach. These modifications are designed for four-point belt securement systems.

Wheelclamp Securement Systems

A wheelclamp restricts forward, backward, and sideward movement but does not prevent rotation. Therefore, the wheelclamp must be used with one or more belts. During rapid acceleration and deceleration, a wheelclamp will not prevent a mobility aid from rotating, and because it is attached to only one wheel, there may be significant structural damage to the mobility aid.

A wheelclamp-and-belt combination provides two-point restraint: the wheelclamp prevents translational movement, and the extra belt limits rotation. One of the major problems of using a single belt with a wheelclamp is the unequal loading on the mobility aid frame. Rotation about the main wheels and movement from side to side is dependent on the configuration of the wheelclamp-belt combination. If two belts are used with a wheelclamp, the loading is more symmetrical and there will be less side-to-side movement or rotation.

Lockdown Securement Systems

The lockdown securement systems that have been studied are designed for use in personal vehicles. They require hardware on the mobility aids and on the vehicle. The interface of these two acts much like a trailer hitch and transmits forces like the belt systems do. Usually the interface is below the mobility aid, directly below the center of gravity. During deceleration the lockdown not only takes the force generated forward but counteracts tipping by holding down the center of the mobility aid. The same is true for forces in the other directions.

SUMMARY AND FUTURE NEEDS

The basic mechanics of mobility aid securement have been discussed. Current securement systems are adequate for normal operations but leave much to be desired. Most are hard to engage and time-consuming to attach, and only the four-belt and lockdown systems can be secured adequately in all directions. Most mobility aids are not designed to be secured or to survive an accident situation. In an ideal world all mobility aids would be transportable, and all securement systems would be easy to use and connect to all mobility aids. To reach this ideal,

1. Realistic standards based on real numbers for accelerations supported from accident data are needed. For example, the frequency of an accident of a particular magnitude of acceleration may be so small that the proposed standards are unrealistic.
2. Mobility aids must be designed to be transportable. They must have the structural integrity to withstand normal operations and accident situations, and they must be designed to be securable.
3. Universal securement systems must be developed. They must connect to all common types of mobility aids and be easy and quick to use.
4. The rehabilitation and transportation communities must be educated about what constitutes safe securement.

SAE, ISO, and the Canadian Standards Association are working on standards that will address the need for realistic standards and transportable mobility aids.

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Engineering Appraisal of Wheelchair Lifts

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The findings of a continuing study to investigate the design, operation, and maintenance procedures of wheelchair lifts in transportation buses are described. The primary objective is to develop structural design guidelines for rigid platform lifts. Structural design aspects of current wheelchair lift specifications are reviewed, as are the demand conditions that better describe the serviceability and ultimate limit state loads for the design of lift structures. The load demand conditions are determined on the basis of a field investigation of rural transit agencies and a survey of fleet managers, fleet maintenance personnel, and bus drivers. The lift structural performance is evaluated on the basis of a finite element model developed for the rigid platform lift. The finite element model is used for evaluating the structural component deformation and strength supplies of the lift structure under the critical demand conditions. The conclusion includes the evaluation of the structural performance of the rigid platform lift. The numerical data are obtained from a lift structure similar to those used in small and medium-sized transportation buses.

This paper is based on an ongoing study to investigate the design, operation, and maintenance aspects of wheelchair lifts. The goal of the multiphased project is to assess, identify, and resolve the sources of wheelchair lift failures in transit buses. The objective of Phase 1 was to perform a preliminary investigation of the design, operation, and maintenance aspects of wheelchair lifts (*1*). In this phase, manufacturers and fleet managers were surveyed, and a mathematical computer-based model describing the lift was developed using finite element techniques. The mathematical model was used to analyze the structural component strengths and deformation. In addition, the framework of a reliability model was established on the basis of repair data developed with the help of transportation agencies.

In Phase 2, the modeling work (both structural and statistical) was continued in order to refine and calibrate the various model parameters. In this phase, an experimental investigation of the operation of wheelchair lifts was initiated to aid in the development of structural specifications to improve such operation. The Phase 1 report from which this paper is developed addresses the problem identification process designed to examine the serviceability of wheelchair lifts. This process is based on a combination of engineering and statistical analysis that was conducted independently using a computer-based finite element model of the lift's structural system. A statistical analysis of a select sample of lift repair data was conducted for developing a reliability model. A discussion of the results of the entire Phase 1 report is beyond the scope of the paper; instead, the focus is on the modeling effort and structural analysis of the rigid platform lift.

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Wheelchair lifts used in transit buses are categorized with respect to their architecture as active (platform) or passive (folding). The following terminologies defining the lift categories are adopted from the specifications (*2*):

- Lift or wheelchair lift: A lift is a level-change device used to assist transit and paratransit users with limited mobility. The terms "lift" and "wheelchair lift" are interchangeable.
- Active lift: An active lift is one that when stowed may interfere with the use of the vehicle entrance at which the lift is located; when raised and lowered, it operates primarily outside the vehicle. It is also called a platform lift.
- Passive lift: A passive lift is one that when stowed allows the unlimited use of the vehicle door in which the lift is located. It is also called a step lift.

OBJECTIVES

The primary goal of this study is to improve the structural design guidelines of rigid platform lifts. The structural analysis model of the rigid platform lift will be presented, and the current specifications that are the basis of the design of the rigid platform lift will be summarized. Structural design aspects of the current specifications are critiqued, and additional load demand conditions that better describe the serviceability and ultimate limit state actions on the lift structure are described. The lift response to these demand conditions are evaluated using the structural analysis model. The numerical proportions and other structural parameters of the lift structure are acquired from a lift being used in public transportation buses.

STRUCTURAL SPECIFICATIONS

Wheelchair lifts used in small transportation buses are commonly called rigid platform or active lifts. The rigid platform lift requires a special entrance to the bus and consists of the main frame, deployment/actuator assembly, and a platform frame. An example of a rigid platform lift is shown in Figure 1. The specifications pertaining to the lift structural system are covered in various publications (*2,3*). In these specifications the design issues are grouped under design loads for service and ultimate limit states, allowable and maximum component stresses, allowable deformations, and testing and durability requirements. The most comprehensive specification covering these aspects is the primary basis of manufacturers' design specifications (*3*).

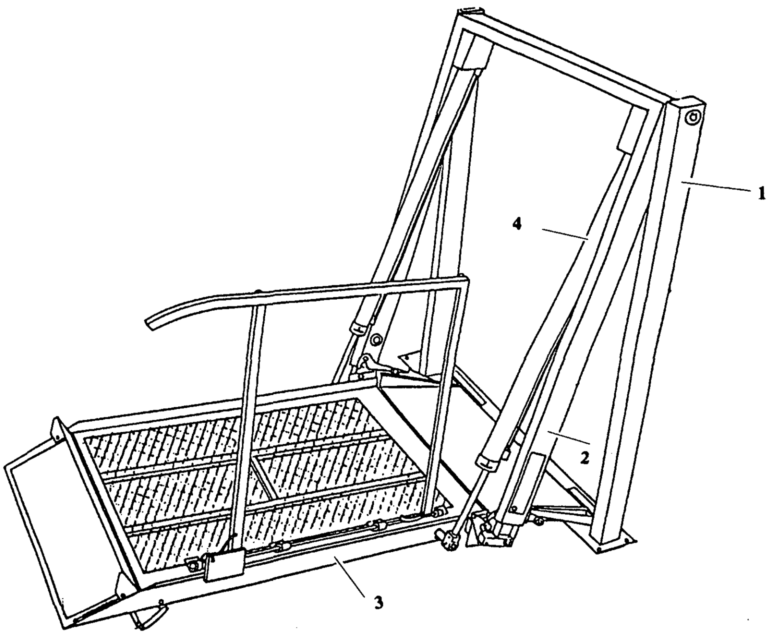


FIGURE 1 Active lift used in transit buses.

The critical design aspects of the lift structural system are as follows (*3*):

1. Lift system self weight is limited to 4450 N (1,000 lbf) for standard buses and 1780 N (400 lbf) for small buses.
2. Service (operating) design load is 2670 N (600 lbf), and ultimate design load is 8010 N (1,800 lbf). Ultimate design load is defined as the load to initiate yielding in any component.
3. Lift service deformations are defined in terms of platform rotations and limited to 3 degrees in any direction.
4. The dynamic actions during lift operation are defined in terms of platform dynamics and limited to 150 mm/sec (6 in./sec) velocity, 0.3 *g* acceleration, and 0.3 *g*/sec jerk.
5. Lift durability is defined as useful life of 12 years and by number of deployment cycles. The durability tests require 10,000 cycles of deployment and 600 operational cycles under 2670 N (600 lbf) followed by 15,000 operational cycles under 1780 N (400 lbf).

STRUCTURAL ANALYSIS

Structural Model

The rigid platform lift (Figure 1) structure consists of three main subassemblies: the main frame, the deployment system, and the platform structure. The main frame consists of two side columns and a common base plate that allows connection to the bus chassis. The deployment system consists of two telescoping members that allow the platform to be raised and lowered. Two hydraulic actuators and two cam brackets that allow the telescoping members to swing forward of the main frame plane are also parts of the deployment system. The platform structure consists of the platform beams, handlebar, and decking.

To bring the lift shown in Figure 1 to full deployment, the dual hydraulic cylinders extend downward approximately 1150 mm (45 in.) to reach the ground. To stow the lift after full deployment, the hydraulic cylinders will retract and fold the platform between the telescoping tube components, upon which the cylinder and sliding tube assembly will swing inward with the assistance of the cam bracket and align with the main frame. The actuators assist in folding the platform and retracting the assembly inside the bus. This motion is achieved by a cam bracket that rotates the platform. During deployment a bridge plate joins the platform with the bus floor, and the platform is held at a semideployed position with two key hinges (also defined as the cam brackets)—one at each end—that allow the platform to rotate 90 degrees.

The geometric properties of the deployment and platform systems are primarily defined by the lift's functional expectations. The wheelchair size that can be accommodated is a function of the platform size, and deployment system geometry is related to the bus's floor clearance from the ground. The rigid platform lift is often used in small to medium-sized transit and paratransit buses. It requires a deployment distance of approximately 1150 mm (45 in.). The platform dimensions vary among different manufacturers and models. In this study, typical platform dimensions of 760 mm (30 in.) wide and 1070 mm (42 in.) long were used.

Component properties and material properties used in the structural model are taken from the lift shown in Figure 1. The model at this stage covers only the fully deployed lift configuration. Other lift configurations, such as fully stowed and semideployed, will be analyzed in future work.

The simplified geometric description of the lift structure is shown in Figure 2. The bridge plate, platform decking, and handrail are deleted from the figure because they do not contribute to the lift's load-carrying capacity. In addition, the key-hinge connections that hold the platform rigidly in deployed position are simplified.

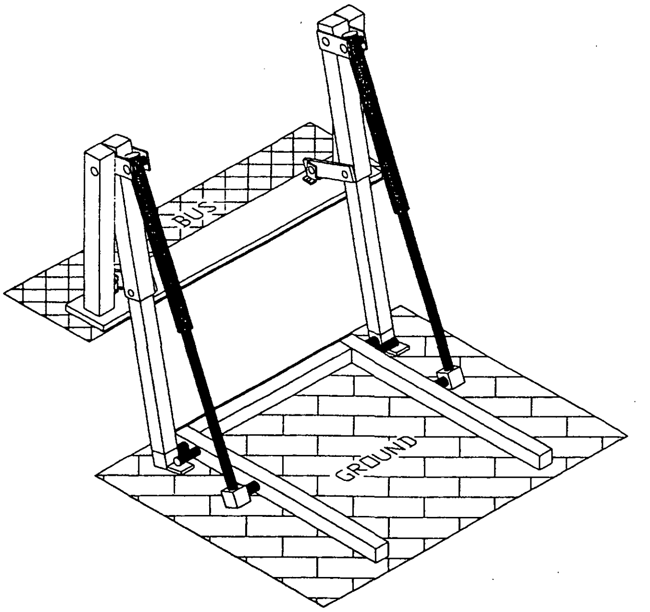


FIGURE 2 Rigid platform lift in deployed position.

Finite Element Model

The finite element model of the lift structural system is developed from the simplified geometry and shown in Figure 3. The nodal coordinates are given in Table 1. Each finite element describes the force-versus-deformation relationship of a portion of structures. In this figure the node numbers are included that designate the element boundaries and connectivity between each element. The structural model is described by seven element groups of two element types; the element types are three-dimensional beam element and three-dimensional truss element. A total of 17 nodes and 20 elements describe the model.

The three-dimensional truss elements are described by cross-sectional area only. The three-dimensional beam elements are described by the moment of inertia with respect to two orthogonal axes with cross-sectional areas. Note the description of the hollow box sections between Nodes 1 through 5 and Node 9 in Figure 3 that telescope during deployment. In these two elements, bending stiffness and, at the joint connecting them, rotational degree of freedom should be present; however, there cannot be any axial stiffness because the components are allowed to slide in and out. This characteristic is modeled by releasing the axial degree of freedom along the axis of the element.

For this analysis the interaction of the lift structure with the bus structure is ignored. The lift frame connections to the bus frame connections are assumed to be fixed.

The element groups, node numbers designating the element boundaries, element indexes, cross-sectional geometry, and geometric properties are given in Table 2. Element Indexes 1 and 2 constitute the main framing, Element Indexes 3 through 12 constitute the deployment system, and Element Indexes 13 through 20 represent the platform structure.

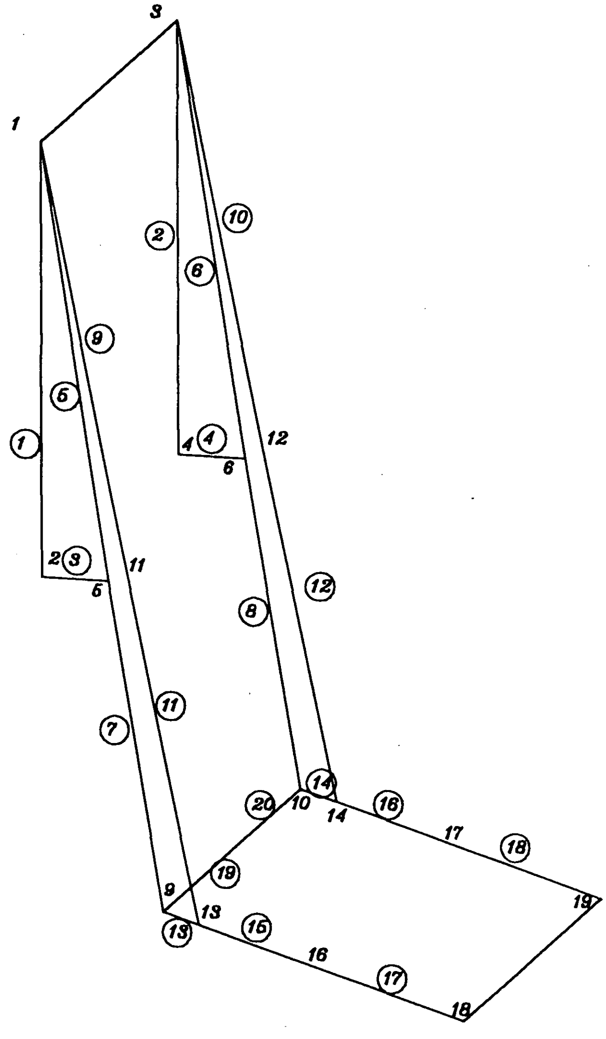


FIGURE 3 Discretized model of fully deployed lift.

Loading Conditions

During deployment and stowing the lift structure is subjected to static and dynamic loads in addition to the passenger (service) loads. Some examples of these load demands are (a) inertia force on the lift in the stowed position while the bus is in motion, (b) upward force from the ground due to lift overextension during deployment (some active lifts include a ground sensor, but the sensor may be inoperable or the ground uneven), and (c) impact factor when the platform motion is initiated under passenger load. These loading conditions are presented in Table 3.

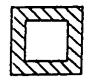
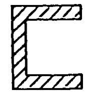
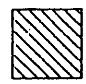
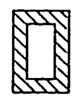
The service level load is increased to 4450 N (1,000 lbf) assuming an impact factor of 1.4, which is a function of rise time and the dynamic properties of the lift structures. The dynamic forces will be converted to equivalent static loads when multiplied with the impact factor. The impact factor is computed using the lift platform velocity of 250 mm/sec (10 in./sec) and a rise time of 0.5 sec to achieve the maximum

TABLE 1 Nodal Coordinates

Node Number	X millimeter	Y millimeter	Z millimeter
1	0	1625.6	762
2	0	0	762
3	0	1625.6	0
4	0	0	0
5	241.3	76.2	762
6	241.3	76.2	0
9	431.8	-1092.2	762
10	431.8	-1092.2	0
11	302.3	152.4	762
12	302.3	152.4	0
13	558.8	-1092.2	762
14	558.8	-1092.2	0
15	431.8	-1092.2	381
16	965.2	-1092.2	762
17	965.2	-1092.2	0
18	1498.6	-1092.2	762
19	1498.6	-1092.2	0

Note: Node numbers 7 and 8 coincide with node numbers 5 and 6.
1 Inch = 25.4 millimeters

TABLE 2 Lift Structural Element Geometry and Properties

Element	Nodes	Geometry	Type	Property
1 2 5 6	1 - 2 3 - 4 26 - 5 27 - 6		Beam Beam Beam Beam	$A = 1620\ mm^2$ $I_x = 1061390\ mm^4$ $I_y = 541100\ mm^4$
7 8	24 - 9 25 - 10		Beam Beam	$A = 810\ mm^2$ $I_x = 466180\ mm^4$ $I_y = 124870\ mm^4$
9 10	20 - 11 21 - 12		Truss	$A = 1160\ mm^2$
11 12	11 - 22 12 - 23		Truss	$A = 1030\ mm^2$
13 14 15 16 17 18	9 - 13 10 - 14 13 - 16 14 - 17 16 - 18 17 - 19		Beam Beam Beam Beam Beam Beam	$A = 1290\ mm^2$ $I_x = 141520\ mm^4$ $I_y = 141520\ mm^4$
19 20	9 - 15 15 - 10		Beam Beam	$A = 1290\ mm^2$ $I_x = 264310\ mm^4$ $I_y = 865760\ mm^4$
3 4	2 - 5 4 - 6		Truss	$A = 290\ mm^2$

1 $Inch^2$ = 645.1 $millimeter^2$

1 $Inch^4$ = 416231 $millimeters^4$

TABLE 3 Load Conditions

Load Index	Load Condition	Configuration	Description
1	Gravity	2@1100 N & 1 @ 2225 N	Service load
2	Platform two beams against ground	2 @ 4450 N	Impact load
3	Platform one beam against ground	1 @ 8900 N	Impact load
4	Platform one beam against ground	3 @ 3100 N	Impact load
5	Platform one beam against ground	2 @ 4450 N	Impact load
6	Gravity	2 @ 2780 N & 1 @ 5560 N	Ultimate load

1 Pound = 4.45 Newton

velocity, which generates an acceleration of 0.05 g, where g is the gravitational acceleration.

In the analysis of the loads when the lift is fully deployed, the loading cases used are service load condition, maximum gravity load to cause first yield of the lift structure, and conditions observed when the lift is overextended to the uneven ground. The loads due to overextension were observed to occur very frequently in the field.

The ultimate limit gravity load specified as 11.1 kN (2,500 lbf) includes impact load. The ultimate load is computed from a factor of safety of 2.5 against yielding required by specifications. More recently, the Americans with Disabilities Act of 1990 (ADA) specifies a factor of safety of 6 for all moving parts of the lift (*4*). The total load due to lift overextension is taken to be 8.9 kN (2,000 lbf) to account for the hydraulic actuators pushing against the ground. This load, acting upward, is moved to various locations of the platform to simulate uneven ground.

The first yield capacity of the lift structure is computed by reanalyzing the structural model under incrementally increasing gravity load until the maximum stress in any component achieves yield strength. The structural analysis of all other load combinations are conducted in combination with the service load condition.

Analysis

The finite element analysis of the lift structural system is performed using the ANSYS computer program (*5*). The analysis output contains the deflections of all nodes, the axial stresses in truss members, and the bending moment shear force and the axial force in the beam members. The member stresses are nominal values. The property of a critical member such as the cam bracket (Members 3 and 4 in Figure 3) changes significantly along its length. For the design of these members, a more refined analysis is required that involves stress analysis using the boundary forces computed from this study. Such analysis will not be covered in this paper.

The finite element analysis of the lift structure is performed for various load conditions for service and limit states. The primary load condition is a combination of passenger and wheelchair weight that is applied as a concentrated load group: 25 percent of the total load applied at the center of each platform edge beam and the rest applied to the center of the platform back beam, all acting downward as shown in Figure 4. All other load conditions to which the lift structure is sub-

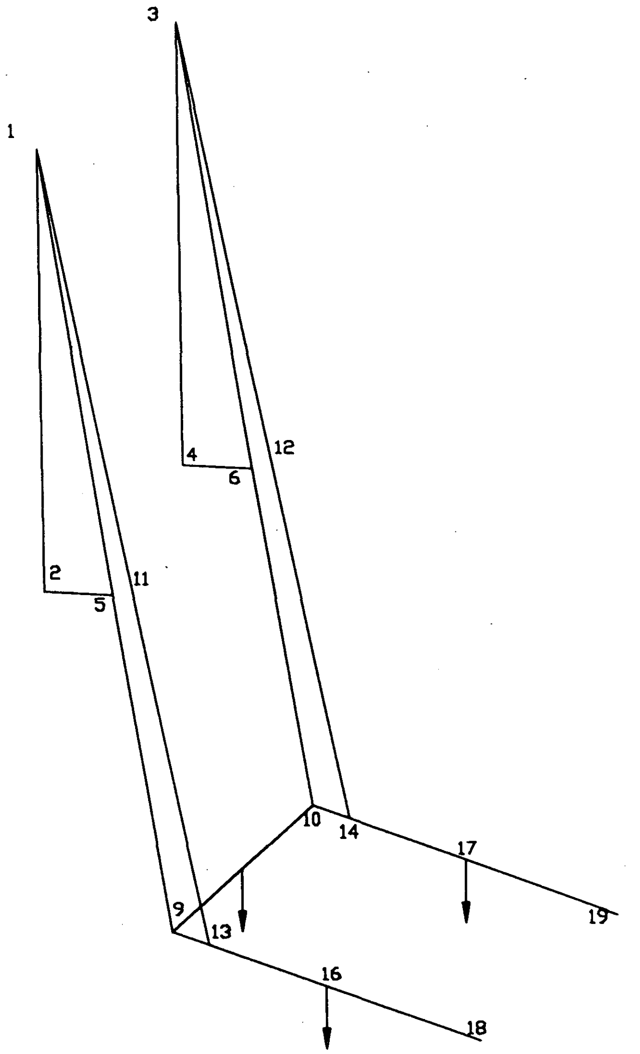


FIGURE 4 Service loading and point of application.

jected are given in Table 3. The various load combinations are given in Table 4.

The analysis results are presented as nodal deformations and component stresses. The nodal deformations under the service load condition are given in Table 5. Figures 5 and 6 show the element forces in the form of a free body diagram under ultimate level gravity load where the element forces are axial for truss members and axial, shear, and bending moments at end beam members. The component stress computations and the pin shear stresses at various locations of the lift structure and their evaluations are described in the following section.

Evaluation of Results

The analysis results are presented in terms of component forces and stresses for the limit state load conditions. The lift strength performance is checked by computing the component and connection stresses to observe if any structural trauma has taken place. The lift operational performance is verified by checking the maximum component deformations and allowable stresses under the serviceability load case. More specifically, the platform rotation is computed as described in the specification (*3*).

The platform rotation is computed as the average rotation of Elements 13, 15, and 17 (shown in Figure 3). The element rotations are computed from the differential vertical deformations of both ends divided by the element length. Under the service load of 4450 N (1,000 lbf) the platform rotation is calculated as 2 degrees, which is below the 3 degrees specified (*3*).

The critical components of the lift structure are given in Table 6 corresponding to each load combination described in

TABLE 4 Load Combinations

Analysis No.	Load Condition
1	1
2	2
3	1+2
4	3
5	1+3
6	4
7	1+4
8	5
9	1+5
10	6
11	1+6
12	7
13	1+7
14	8
15	1+8
16	9
17	1+9
18	10
19	1+10
20	11
21	1+11
22	12

TABLE 5 Nodal Deformations Under Service Load Conditions

Node	U_x millimeter	U_y millimeter	θ_z radian
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5,6	- 0.004572	- 0.000025	- 0.002097
9,10	- 7.597826	- 0.277139	- 0.009526
11,12	- 4.109491	-0.857682	- 0.002798
13,14	- 7.598054	- 1.590599	- 0.011257
15	- 7.600899	- 0.601701	- 0.009526
16,17	- 7.598054	- 7.044868	- 0.014502
18,19	- 7.598054	- 14.780641	- 0.581915

1 Inch = 25.4 millimeter

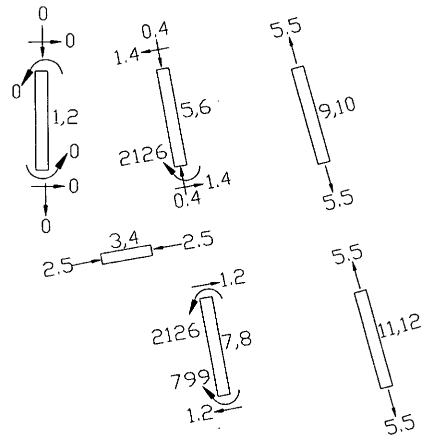


FIGURE 5 Element forces in deployment system components under ultimate level gravity load (moment: kN-mm; force: kN).

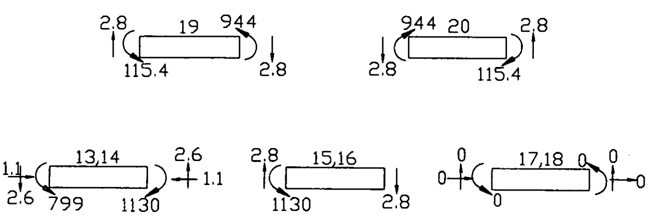


FIGURE 6 Element forces in platform components under ultimate level gravity load (moment: kN-mm; force: kN).

Table 4. In this table the load condition, the critical components, and a value for uniaxial stress or the yield condition are described. For example, in the service load case (Load Case 1 in Table 4), Elements 3 and 4 (Figure 3) reach a uniaxial stress of 290 mPa (42,000 psi).

A close investigation of Table 6 indicates that various lift components are overstressed even under service load conditions. The critical components 3 and 4 under the service load case correspond to the cam brackets that allow the lift assembly to swing in and out and assist in holding the platform during the stow-away operation. The overload of the cam bracket, shown in Figure 7, was observed during the field investigation. To be more specific, several lifts with rewelded and retrofitted cam brackets were observed during field investigations (*1*).

Other load cases corresponding to ultimate limit state loads also cause very high stresses in some of the lift components, the platform beams indexed on Elements 13 through 18 in Figure 3. Often, component yielding is not observed as noticeable damage. However, repeated yielding of moving parts causes misalignment and general lack of integrity of the lift structure that will lead to operational problems.

Five sets of pins provide load transfer between members. These pins are of different diameters and are located at Nodes 1 through 6 and 9 through 12 (Figure 3). The shear stresses

TABLE 6 Stresses of Critical Components

Load Case	Critical Components	Element Stress (mpa) Yield Stress = 344.5 mpa
1	3,4	289.4
2	3,4,13,15,17	344.5
	7	303.2
3	3,4,13,15,17	344.5
	7	275.6
4	3,4	344.5
	13,14	234.3
	15,16	227.4
5	3,4,13,15	344.5
6	3,4	344.5
7	3	344.5
8	3,4	344.5
9	3	344.5
10	3	344.5
11	3,4	344.5
12	3,4	344.5

1 Psi = 6.89 kPa

in the pins are shown in Figure 8, evaluated from the free body diagram for all load cases. The shear stresses are higher than the allowable limit. For example, the level of near 68 mPa (9,900 psi) for Pin 4 in Figure 8 is high enough to cause reliability concerns. If the ADA mandate of a safety factor of 6 is adopted in specifications, these stresses should be limited to 15.2 mPa (2,200 psi) for steel with a uniaxial yield strength of 400 mPa (60 ksi) (*6*).

The finite element analysis of the lift structural system provides the deformations of nodes and stresses of the components. Such analysis allows overall understanding of the structural system and identification of problem areas. The study will continue with the experimental investigation of prototype lifts. This will allow the verification and calibration of the analysis model.

SUMMARY AND CONCLUSIONS

A critical review of the specifications for rigid platform lifts is presented. A structural model of the rigid platform lift is developed for evaluating and improving the design specifications. Load conditions are developed to describe the serviceability and the limit state load demands on the lift structure. These load conditions are developed after extensive field investigations and based on the survey of the transit maintenance mechanics and drivers.

Lift structural analysis is performed on a prototype lift structure. The analysis results are described in terms of serviceability deformations and ultimate force demands on the components. From the preliminary investigations and analysis results, it is clear that the lift structural system contains weak links such as the cam bracket and pins. These weak links will be verified during the experimental testing of lifts.

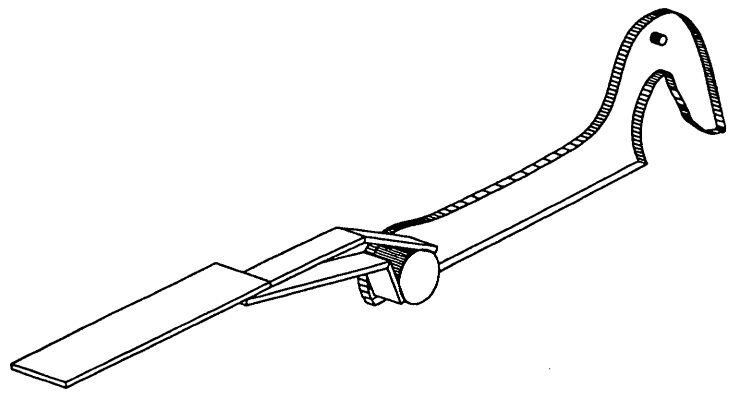


FIGURE 7 Cam bracket connecting middle of inside frame with base of lift.

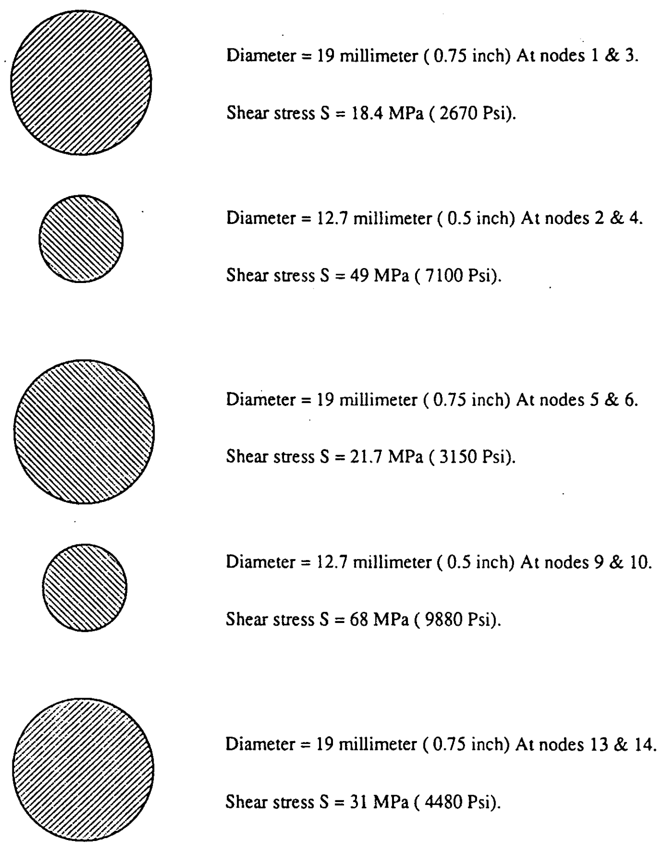


FIGURE 8 Shear in pins under ultimate level gravity load.

The analysis model developed and presented in this paper proved capable of predicting the load path in the lift structure. The weak links identified with the use of this model match our field observation. It is strongly recommended that new load cases be included in the specification. The field investigation indicated that the serviceability and limit state demands on the lift are far different than currently specified, thus lift reliability is compromised by repeated yielding of certain components. Two significant changes recommended for future specifications are to increase the factor of safety and to use the critical load conditions described in this study for the component design.

ACKNOWLEDGMENTS

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Procedure for Reliability Analysis of Wheelchair Lifts

SNEHAMAY KHASNABIS, HALUK AKTAN, AMARNATH KAMBHATLA, AND QUN LIN

Transit experts are concerned that wheelchair lifts in transit buses often do not work. The exact nature of the problems related to these lifts is not documented in the literature, but it is generally believed that the problems are not the consequence of a single factor but are caused by a combination of factors encompassing the lifts' design, manufacturing, operation, and maintenance. The objective of a project being conducted at Wayne State University is to assess and identify the sources of failure of wheelchair lifts in transit buses. As a part of the project the framework of a reliability model was established using available repair data on wheelchair lifts. A procedure for analyzing reliability of wheelchair lifts on the basis of commonly available repair data is presented. Repair data for two types of lifts for a random sample of five from each category were collected for 5 years from the regional transit agency in southeast Michigan. These data were used to develop, test, and validate Weibull models for analyzing the reliability of the lifts. The results indicate that the distribution of repair data, measured either in miles between repair (MBR) or time between repair (TBR), follow Weibull distribution patterns. Furthermore, the consistency in the parameters (for similar lifts) suggests that it is possible to predict repair needs of lifts as a function of TBR and MBR.

Many consider the enactment of the Americans with Disabilities Act of 1990 (ADA) to be a major step toward ensuring access to public facilities for persons with disabilities. Public transportation agencies in the United States have made serious efforts to provide such access to buses through wheelchair lifts since 1985. The ADA is expected to strengthen the commitment of the transportation sector to this cause. The purpose of the act is to make sure that the United States becomes a nation with transportation options for all its citizens regardless of their mobility constraints. The act stipulates that publicly funded systems must purchase (or lease) only accessible bus and rail vehicles so that no one is discriminated against when using public transportation facilities.

There is a concern today that wheelchair lifts in transit buses are often not in working condition. Although the exact nature of the problems is not documented in the literature, it is generally believed that they are not the consequence of a single factor but are caused by a combination of factors encompassing the design, manufacturing, operation, and maintenance of the lifts. In addition, compatibility of the lift life span with the bus life span concerns all operators.

This paper is the result of a project conducted at the Department of Civil Engineering, Wayne State University, to investigate the design, operation, and maintenance aspects of wheelchair lifts. The objective of the multiphased project is to assess and identify the sources of wheelchair lift failures in transit buses. In Phase 1, a preliminary investigation of the design, operation, and maintenance of wheelchair lifts was conducted. Manufacturers and fleet managers were surveyed, and a finite element model was developed to analyze the structural components of the lift mechanism. The framework of a reliability model was established using available repair data on wheelchair lifts.

In Phase 2, the modeling work (both structural and reliability) was continued in an effort to refine the models and to calibrate the various model parameters. An experimental investigation of the operation of wheelchair lifts was conducted in Phase 3 to aid in the development of structural specifications to improve the operation of wheelchair lifts. The Phase 1 report from which this paper is developed addresses the problem identification process designed to examine the serviceability of wheelchair lifts by a combination of engineering and statistical analysis. A discussion of the results of the entire Phase 1 report is beyond the scope of the paper, which instead will focus on the statistical analysis of a random sample of lift repair data.

TERMINOLOGY

Wheelchair lifts used in transit buses are categorized with respect to their architecture as active (platform) or passive (folding). The following terminologies are adopted from the U.S. Department of Transportation (*1*):

- Lift or wheelchair lift: A level-change device used to help those with limited mobility use transit and paratransit services. The terms "lift" and "wheelchair lift" are interchangeable.
- Active lift: An active lift is one that when stowed may interfere with the use of the vehicle entrance at which the lift is located and that when being raised and lowered operates primarily outside the body of the vehicle. It is also called a platform lift.
- Passive lift: A passive lift is one that when stowed allows the unlimited use of the vehicle door in which the lift is located. It is also called a step lift.

PURPOSE

Several transit operators in Michigan were interviewed for their input to the problem identification process. A compre-

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hensive list of survey questions was prepared addressing issues of design, manufacturing, maintenance, and operation of wheelchair lifts. The survey was conducted on site with personal visits to transit operators. During the visits the interviewers tried to determine the availability and quality of repair data for wheelchair lifts. It was clear from the discussion with the transit agencies that the larger operators were more likely to have a comprehensive data base on lift maintenance and repair. As such, it was decided to investigate the repair data on step lifts available from the largest operator in southeast Michigan, the Suburban Mobility Authority for Regional Transportation (SMART). The purpose of this paper is to present a procedure for analyzing the reliability of wheelchair lifts on the basis of commonly available repair data. The specific objectives of the analysis conducted with the repair data are as follows:

1. To determine if there is a statistical pattern in the frequency and distribution of repair needs of wheelchair lifts;
2. To develop a reliability model for predicting repair needs, assuming the existence of a pattern; and
3. To determine if there are significant differences among the distributions of repair needs of different types of lifts.

METHODOLOGY

Weibull distribution is a common tool for reliability analysis of machine components. Weibull distribution was originally proposed for interpreting fatigue data; later it was extended to a variety of engineering problems, particularly those dealing with service life phenomena (*2*). Past research has shown that the Weibull distribution well describes the characteristic life of individual machine components and that exponential distribution (which can be shown to be a special case of Weibull distribution) is better suited to explain levels of assemblies or systems. Maze and others have demonstrated the application of Weibull distribution in transit maintenance and repair data (*3–5*). A sample of the lift repair data retrieved from the SMART buses when plotted on Weibull probability paper suggested a linear relationship typically expected of Weibull distribution (explained later in this paper). It was decided to apply the Weibull distribution to explain mathematically the repair needs of wheelchair lifts.

Assumptions

Two major assumptions were made before Weibull testing was conducted:

1. Current literature suggests that Weibull distribution appears to explain failure of component data better than system data. This is not to say, however, that system data do not fit Weibull distribution. Whether a lift is a component or a system is a matter of opinion. If one considers the bus to be an integrated system comprising the wheelchair lift, engine, chassis, transmission, brakes, and so on, then each of these entities could be considered a component. On the other hand, each entity in its own right could be considered a subsystem with subcomponents. Thus, a lift could be considered a subsystem consisting of subcomponents such as the platform, lifting device, and control mechanism. For this research, the lift was assumed to be a component.
2. Ideally, Weibull distribution explains failure data when, after failure, a component is discarded and replaced by a new component. But generally a lift does not fail in its entirety, and generally it is not discarded. Instead, repairs are conducted when needed. For the statistical analysis, it was assumed that after a repair, the lift becomes functionally a new component.

A software called Qualitek-2 developed by NUTEK was donated to the Department of Civil Engineering, Wayne State University; the software was used for analyzing the lift repair data. Qualitek-2 is a comprehensive package used extensively for failure data analysis; it can develop the Weibull parameters (slope and characteristic life), given the appropriate failure and repair data (*6*). The software can also test the goodness of fit of the Weibull model developed and generate confidence ranges of expected life of the component for various levels of statistical significance.

Mathematical Basis

The Weibull density function is of the following form (*2*):

$$f(x) = \left[\left(\frac{b}{\Theta - x_0}\right)\left(\frac{x - x_0}{\Theta - x_0}\right)^{b-1}\right] \times \left\{\exp\left[-\left(\frac{x - x_0}{\Theta - x_0}\right)^{b}\right]\right\} \quad (1)$$

where

x_0, b, Θ = parameters determined empirically or experimentally;
x = random variable;
x_0 = expected minimum value of x, or location parameter;
b = Weibull slope, or shape parameter, and
Θ = characteristic life, or scale parameter.

The cumulative distribution function, derived by integrating Equation 1, is

$$f(x) = \int_{-\alpha}^{x} f(x)dx = \int_{x0}^{x} f(x)dx$$

$$f(x) = \int_{x0}^{x}\left(\frac{b}{\Theta - x_0}\right)\left(\frac{x - x_0}{\Theta - x_0}\right)^{b-1} \exp\left[-\left(\frac{x - x_0}{\Theta - x_0}\right)^{b}\right]dx$$

Now, suppose

$$y = \left(\frac{x - x_0}{\Theta - x_0}\right)^{b}$$

then

$$dy = b\left(\frac{x - x_0}{\Theta - x_0}\right)^{b-1}\left(\frac{1}{\Theta - x_0}\right)dx$$

or

$$f(x) = \int e^{-y}dy$$

yields

$$f(x) = 1 - \exp\left[-\left(\frac{x - x_0}{\Theta - x_0}\right)^b\right] \qquad (2)$$

To simplify the model development process empirically, it is sometimes assumed that the lower bound of life x_0, the expected minimum of the population, is zero. This assumption reduces the Weibull cumulative distribution function specified in Equation 2 to

$$f(x) = 1 - \exp\left[-\left(\frac{x}{\Theta}\right)^b\right] \qquad (3)$$

Equation 3 is a simplified version with two parameters, compared with the three-parameter function specified in Equation 2.

Equation 3 can be rewritten as

$$\left[\frac{1}{1 - f(x)}\right] = \exp\left(\frac{x}{\Theta}\right)^b$$

Taking natural logarithms on both sides,

$$\ln\left[\frac{1}{1 - f(x)}\right] = \left(\frac{x}{\Theta}\right)^b$$

$$\ln\ln\left[\frac{1}{1 - f(x)}\right] = b(\ln x) - b(\ln \Theta) \qquad (4)$$

Equation 4 has a form

$$Y = bX + C$$

where

$$Y = \ln\ln\{1/[1 - f(x)]\}$$
$$X = \ln x$$
$$C = -b\ln\Theta$$

The equation $Y = bX + C$ represents a straight line with a slope and intercept C on the Cartesian X,Y coordinates. Hence, a plot of Y against X will also be a straight line with slope b. Thus, the parameter b in the Weibull function is referred to as the "slope parameter." Figure 1 demonstrates different numerical values of Weibull slope. It can be shown further that when b equals 1, the Weibull distribution becomes an exponential function and that when b equals 3.5, it becomes a normal distribution.

To determine the probability that a part will fail at the characteristic life or less, from Equation 3

$$f(x) = 1 - \exp\left[-\left(\frac{x}{\Theta}\right)^b\right] = 1 - \exp\left[-\left(\frac{\Theta}{\Theta}\right)^b\right]$$
$$= 1 - e^{-1} = 1 - \left(\frac{1}{e}\right)$$
$$= 1 - \left(\frac{1}{2.718}\right) = 0.632$$
$$= 63.2 \text{ percent} \quad \text{for } x = \Theta \qquad (5)$$

Thus, the characteristic life is the life by which 63.2 percent of the parts will have failed. Last, as stated before, the plot of Y versus X is a straight line with a slope of b. A special coordinate paper known as the Weibull probability paper, with a logarithmic abscissa scale and an ordinate scale transforming $f(x)$ to Y, is generally used to plot the distribution. Hence, a Weibull variable x plotted versus $f(x)$ on the paper will be represented as a straight line with a slope b as demonstrated in Figure 2.

RESULTS

A brief description of the data base used and the results of the analysis are presented in the following.

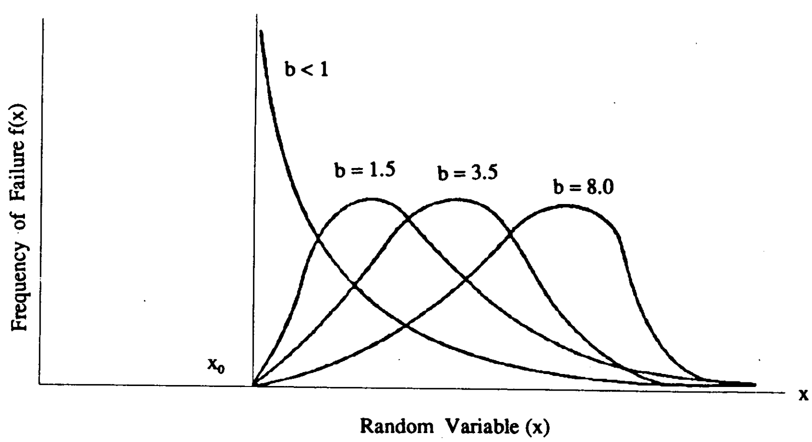

FIGURE 1 Density function of Weibull distribution (*2*).

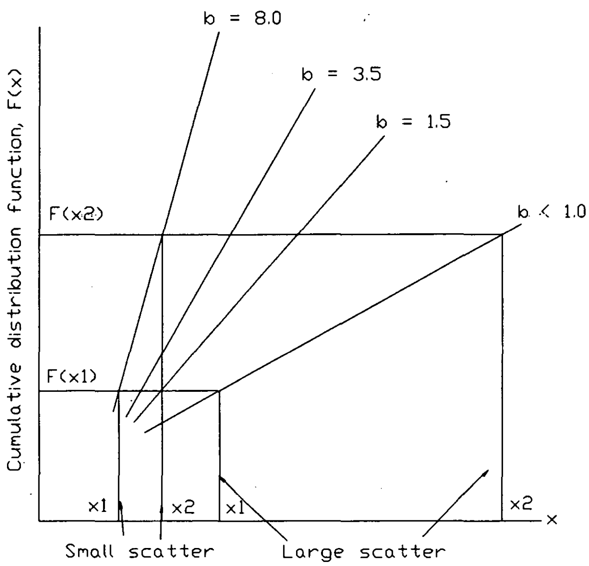

FIGURE 2 Weibull plots for various slopes on Weibull probability paper.

Data Base

The data base on lift repairs collected from SMART included the following:

- Period: 5 years (January 1, 1985, through December 31, 1989)
- Type of repair
  - General
  - Electrical
  - Mechanical
  - Body
  - Hydraulic
- Date of repair
- Mileage on day of repair
- Expenses incurred by labor hours and parts

These data were obtained from SMART for two types of step lift (A nd B), for five large transit buses for each type, making a total of 10 buses. The 10 buses were selected at random from more than 200 buses. Note that the repair data do not include the information on regular maintenance conducted at fixed intervals, usually every 3,000 mi. The data were then recast using the dBase III Plus software to depict information on the date of the repair, mileage, and expenses incurred in each of the five repair categories.

A review of the current literature indicates that for engineering analysis of repair data, two primary variables are used as the indicators of longevity of machine components: miles elapsed between successive repairs (MBR) and miles elapsed between successive repairs (TBR). For lifts, the number of cycles of operation is considered an ideal variable to depict longevity. Cycle data were not available, so MBR and TBR data were used in this study for lift reliability analysis. The repair cost data included in the data base were not used in the statistical analysis presented, primarily because of a wide variance in the distribution. An effort was made to segregate the MBR and TBR data by cost; however, this effort was discontinued because the resulting sample size became too small for statistical validity.

The MBR and TBR data were initially analyzed to conduct some basic statistical evaluation. Table 1 shows the means and standard deviations of the MBR and TBR distributions of the five lifts for Type A and B categories, for all repair codes considered together. The means of the two distributions are the mean time between repair (MTBR) and mean miles between repair (MMBR). Also included in Table 1 are beginning mileage and date, end mileage and date, number of repairs conducted during the 5-year period (N), and number of repairs per month (n). Finally, the grand mean values for the appropriate columns are also given in Table 1.

Table 1 indicates some trends that deserve attention. First, the consistency in the values of MTBR and MMBR and their corresponding variances is clearly noteworthy, despite the difference in the number of times that repair was needed (N-value). Second, Type A lifts appear to have greater longevity

TABLE 1 Summary of Repair Data for Type A and B Lifts (All Repairs Together)

Lift Type & number	Beginning		TBR (months)		MBR(miles)		N Number of	Repairs Per	End	
	Date	Mileage	Mean	Std. Dev.	Mean	Std. Dev.	Repairs	month	Date	Mileage
A-1	04-13-85	174,400	2.806	4.247	12,901	19,190	19	0.375	12-15-89	419,500
A-2	04-05-85	180,000	2.306	2.078	10,330	9,405	23	0.434	09-21-89	416,400
A-3	02-04-85	168,600	1.953	2.579	7,940	9,729	30	0.535	12-15-89	406,840
A-4	01-03-85	166,200	2.251	2.096	9,848	7,264	26	0.441	12-15-89	412,300
A-5	05-06-85	141,200	3.034	2.276	14,411	9,573	18	0.327	12-06-89	386,000
Grand Average			2.470	2.654	11,086	11,032	23.3	0.422		
B-1	01-08-85	91,700	1.245	1.388	6,508	6,508	49	0.881	12-04-89	291,690
B-2	01-02-85	86,700	1.820	1.675	8,176	8,176	33	0.559	12-13-89	296,500
B-3	12-27-84	86,300	1.353	1.429	6,998	6,998	45	0.717	12-18-89	295,300
B-4	01-24-85	92,800	1.415	1.710	8,401	8,401	41	0.695	12-13-89	297,500
B-5	01-28-85	117,100	1.455	1.213	6,259	6,259	41	0.695	12-19-89	301,600
Grand Average			1.457	1.483	7,268	7,268	41.8	0.710		

than Type B. A review of the grand mean values shows that on the average for Type A lifts, a repair was needed every 2.47 months or every 11,086 mi. The corresponding figures for a Type B lift were 1.46 months and 7,268 mi. Third, the number of repairs needed for the same 5-year period for Type A lifts was less than that for Type B. Type A lifts needed repair at the rate of 0.42 times per month; the corresponding figure for Type B was 0.71. Last, there was a strong correlation between MBR and TBR (correlation coefficient exceeding .90, not shown in the table). The ratio of MBR and TBR was an indicator of the number of miles driven per month for the bus equipped with the lift in question.

Analysis of MBR Data

Summarized versions of the Weibull test results of repair data of the MBR distribution for the 10 lifts (5 for Type A and 5 for Type B) are presented in Table 2. Figure 3 is adapted from the graphics output of Qualitek-2 representing the cumulative distribution function (CDF), as given in Equation 2, for Lift A1. The following observations from this table are in order:

1. Table 2 shows that in all 10 cases there is an excellent correlation between the dependant variable Y and the independent variable X in Equation 3 as indicated by high R^2-values (coefficient of correlation). The lowest R^2-value obtained is .928 for Lift A2, and the highest is .983 for Lift A1.

2. Table 2 also shows that the characteristic life (63.2 percentile value) for Type A lifts varies from 7,063 to 16,317 mi. The corresponding values for Type B lifts range from 5,485 to 8,801 mi. The composite averages of the characteristic values for Type A and B lifts are 11,034 and 7,254 mi, respectively. Furthermore, a closer examination of the characteristic life value shows that for Type A and B lifts, there are two outliers each in the distribution: A3, A5 and B1, B2. The characteristic life values in the other three cases, for Types A and B, are near the composite averages of 11,034 mi and 7,254 mi, respectively. Furthermore, a closer examination of the characteristic life value shows that for Type A and B lifts, there are two outliers each in the distribution: A3, A5 and B1, B2. The characteristic life values in the other three cases, for Types A and B, are near the composite averages of 11,034 mi and 7,254 mi, respectively.

3. The slope parameter b is within the proximity of unity, with 6 of the 10 values being less than 1 and the other 4 values exceeding 1.

4. In Table 2, the equations developed for the linear Weibull function (Equation 5) are also presented in the last column. The relationship between these equations and the parameter's slope and characteristic life are as follows:

From Equation 3,

$$Y = \ln \ln\left[\frac{1}{1 - f(x)}\right] X = \ln XC = -b \ln \Theta$$

so that $Y = bX + C$.

Referring to Lift A1 from Table 2,

$$b = 0.6505$$

$$C = -5.9961$$

since

$$C = -b \ln \Theta$$

$$-5{,}9961 = -0.6505 \ln \Theta$$

$$\ln \Theta = \left(\frac{5.9961}{0.6505}\right) \doteq 9.2176$$

so that

$$\Theta = e^{9.2176} = 10{,}073$$

Note that this value matches the calculated value of 10,075 as shown in Table 2.

TABLE 2 Weibull Parameters for MBR Distribution

Lift Type & number	R^2 Correlation Coefficient	Θ Characteristic life in miles	b slope	N Number of repairs	Equation Y=bX+c
A-1	0.9839	10075	0.65	19	Y=0.651X - 5.9961
A-2	0.9281	10811	1.09	23	Y=1.094X - 10.1562
A-3	0.9838	7063	0.76	30	Y=0.768X - 6.8052
A-4	0.9772	10904	1.41	25	Y=1.412X - 13.1255
A-5	0.9609	16317	1.62	17	Y=1.629X - 15.8052
Average		11034	1.10		
B-1	0.9518	5485	0.96	49	Y=0.962X - 8.2749
B-2	0.9558	8801	1.00	33	Y=1.003X - 9.1082
B-3	0.9776	6942	0.98	42	Y=0.981X - 8.6752
B-4	0.9789	7066	1.08	40	Y=1.086X - 9.6243
B-5	0.9679	7979	0.98	41	Y=0.989X - 8.8947
Average		7254	1.00		

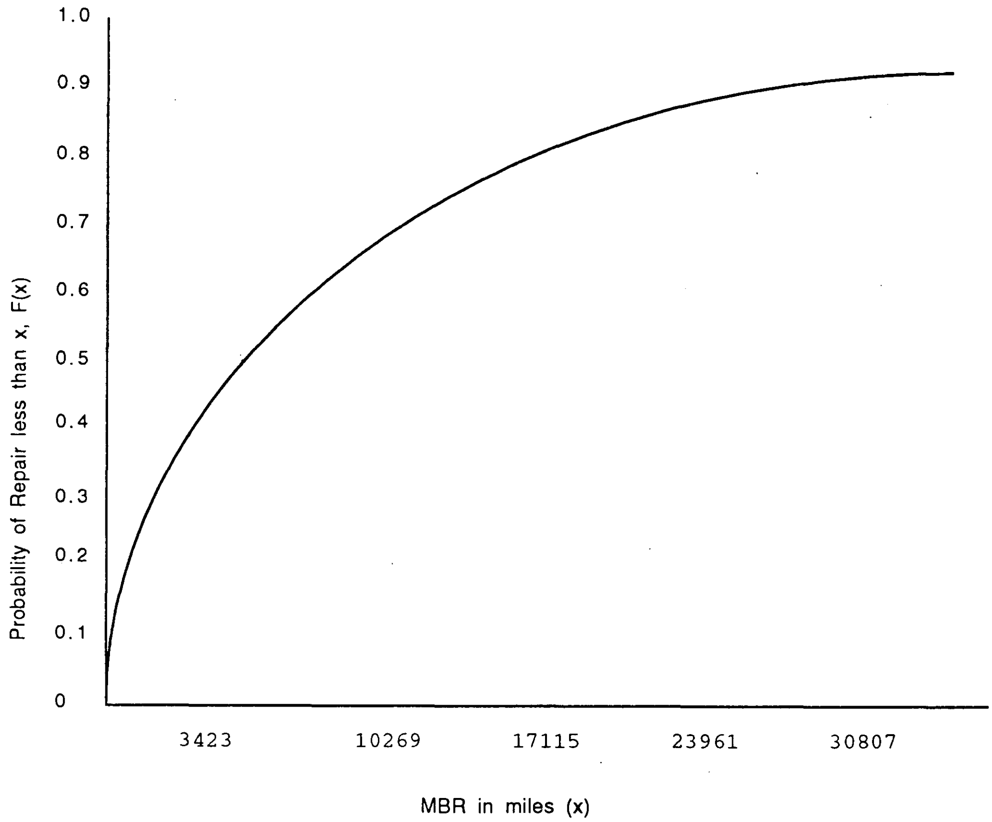

FIGURE 3 Weibull cumulative MBR distribution function for Lift A1 (Θ = 10,075 mi, *b* = 0.65).

Analysis of TBR Data

Table 3 shows the Weibull parameters for TBR distribution for the same 10 lifts. These tables can be interpreted the same way as explained for the MBR distribution in the preceding section. As with the MBR distribution, the characteristic life for the TBR distribution (63rd-percentile value of the time elapsed in months between successive repairs) is higher for Type A than for Type B lifts. This would seem to further support the idea that the longevity of Type A lifts is greater than for Type B. The following observations on the TBR Weibull function can be noted:

1. The consistency in the characteristic-life values within the same type of lift is worth noting, notwithstanding the difference between Type A and B lifts. For Type A lifts, the

TABLE 3 Weibull Parameters for TBR Distribution

Lift Type & number	R^2 Correlation Coefficient	Θ Characteristic life in months	b Slope	N Number of Repairs	Equation Y = bX + c
A-1	0.956042	2.08926	0.700	19	Y = 0.70X - 0.5191
A-2	0.848980	2.45072	1.060	23	Y = 1.06X - 0.9565
A-3	0.963278	1.67867	0.820	30	Y = 0.82X - 0.4282
A-4	0.973360	2.40805	1.110	25	Y = 1.11X - 0.9774
A-5	0.958320	3.44458	1.180	17	Y = 1.18X - 1.4659
Average	0.939996	2.41430	0.974	22.8	
B-1	0.9773260	1.55440	0.758	49	Y = 0.76X - 0.4791
B-2	0.9377720	1.86181	1.050	33	Y = 1.06X - 0.6562
B-3	0.9837175	1.35523	0.960	42	Y = 0.96X - 0.2948
B-4	0.9498300	1.39313	1.170	40	Y = 1.17X - 0.3899
B-5	0.9826970	1.57874	1.160	41	Y = 1.16X - 0.5310
Average	0.9662685	1.548662	1.019	41	

composite average characteristic life is 2.4143, indicating that 63 percent of the time a repair is likely to be warranted within 2.414 months. The corresponding figure for Type B lifts is 1.548662.

2. The slope parameter b for TBR distribution is close to unity, with 4 of the 10 observations being less than 1 and the remaining values exceeding 1.

3. In Table 3, the equation developed for the Weibull function is also presented in the last column. The relationship between these equations and the parameters b and characteristic life are the same as those explained for the MBR distribution.

Model Validation

The R^2-values presented in Tables 2 and 3 exceeding .90 in all the cases analyzed indicate an excellent correspondence between the model output and the observed data. Another validation effort was made by developing the parameters from a group of three lifts and applying these parameters on the remaining two lifts. The following three-step process was followed:

1. The mean values of the two parameters (slope and characteristic life) were computed for Lifts A1, A3, A5, B1, B3, and B5 (i.e., every other lift).

2. These parameters were applied to compute the CDF $f(x)$ for the remaining lifts—A2, A4, B2, and B4—as

$$f(x) = 1 - e^{-\left(\frac{x}{\Theta}\right)^b}$$

where b and Θ are the mean parameters and x is the random variable (i.e., MBR or TBR).

3. The computed CDF (using the preceding parameters) were compared with the actual observations for Lifts A2, A4, B2, and B4.

The results of this comparison are presented in Tables 4 and 5 for A2 and B2 lifts for MBR and TBR distributions, respectively. A visual comparison of these two distributions is presented in Figures 4 and 5. The tables and figures are self-explanatory and indicative of the very close correspondence between the observed data and the model output. For example, Table 4 indicates that according to the model, there is a 55.3 percent probability that a Type A lift will require a repair within 9,000 mi. For Lift A2, a repair was needed within 9,000 mi 52.3 percent of the time. Similarly, the model predicts that there is a 43.2 percent chance that a Type B lift will need a repair within 0.77 months. For Lift B2, 45.6 percent of the repairs were warranted within 0.77 months. Similar validation conducted for Lifts A4 and B4 (not shown in this paper) showed excellent correspondence between the model output and the observed data.

CONCLUSIONS

This paper aims to present a statistical approach for analyzing reliability of wheelchair lifts. Repair data for two types of lifts for a random sample of five from each category were collected for 5 years from the regional transit agency in southeast Michigan. These data were used to develop, test, and validate Weibull models for analyzing the reliability of the lifts. The procedure presented requires the availability of repair data

TABLE 4 Comparison of Weibull Model Output $f(x)$ with Actual MBR Values for Lift A2 (N = 23)

MBR (miles)	Frequency	Percent	Percentile	Model
0-2000	3	13.1	13.1	16.1
2000-3000	3	13.1	26.2	23.2
3000-3600	4	17.4	43.6	27.2
3600-9000	2	8.7	52.3	55.3
9000-13000	5	21.7	74.0	68.7
13000-18000	3	13.1	87.1	80.2
18000-+	3	13.1	100.0	100.0

TABLE 5 Comparison of Weibull Model Output $f(x)$ with Actual TBR Values for Lift B2 (N = 33)

TBR (months)	Frequency	Percent	Percentile	Model
0-0.2	4	12.2	12.2	16.8
0.21-0.47	5	15.2	27.4	31.2
0.48-0.77	6	18.2	45.6	43.2
0.78-1.70	5	15.2	60.8	66.3
1.71-2.90	5	15.2	76.0	81.6
2.91-3.84	5	15.2	91.2	88.3
3.84- +	3	9.1	100.0	100.0

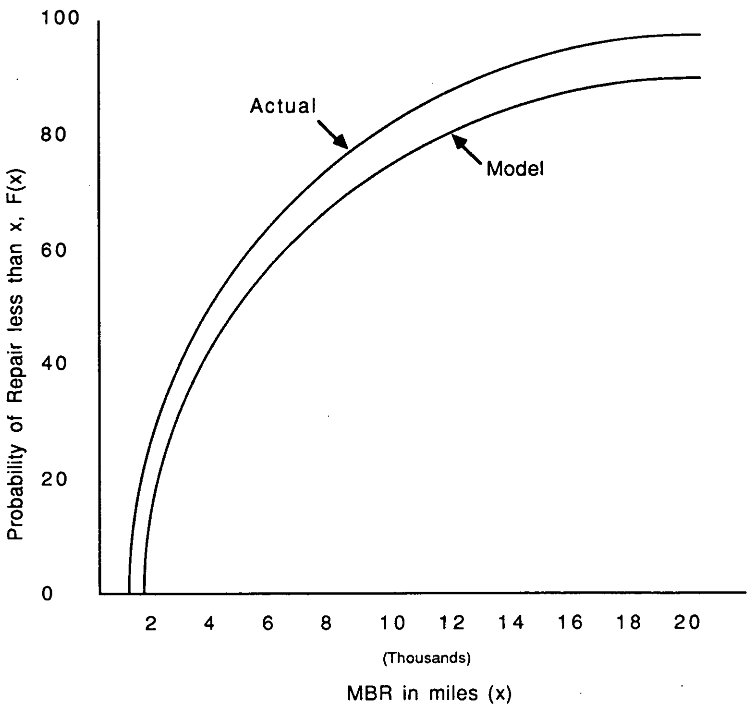

FIGURE 4 Comparison of actual data with model output for Lift A2.

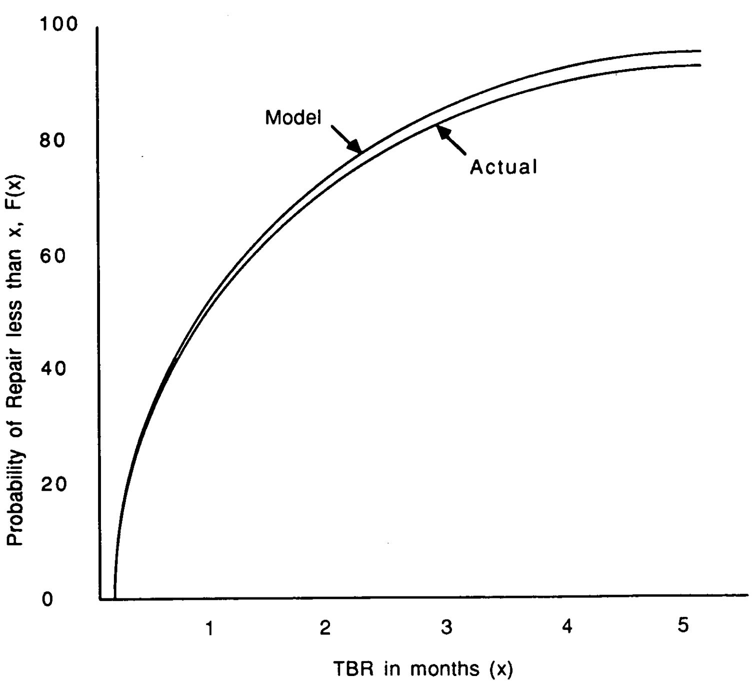

FIGURE 5 Comparison of actual data with model output for Lift B2.

likely to be collected by most large transit operators. The conclusions of this study follow:

- There is strong correlation between MBR (in thousands of miles) and TBR (in months) for wheelchair lifts.
- The statistical analysis of a 5-year repair data base of two types of lift for 10 lifts indicates that the distribution of repair data, measured either in MBR or TBR, follows Weibull distribution patterns.
- On the basis of the consistency in the values of the model parameters (slope and characteristic life), it is possible to predict repair needs of wheelchair lifts as a function of the distribution of MBR or TBR.
- From the distribution of TBR and MBR, it is possible to determine if there are significant differences between the repair needs of different types of lifts.
- Further studies should be conducted to incorporate cost factors in the reliability analysis of wheelchair lifts. The procedure presented in this paper is based entirely on the distributions of TBR or MBR.

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The opinions and comments expressed in this paper are entirely those of the authors and do not necessarily reflect the policies and programs of the agencies mentioned.

Transportation Technologies for Improving Independence in Canada

LING SUEN AND TOM GEEHAN

The Canadian Charter of Rights and Freedoms protects persons with physical and mental disabilities against discrimination in Canada. The Canadian Human Rights Act prohibits discrimination against persons with disabilities in the provision of goods and services, including transportation. Transport Canada's policy on accessible transportation states that "accessible transportation is a right, not a privilege." Transport Canada has been working since the late 1970s to guarantee all Canadian citizens access to transportation services, emphasizing the application of appropriate technologies that help to integrate all disabled groups into mainstream activities of society. The concept of complete accessibility is important, and it is necessary to design for the individual rather than for general population. Advances in mobility, information, and communication and control technologies in urban public transportation are discussed. It is concluded that appropriate technologies, although only part of the solution, will go a long way to improving the fit between the individual and the environment. Early consumer involvement is required, as is consistent application across the transportation spectrum. More user-friendly and ergonomically sound designs, in addition to user and operator training and better marketing and dissemination of technologies, are critical to success.

In the late 1970s, Transport Canada initiated a program for travelers with disabilities. This program came to include a variety of activities aimed at removing barriers to transportation services and facilities under federal jurisdiction. In 1983 Transport Canada's policy on transportation of persons with disabilities was developed. The policy set out the government's intention and responsibility to ensure that safe, reliable, and equitable services were available to travelers with disabilities on all transportation modes under federal jurisdiction. In October 1991, Transport Canada's policy on accessible transportation was further refined and stated that

> Accessible transportation is a right, not a privilege. All Canadians should be able to use Canada's transportation system without impediment. Transport Canada supports fully integrated, barrier-free transportation that accommodates the needs of seniors and persons with disabilities. (*1*)

The Canadian Charter of Rights and Freedoms, put forth in April 1982, protects persons with physical and mental disabilities against discrimination. The Canadian Human Rights Act prohibits discrimination against persons with disabilities in the provision of goods and services, including transportation. Under the National Transportation Act of 1987, as amended in July 1988, the National Transportation Agency can also regulate to eliminate undue obstacles.

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APPLICATION OF TECHNOLOGIES

The Transportation Development Center (TDC) of Transport Canada is concerned mainly with the application of appropriate technologies. A technology may be considered appropriate when its application is (a) compatible with the concept of full accessibility across the entire travel continuum, (b) in reaction to or anticipation of goals relating to full integration and self-reliance, and (c) designed for individual users.

Complete Accessibility

Transportation technology deals with all aspects of a journey: planning, access to the system, the trip itself, and egress from the system. This definition of complete accessibility encompasses the entire travel continuum: the vehicle, the terminal and transfer points, the route, the operational and procedural systems, and the emergency systems—as well as the trip planning information, orientation, and communication system (Figure 1).

Integration and Self-Reliance

Canada's disabled citizens can participate fully in the country's society and economy if they have easy access to and from work, recreation activities, and other amenities or opportunities (Figure 2). The transportation system is essential. Transportation technologies should allow individuals to realize their potential by enabling them to travel from origin to destination with independence and self-reliance and with emphasis on integration into society; for example, a self-locking wheelchair securement system is superior to one that requires assistance, because it helps to preserve privacy and dignity. Similarly, smart cards and other silent communication technologies enable travelers to convey their special needs without publicly acknowledging their impairments.

Ergonomic Design

The traditional approach to planning the transportation system has been to design for the "average" user according to a normal design curve. This approach generally results in a

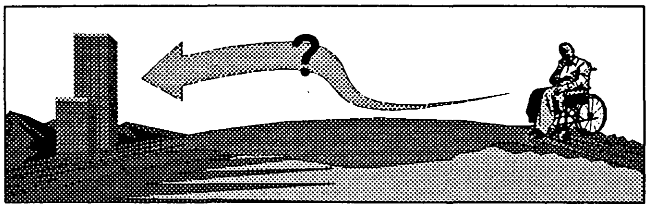

FIGURE 1 Entire travel continuum.

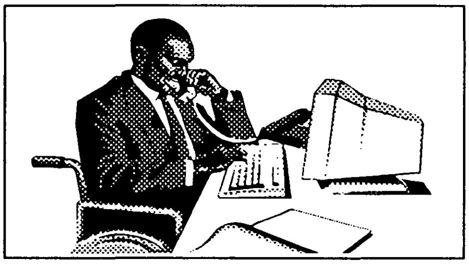

FIGURE 2 Integration and self-reliance.

minimal standard. Designs should meet the needs of individual users at the 85th percentile or higher (Figure 3). In Canada, people who reported trouble in using transportation systems include travelers with mobility or agility disabilities (about 2.0 million Canadians); those with visual, hearing, or speaking disabilities (about 1.5 million); and persons with learning, emotional, psychiatric, or developmental disabilities (about 0.7 million). Designing for individuals at the end of the normal curve will generally meet the needs of all users. Ramps for wheelchairs, for example, also help elderly persons and people pushing strollers, carrying baggage, or supervising very young children.

TYPES OF TECHNOLOGIES

There are many possible ways to classify transportation technologies; one method is according to basic functional goals of increasing travelers' independence (Table 1).

TDC has carried out projects that investigate the application of a number of technologies—including mechanical systems, information and display systems, telecommunication systems, and microelectronics—with the aim of enabling individual users to achieve the basic goals of improving mobility, information, communication, and control. This paper reports development to date in these areas, highlighting Canadian advances in the transportation arena where applicable.

Mobility Technologies

The application of appropriate technologies to improve the access of mobility-impaired travelers to public transportation is largely oriented toward the use of mechanical systems for changing levels in vehicles and terminals. These systems include lifts, ramps, and floor-lowering devices.

In Canada, the trend toward an integrated fully accessible transit system is gathering momentum. British Columbia was

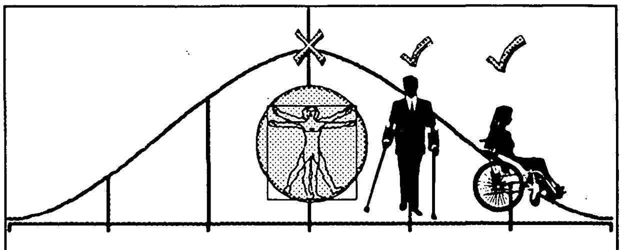

FIGURE 3 Design for individuals.

the first province to adopt a policy of full transit accessibility—for Vancouver in 1990 and for Victoria in 1991. Alberta began to bring about barrier-free transportation systems in 1991, and Ontario has adopted a policy that all new transit buses must be low-floor buses starting in 1993.

Fully accessible transit can be accomplished with lift-equipped buses or low-floor buses (Figure 4). The trend in Canada is toward low-floor buses, and TDC plans to gather data from accessible transit systems on both lift-equipped and low-floor buses to aid in the design and prototyping of an accessible urban transit bus suitable for Canadian operation. This program will be carried out in close cooperation with provincial governments, transit operators, and manufacturers. The low-floor New Flyer bus is now in operation in Victoria, British Columbia; Kitchener, Ontario; and St. Albert, Alberta. Other, smaller low-floor buses available on the market include the Elf II and Orion II. The Orion II is a 22- or 24-ft heavy-duty transit bus with front-wheel drive and low floors; it is manufactured by Ontario Bus Industries. The Elf II is a 31-ft medium-duty transit bus with front-wheel drive and low floors; it is being developed by Overland Custom Coach of Thorndale, Ontario. The prototype is being sponsored by several agencies, including TDC.

Once a passenger is on board, wheelchair securement and passenger restraint systems should be in place to ensure the traveler's safety. Many devices on the market are designed to satisfy these needs: belts and tracks, hooks and rods, clamps, rim pins, and so forth are made by a wide variety of companies. The Oregon State University undertook a project to develop a standard securement system that would work with all mobility aids (*2*). This design includes a latching mechanism and a two-point interface unit that is attached to the mobility aid. TDC has worked on securement systems for various types of vehicles and has successfully developed and tested different securement units for vans and minibuses (*3,4*).

Development of standards is another technique to normalize technologies in the transportation arena. The most critical issue affecting the safety of elderly and disabled travelers is the lack of national standards for vehicles, wheelchairs, and mobility aids used in transportation. TDC chose to address this problem by supporting work aimed at developing or revising Canadian Standards Association (CSA) standards relating to the vehicle, the wheelchair, securement, and restraint. A joint federal-provincial effort with CSA and the Canadian Urban Transit Association has been launched to encourage provinces to refer to the CSA standards in provincial regulations. This project is expected to end in 1992–

TABLE 1 Classification of Technologies by Goals

BASIC GOALS	OBJECTIVES	TYPICAL TECHNOLOGY
• mobility	• education, personal business • employment (for activity, self-satisfaction, livelihood)	• mechanical systems
• information	• education and information • orientation and wayfinding	• information displays
• communication	• social interaction, recreation • interaction with service providers	• telecommunications
• control	• independence, self-reliance • security (physical, psychological) • daily living (e.g., shelter, mobility)	• microelectronics

FIGURE 4 New Flyer low-floor bus.

FIGURE 5 GSM accessible taxi.

1993. Standards for accessible coaches and their wheelchair securement systems will be the next priority.

As for accessible taxis, TDC has sponsored several projects relating to developing and selecting suitable vehicles, designing the demonstration service, and evaluating the results. TDC has participated in trials of several commercially available vehicles for adaptation as accessible taxis (Figure 5). Efforts directed toward a redesign of the GSM taxi to meet the requirements of elderly and disabled users resulted in one vehicle now in demonstration service and undergoing evaluation in Montreal (*5*). The results show that driver training is crucial to the success of the service.

Information Technologies

Applying information and display technologies appears to be appropriate for helping persons with disabilities access public transportation information. The solutions to such travel problems lie less in starting new research and development (R&D) activities than in implementing well-established technology. Existing technology can help with information and orientation in vehicles, at bus stops, and in terminals.

One example is the Visual Communication Network (VCN) developed by Télécité Inc. and demonstrated on the Montreal Métro (Figure 6). The VCN provides vital information for passengers inside transit vehicles on a real-time basis, serving the general public with special emphasis on passengers with

FIGURE 6 Télécité information display.

visual and hearing impairments. Another example—in London, England—is the Talking Bus Stop being implemented at 100 bus stops on the route from Sudbury to King's Cross. At the touch of a button, this system verbally announces the arrival times of the next three buses and warns of any delays.

During Expo 86, a prototype of an automated telephone information system was developed and demonstrated by Oracle

Communications as part of the Transport Canada–funded Integrated Transportation Information System project. The prototype used computerized speech to provide an automated transit information menu for the greater Vancouver area; it included general transit information, bus schedule information, and trip planning information. Callers could interact with the system using tone entry from a standard touch-tone telephone. The prototype was demonstrated to the public during Expo 86.

TDC is interested in augmentative information systems such as these, as well as signage and tactile aids for persons with perceptual and sensory impairments. Other technologies that warrant further consideration include audio pathways, warning lights, audio induction loop systems, and tactile aids. These systems have been evaluated (*6*), and the next stage is operational demonstrations.

The transportation problems of cognitively impaired travelers remain difficult to define. More work should be carried out to eliminate communication and orientation barriers via modern microelectronics and information technology. The merits of training and education of potential travelers and travel service providers should be investigated.

Communication Technologies

Telecommunication systems can be applied to help individuals with disabilities to communicate with transportation providers.

A demonstration of HandyLine, an adaptation of telephone communications that permits automatic reservation and confirmation of requests for paratransit services, is under way in Vancouver (*7*). This system promises to improve service efficiency by automating routine inquiries and services and by handling reminder calls to clients, thus reducing no-shows and boarding delays (Figure 7). In Victoria, an automated telephone information system for the general public, called BusLine, is being implemented. Extending these systems to connect with telecommunication devices for the deaf is a natural follow-on, as automated telephone information systems are becoming commonplace. The public communicates with both systems through the touch-tone keys on their telephone. Although the evaluation has just begun, it is believed that such systems will prove beneficial to travelers with disabilities, most notably those with speech impairments.

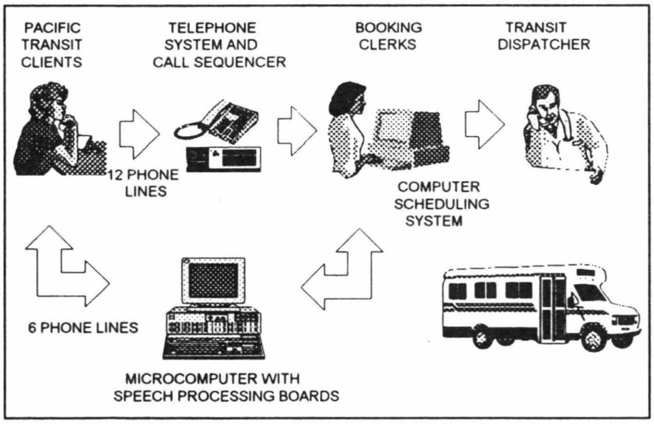

FIGURE 7 HandyLine telephone system.

Development of an automated information kiosk (Communicaid) was completed in 1992 under TDC sponsorship (*8*) (Figure 8). This system provides traveler information (such as flight arrivals and departures, location of amenities, and ground transportation) for people with sight, speech, or hearing impairments. It includes a touch screen with simplified controls and magnification and contrast adjustment for those with sight impairments. Translaid, a portable translator, is also being developed under TDC sponsorship for application in transportation terminals. It permits individuals with speech or language difficulties to communicate directly with a service agent by keying appropriate questions and responses on a dual-screen computer terminal (one screen for the passenger and the other for the service agent).

Systems such as Communicaid and Translaid may also have application in many types of transportation terminals and multimodal stations, providing the public with another means of communicating with service providers.

Control Technologies

Another appropriate technology is microelectronics: for example, in-vehicle guidance, cellular telephone communication, and emergency location systems.

FIGURE 8 Communicaid kiosk.

The application of microelectronics technology in the context of intelligent vehicle-highway systems (IVHS) programs in North America offers great promise of helping persons with disabilities to achieve mobility and independence safely. These efforts may appear to be more applicable to private transportation, but travel advisory, travel planning, priority parking, and so forth could be adjunct services for public transit clients who drive their automobiles to the park-and-ride lot of a transit station. To avoid cumbersome and unsafe retrofits, the needs of elderly people and persons with disabilities must be recognized early in the development of IVHS systems and in-vehicle devices, not as an afterthought. Public transit operators should also be involved to ensure that these systems are designed to incorporate their needs.

The application of these microelectronic devices and related computer systems also offers great promise for cost-effective control of parallel transit and dial-a-ride systems (Figure 9). In-vehicle navigation and route guidance units that include two-way communication with central control could greatly improve response times to changes in the service. Computerized dispatching is also required to better schedule the vehicles. In this area, TDC has sponsored projects such as the development of a generic computerized scheduling software package called the DART Manager in 1985.

Smart card technology may find application in the public transportation arena as a way for the user to communicate silently any special needs to the operator. Such cards could also be used for fare collection in user-subsidy programs to eliminate money-handling and accounting problems or as identity or control cards to gain access to priority parking in a park-and-ride lot.

FIGURE 9 Dial-a-ride control systems.

CONCLUSIONS

Appropriate transportation technologies can improve the fit between individuals and their transportation environment. In so doing, they benefit everybody. Table 2 illustrates the relative potential benefits—at the current level of development—of three alternative solutions to accessibility problems of various groups of travelers with disabilities.

The potential benefits of solutions differ according to the needs of individual travelers. For example, technological solutions for individuals with mobility impairments offer fewer benefits than do architectural solutions, because R&D is relatively advanced; the reverse is true for those with vision, hearing, or speech impairments. On the other hand, technological solutions to assist individuals with cognitive or emotional disabilities would probably offer fewer benefits than would solutions oriented toward training. Therefore, appropriate and ergonomically sound solutions for the different groups should be determined, and resources should be invested accordingly. To ensure the successful application of technological solutions, the following points should be considered:

- Early consumer involvement in R&D to avoid expensive and unnecessary retrofitting later;
- Consistent application over the entire transportation spectrum to allow for full integration and continuity across all aspects of the trip;
- More user-friendly and ergonomically sound designs of existing simple mechanical technologies;
- Better training of both the user and the operator in using the technologies; and
- Better marketing and dissemination of technologies through greater cooperation with users, private industry, and manufacturers to alleviate problems of ill-defined market, low economic status of users, and low interest of industry.

With cooperation from technology users and technology builders, certain solutions demonstrated here could improve the fit between the users and the environment. The remaining challenge is that of finding a compromise between the needs and desires of the users and the costs and risks of the technology.

REFERENCES

1. *Access for All: Transport Canada's Policy on Accessible Transportation*. TP 5014. Transport Canada, Ottawa, Ontario, Oct. 1991.

TABLE 2 Potential Benefits of Alternative Solutions

Disability Category	Accessibility Solution		
	Architecture	Technology	Training
Mobility	**High**	Med-High	Low
Vision	Medium	**High**	Medium
Hearing/Speech	Low	**High-Med**	Medium
Cognitive	Medium	Med-Low	**High**