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Information and Control Systems for Paratransit Services

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The current uses of information and control systems in paratransit services are reviewed, and new applications that are currently being developed are discussed. Thus far, the greatest use has been by the conventional transit and taxi industries for accounting, payroll, and limited management information. In both of these industries, the larger operators have recognized that the costs of automating these clerical functions are readily justified by the benefits. However, for many other functions, the questions of whether automation will produce benefits and whether the costs can be justified are still open. In several functional areas, most strikingly brokerage and pooling services, advances in computer technology and reductions in computer costs are already making a stronger economic argument for automation. At present, however, the ability of many of the more innovative applications of computer technology to paratransit to provide real economic advantages is unproven.

Information and control systems are central to most forms of paratransit because of the importance of managing, organizing, and assigning the vehicles that provide the transportation. Each type of service has different characteristics, and the appropriate type of information and control system also varies considerably. However, there are several important questions that must be addressed independently of the specific service being studied. These include

1. What are the benefits of using information and control systems?
2. Do these benefits justify the costs of implementation?
3. What are the major problems in using these systems?
4. What role should the federal government play in furthering appropriate uses?

This paper explores these issues by drawing on experience obtained from information and control systems already implemented or currently being developed.

The paper is structured around the following functions that might be performed by the information and control system of a paratransit service:

1. Customer information—responding to service enquiries from the public and service inventory;
2. Operations planning—planning the transportation system;
3. Operations control—monitoring and controlling the operation of the system;
4. Maintenance support—parts inventory, planning fleet maintenance, and monitoring vehicle performance;
5. Management information—monitoring and reporting on system performance; and
6. Accounting—including payrolls and general ledgers.

In general, any information and control system will perform only a small subset of these possible functions; indeed, for most services some of them are not even required. Table 1 presents a matrix of these functions, indicating past, current, or planned use for each type of

paratransit service, and the following sections of this paper review various experiences with information and control systems in different types of transportation services.

CONVENTIONAL TRANSIT

Not surprisingly, thus far, the transit industry has made heavier use of information and control systems than any of the other services being considered here. This is partly because of the size and longevity of most transit properties, factors that tend to make management and control more difficult, and partly because the federal government has funded and encouraged the development and installation of several of these systems. Although it is quite easy to determine the extent of use of information and control systems by the transit industry, it is much harder to assess the cost-effectiveness of these systems. Here, only a brief review is possible, but any available evidence of benefits is included.

Customer information is still typically provided by telephone operators, who rely principally on their knowledge of the system and supplement this with printed information. The principal problems with this approach are the length of time before an operator can be fully trained and useful and the difficulty of organizing printed material for fast access. Two levels of automation have been implemented or are currently being planned in attempts to overcome these problems. The first level involves the use of microfiche to store the route information, and the second level uses a computer data base. In the fiche-based systems, retrieval of the correct information may be either mechanical [e.g., the Chicago Transit Authority (CTA)] or computer aided [e.g., the Southeastern Pennsylvania Transportation Authority (SEPTA)]. The principal advantages of the mechanical-fiche approach are its low cost (about $30 000 for the CTA system) and the reduction in operator training time (90 percent for CTA). With automated-fiche systems, access time is reduced to less than 10 s, and significant gains in operator productivity can be achieved. A Stanford University study (1) indicated that a 15 to 20 percent time saving is possible with a microfiche system. Such productivity increases could well justify costs much greater than those of the CTA system.

It is interesting that in this type of use, as well as in several others, Canada is slightly ahead of the United States in implementing information and control systems. In a demonstration project in Mississauga, Ontario, a bus-passenger information system has begun to use an automated-voice response after a 2-year manual test. The computer system informs the person requesting information the times of arrival of the next two buses serving the route and stop number specified. Washington, D.C., and Los Angeles are currently planning fully computerized, customer transit information systems without automatic voice response.

At least in concept, a computer data base can be easily edited if the services change and can also organize and present different, and more generally useful, information than the traditional single route. However, there is still considerable disagreement in the industry on the benefits of any type of automation of customer information services and no strong movement toward its general application.

Operations planning for fixed-route bus service focuses on scheduling buses to routes and drivers to buses. The run cutting and scheduling (RUCUS) package that was developed with Urban Mass Transportation Administration (UMTA) funding is now being used by a variety of transit properties, again, typically with UMTA financial assistance. RUCUS builds a set of driver runs to meet a specified set of headways on each route so as to minimize operating cost given the existing labor agreement. Traditionally, for an even moderately sized property, this run cutting process has been laborious and time-consuming and required considerable skill on the part of the schedule makers. New runs are typically generated 3 or 4 times/year and, because of the cumbersome nature of the manual process, only minor changes are made from the previous year's schedule. But once the RUCUS package and necessary data files are established for a property, alternative schedules can be tested quite quickly. In some instances, RUCUS-generated schedules have been able to reduce the cost of operation slightly (by 1 or 2 percent), but the major benefits realized thus far have been through its use as a management aid and easier access to data. For example, management can readily estimate the cost of a particular change in the labor agreement and thus be more effective in union negotiations. Similarly, schedule makers can now concentrate on the service being provided to the public rather than on the mechanics of run cutting. Perhaps more significant, a computer data base describing the service being provided can be a key to the integration of a wide range of information and control system functions. On the cost side, a one-time RUCUS software installation cost of $50 000 to $100 000 is typical for a moderately sized operation, and there is perhaps a similar annual cost for running the program if time is purchased on a large machine.

San Diego Transit, probably one of the leaders in the transit industry in using information systems, has carried their use in planning one step further by an on-line verification of each driver's run selection. This software, developed in-house, is credited with the prevention of costly mistakes in the shake-up that could result in having to repeat the pick. The program is tied into the system accounting and payroll programs so that the driver pay for the next period is automatically determined on the basis of his or her run selection. Los Angeles is experimenting with using the computer as an aid to driver training and new-route study through on-line simulation, a technique that could significantly reduce the cost of driver training and improve the effectiveness of drivers on the extra board.

Operations control for fixed-route buses focuses on the maintenance of on-time service and the correction

Table 1. Application of information and control systems to paratransit services.

Function	Conventional Transit	Conventional Taxi	Dial-a-Ride	Shared-Ride Taxi	Transportation Brokerage	Van and Car Pooling
Customer information	x		x		x	x
Operations planning	x				x	x
Operations control	x	x	x	x		
Maintenance support	x	x				
Management information	x	x			x	
Accounting	x	x				

of deviations from schedule as they occur. At present, this process is a manual one in which on-street supervisors and central dispatchers attempt to identify problems and reallocate buses through radio instructions. In the future, bus-location systems may become part of computer control systems that could provide the dispatcher with a coherent picture of operations on a route and, perhaps, suggest alternative corrective actions when problems develop.

Central to this concept is an automatic vehicle-monitoring capability for fixed-route bus service. Such systems have been tested in Chicago, Philadelphia, Vancouver, and Toronto, and further tests are planned for Los Angeles. Sudbury, Ontario, has recently implemented a signpost-based, manually monitored, bus control system. Chicago, which earlier experimented on a limited scale with a similar bus-location system, is planning an expanded system that will eventually incorporate an on-line computer. Again, however, there is no real evidence that this type of use justifies the costs and very few operators have strong active interest in it.

The final three areas of maintenance support, accounting, and general management information are, perhaps, the most amenable to computerization, and computers are, in fact, widely used for these functions in the transit industry. A major focus of current work in this area is the development of a uniform system of accounts and a records and reporting system, which is required under section 15 of the 1974 Amendments to the Urban Mass Transportation Act of 1964. To be eligible for grants under section 5 of the act after July 1, 1978, all applicants must be using this uniform system of accounts and records. UMTA is assisting transit operators in converting to this new system by making the conversion cost eligible for funding under the section 5 grant program as either a capital or an operating expense. A 1976 American Public Transit Association (APTA) project report estimated that the industrywide cost of this conversion would require a federal contribution of more than $40 million (2). This indicates both the importance of federal assistance in such a standardization and how difficult it is to achieve uniformity in a large industry once diverse information systems are already in general use.

Vehicle maintenance systems beyond parts inventory are now being implemented by some of the larger transit properties with the principal objectives of increasing maintenance-employee productivity, reducing clerical requirements, and reducing the number of on-the-road breakdowns. As an example of one such system, CTA this year implemented a vehicle maintenance system that is designed to increase maintenance-employee productivity by 10 percent over a 3-year period. This system involves recording the type of task and bus number of each employee's current activity so that standards can be developed for each type of job. The data base can also be used to determine the current status of the buses and the labor force. Whenever a dispatcher receives notification of a bus breakdown, the information is keyed into the computer, and a complete maintenance history of the vehicle is available at the appropriate garage. To aid in scheduling preventive maintenance, a computer record of travel since the last inspection is maintained so that a list of buses close to their scheduled inspection time is always available.

To summarize, there are great differences in the uses of information systems among transit properties. Most properties use computers for the clerical aspects of maintenance support, management information, and accounting. Beyond these functions, some properties are moving into other areas—even toward an integrated information-system approach that would cover all the suggested functions. Two properties in this category are San Diego Transit and the Santa Clara Transit District. In Santa Clara, California, which is in the process of expanding its fleet by a factor of two to about 500 buses, an integrated system is being developed that will include a driver-actuated, computer-assisted bus monitoring system, an on-line customer information system having address lookup, RUCUS, and an on-line maintenance program. This is clearly an innovative and imaginative system and will require an annual operating budget of at least $250 000. It remains to be seen what tangible benefits will result and whether other properties will be persuaded that such applications are cost-effective. A potential role for government exists here in the monitoring of these systems both to assess their effectiveness and to publicize the results.

CONVENTIONAL TAXI

The taxi industry represents a sharp and interesting contrast with the transit industry. Of particular relevance to the subject at hand are

1. The lack of federal funding for, or regulation of (or, until recently, interest in), the industry;
2. The private enterprise nature of taxi operations that necessitates profitable operations; and
3. The fragmented nature of the industry, which is composed principally of small operators.

For all of these reasons, one might expect the taxicab industry to make much less use of information and control systems than the transit industry. Furthermore, since their use of automated systems is not affected by federal funding, a lasting use must be cost-effective on the basis of full costs and internal benefits—a much harsher standard than in the transit industry. In practice, although there has been less experimentation with unusual applications of computers in the taxi industry, the use of computers for routine tasks is already widespread among medium and large operators. For example, a 1976 International Taxicab Association (ITA) survey of a small sample of taxi companies operating more than 25 cabs each showed that more than 75 percent of them used computers routinely. About half of these had an in-house computer, and the remainder used an outside service bureau. The most common functions that the computers perform are accounting, payroll, maintenance support, and evaluation of driver performance. Significantly, none of the companies surveyed currently use a computer to assist in the dispatching process (operations control), although some expressed an interest in the possibility of doing so in the future.

At present, there is much diversity among the computers and software being used in the taxi industry; each system is to a great extent a custom product. However, as in the transit industry, an effort is now under way to standardize the statistics that each firm produces. This project (Taxistats 2) has resulted in a software package that will be run by ITA to generate industry and firm reports. The proposed uniform statistics have been gathered on a test basis from approximately 20 companies, and the system is now ready to be used nationally. It is designed to be compatible with the corresponding transit system and can include shared-ride as well as exclusive-ride systems. Taxistats 2 will soon be required for subsidized systems, but will be voluntary for other systems. Given the small number of required participants and the lack of the financial incentive of federal assistance, what impact the system will have on the taxi industry is questionable.

It is striking how sparingly computers have been used

for dispatching operations; only the Los Angeles Yellow Cab Company and the Diamond Association of Montreal have done so on a large scale. In Los Angeles, a computer system was installed in the winter of 1971-1972. As a request for taxicab service was received, it was entered into the system, which validated the order, assigned the request to the appropriate dispatcher along with the number of the appropriate cab stand for use in servicing the order and, if a cab was available at that stand, its number. Drivers were to report their locations when available for service. However, the system was oversold to the drivers in terms of possible increased revenue and, when the radio frequencies available for driver input could not handle the volume, the drivers lost faith in the system. The driver-location phase of the loop was dropped and the system continued to function without it.

By the fall of 1973, it was evident that this system had a number of deficiencies that required correction—limited capacity to handle standing advance orders, inadequate handling of call-backs, inconvenient search for alternative stands, and slow response times when the system was handling more than 300 orders/h. By the summer of 1974, a new minicomputer system was installed with improved software that operated satisfactorily until the company ceased operation in December 1976.

In Montreal, Diamond, which provides dispatching services to 1000 cabs and processes about 4000 orders/d, has been using a computer since 1973 to control communications between the dispatchers and the drivers. The major problems to overcome were favoritism and call piracy, but these have been solved and at the same time, driver earnings have increased by 20 percent as a result of the greater operating efficiency (3). New computer dispatching systems are currently being implemented in Mississauga (Intercab Taxi Company), Ottawa (Blue Line Taxi), and Detroit (Checker). Both of the new Canadian systems involve computer matching of calls with cabs waiting at stands and mobile displays that provide the drivers with their assignments. It is still too early to evaluate the effectiveness of these new systems.

All of these uses are by very large taxi companies, and it is not yet clear to what extent, and how quickly, other large- and medium-sized companies will follow. The principal potential benefits appear to be greater efficiency in the use of vehicles through the elimination of dispatcher favoritism and call piracy, but there will be a capital investment required and operators will have to be shown that computers can in fact produce these benefits. It is probable that these systems will diffuse only very slowly without active participation of the federal government in demonstration projects and, possibly, financing. At present, there is neither a demand for automated dispatch systems on the part of taxi operators nor a supply in terms of dispatch systems with proven ability to deliver the potential benefits.

Given the poor financial conditions of many taxi companies, the use of computers must be based on compelling economic arguments. The reduction in total system cost through automation of clerical functions is accepted, and the road to more significant uses will almost certainly be based on a low marginal cost for these additional functions. The efficacy of this argument remains to be seen.

DIAL-A-RIDE

Dial-a-ride is still in the earliest stage of development; no more than 100 or so systems are yet operating, and none of them have existed for more than 7 years. The use of information and control systems by dial-a-ride operations has focused on the control of operations, as does this discussion.

Dial-a-ride represents an extreme form of paratransit service and relies most heavily on a complex, real-time control function. In the pure many-to-many (or unstructured) form, the activities of each vehicle are decided on the basis of the current state of the system and must be continually relayed to the driver. Although this is by no means the only form of dial-a-ride operating today, the discussion below will begin by concentrating on this and then note how other configurations alter the control system requirements.

Automated operations control for dial-a-ride can take the form of computer decision making, computer information storage and retrieval (this will be referred to as computer assisted), digital communication with the vehicles, and combinations of these. Automated control has the following potential benefits: improved service quality (particularly reliability), controlled service quality, simultaneous provision of different types of service, improved vehicle speeds, reduction of the knowledge of the area required of dispatchers, increased vehicle productivity, and increased size of systems. The principal penalty associated with automated control systems is increased control cost, and its justification depends on the existence and extent of these supposed benefits and their importance.

Thus far, automated control systems have been used by unstructured dial-a-ride operations at only three sites: Haddonfield, New Jersey; Santa Clara, California; and Rochester, New York. The Haddonfield control system was used in the latter stages of the UMTA-sponsored demonstration project that operated from 1972 to 1975. Dial-a-ride service was provided by a 10-vehicle fleet serving a 2800-ha area. The computer control system used a 32K-word general purpose machine that was responsible for assigning customers to vehicles (4). When fully operational, the system succeeded in improving service quality, in particular reducing passenger wait time by about 17 percent, but did not achieve any of the other benefits suggested above (5). Part of the reason for this was the short time (less than 6 months) that the system functioned to full effect. The computer control system was removed at the scheduled end of the demonstration project and has not been used since then. Although its cost is not available, this particular control system could not be justified by the benefits demonstrated in Haddonfield.

In contrast, the Santa Clara system was not a federally funded demonstration, and its computer control system was developed without UMTA support. Thus, a complete assessment of its performance is harder to make because of incomplete documentation (6). Furthermore, the Santa Clara system operated for fewer than 6 months (November 1974 to May 1975) and only under computer control, which makes it more difficult to draw any conclusions and impossible to compare manual and computer dispatching. Santa Clara was by far the most ambitious dial-a-ride system implemented at that time, having about 75 buses operating in a 50 000-ha area that has a population of 1.1 million. The control system used in Santa Clara was loosely based on that used in Haddonfield, although the computer was used to assist the dispatcher rather than to make the assignments directly. It is probable that such a large system would not have been undertaken without an automated control system, but no other benefits can be attributed to it. Once again, the control system cannot be justified on the basis of any demonstrated benefits. Since the termination of the Santa Clara system, the control system has not been used anywhere else.

Dial-a-ride has been operating in Rochester for 4 years, the last two of which have been under the auspices of the UMTA Service and Methods Demonstration Program. Currently, two separate but connected areas of

about 4600 ha and 100 000 population are being served with a fleet of 10 to 15 vehicles. As part of the demonstration project, an automated control system was installed and has been functioning for almost 2 years. This control system is also based on Haddonfield's, but has significantly greater capabilities, in particular direct two-way digital communication between the drivers and the control center and computer. In addition, the computer assignment algorithm has been enhanced to allow multiple types of service and to effectively control service quality. This computer decision making is performed on a large remote time-sharing computer with local computers to handle communications and the controller terminals.

A comparison between manual dispatching and the automated control system in the smaller area (Irondequoit) has shown that in some respects, service quality has improved significantly with computer dispatching (Table 2) (7). For example, the mean total service time for immediate requests decreased from about 40 to 28 min, with much lower variability. All of the benefits suggested above have been demonstrated in Rochester except the ability to increase vehicle productivity through the use of computer control. Unfortunately, this is the most important anticipated benefit, and the failure to demonstrate it is a serious disappointment. There are several reasons for the unchanged vehicle productivity. Probably the most important is that vehicle unreliability over the past 2 years has so alienated potential users that dial-a-ride is now viewed very much as a last resort; service has been bad for so long that improvements make no difference to a skeptical public. A second reason is that, because of budgetary pressure, the service has been gradually reduced over the past year in terms of area served, the number of vehicles operating, and the hours of service and demand is considerably decreased, making higher vehicle productivities still harder to achieve.

The control system used in Rochester, although effective from many points of view, still cannot be justified economically for such a small system. It is possible that a similar automated control system could be implemented at a hardware rental cost of $5000/month and a lifetime communication hardware capital and operating cost of $4500/vehicle (i.e., about $100/month/vehicle). Let us examine the economics of such a control system by asking the question, How large a vehicle productivity increase is required to offset the increased control cost? The Rochester system has also shown that an automated control system will neither increase nor decrease control staff requirements. The monthly cost of operating a 20-vehicle system (at a cost of $15/vehicle-h for 12 h/d, 5 d/week) will be about $76 000. Thus, an increase in vehicle productivity of only 10 percent would justify the installation of such a control system. Although no increased productivities have yet been observed, it is easy to justify continuing the search; the rewards are potentially large.

Turning to more structured forms of dial-a-ride, the greater the degree of structure imposed, the less likely is any role for the automated control system or the simpler the system will be if it is implemented. The most common type of structuring is the zonal-loop type of service in which the service area is divided into mutually exclusive zones that have one vehicle operating a loop on a fixed-time cycle in each zone. Ann Arbor, Michigan; Bay Ridges, Ontario; Regina, Saskatchewan; and other Canadian operators provide this type of service with the focus of each zone being a transfer stop on a line-haul transit facility. Decision making in this type of system is considerably easier than in the unstructured form, and the control requirements are also somewhat simpler. Thus far, Regina with 15 buses and Ann Arbor with 32 vans (operating in dial-a-ride service at a single time) have implemented some form of computer assistance for this type of service, and Calgary with 6 vans is in the process of doing so. In Regina, the computer lists the regular riders on files that are organized into trip sheets and printed daily for the use of drivers, and using the computer to store and organize requests for immediate service is being considered.

The Ann Arbor control system is considerably more complex than the Regina one, representing a fully computer-assisted dispatching system (8). In this system, the computer, which has a 48K-word core, makes almost no decisions, but rather accepts the booking of requests, displays information for the dispatcher, and stores the assignments made by the dispatcher. One of the implications of this system is that dispatchers are still the prime determinant of service quality and so must be highly skilled and reliable. This control system has been operating for almost 2 years, and although the resulting benefits have not been evaluated, it is thought that without the system only about half the current number of vehicles could be effectively controlled. Ann Arbor is not an UMTA-sponsored demonstration project, but received a capital grant that covered most of the $498 000 cost of the information and control system. Recently, digital communication has also been introduced between the control center and the vehicles.

The control system being implemented in Calgary is essentially the same as that in Ann Arbor except that in Calgary the computer will send the information to land-based printers at the transfer points rather than to

Table 2. Comparison of manual and computer dispatching in Irondequoit.

Measure of Service	Manual (min)	Computer (min)	Preferred	Improvement (%)	Statistically Significant Difference at 95 Percent Level
Immediate passenger requests					
Mean wait time	29.69	17.44	Computer	41	Yes
SD of mean wait time	20.42	10.23	Computer	50	Yes
SD of mean daily wait time	5.93	4.12	Computer	30	—
Mean pickup time deviation	5.51	6.25	Manual	-13	—
SD of mean pickup time deviation	16.24	8.53	Computer	47	Yes
SD of mean daily pickup time deviation	3.94	2.49	Computer	37	—
Mean ride time	10.41	10.72	Manual	-3	—
SD of mean ride time	5.49	7.19	Manual	-31	Yes
SD of mean daily ride time	1.35	1.28	Computer	5	—
Advance passenger requests					
Mean pickup time deviation	7.12	4.24	Computer	40	Yes
SD of mean pickup time deviation	15.29	10.87	Computer	29	Yes
SD of mean daily pickup time deviation	5.99	2.32	Computer	61	Yes
Mean ride time	10.60	13.05	Manual	-23	Yes
SD of mean ride time	7.11	7.27	Manual	-2	—
SD of mean daily ride time	1.61	1.83	Manual	-14	—

mobile displays on the vehicles.

In summary, the future role of automated control systems in dial-a-ride is not yet decided. There have been several such systems implemented in the past 3 years, but no two have been the same and no economic benefits have been observed to offset the implementation expense. It is anticipated that as the latest experiences in Ann Arbor and Rochester are evaluated, increasing attention will be paid to demonstrating economic feasibility. It is clear that small dial-a-ride systems can be operated without computer control and that large systems cannot. What is less clear is whether large systems will play an important role in urban transportation over the next few years.

SHARED-RIDE TAXI

Shared-ride taxi is very similar to dial-a-ride from a technical point of view, the only difference in the control problem being a more binding vehicle capacity. However, the distinction between conventional transit and taxi is also true between dial-a-ride and shared-ride taxi. Although shared-ride taxi is now included in the UMTA definition of transit services, operators of shared-ride systems have not yet received anything like the federal funding or technical assistance from which dial-a-ride operators have benefited. It is not surprising then that there has been much less innovation in shared-ride taxi services than in dial-a-ride. All the potential benefits to dial-a-ride would also apply to shared-ride taxi. In systems in which drivers are paid on an incentive or commission basis, the potential benefits include (as for conventional taxi) the reduction or elimination of dispatcher favoritism and the stealing of passengers by cabs other than the one assigned.

Despite these potential benefits, the only known use of automated control by a shared-ride taxi system was that in Davenport in 1972. In this case, the Royal Cab Company reported an increase in revenue from 20¢/km (32¢/mile) with manual dispatching to 27¢/km (44¢/mile) with computer dispatching (9). Despite this favorable result, the computer was quickly withdrawn from service because it was unable to keep up with the volume of requests. Furthermore, despite some publicity for the Davenport results, no other shared-ride taxi operator has followed suit—either the costs and risks are too high or the benefits are not credible.

A quite different development is the work at Carnegie-Mellon University on improved taxi meters. One new meter would have the fare for a trip determined by computer, communicated to the taxi, and displayed on the meter—all at the start of the passenger's trip. This would remove uncertainty in the passenger's mind about the ultimate cost of the trip and also allow promulgation of more complex and equitable fare structures for both exclusive-ride and shared-ride operations.

Automated control may well be an important issue in the future expansion of shared-ride taxi service; one oft-cited obstacle is the difficulty of manually dispatching large shared-ride fleets. However, if shared-ride taxi service is to expand significantly, two prerequisites would seem to be the demonstration of effective control systems for large fleets and a means for private operators to acquire these systems at reasonable cost. A good illustration of the capabilities and limitations of manual dispatching is provided by the Black and White Cab Company of Little Rock, which currently provides shared-ride service with 75 taxis controlled by two dispatchers without computer assistance. This operation, which is far larger than any existing dial-a-ride service, has a severe dispatching problem that is one of the factors preventing further expansion. This experience tends to confirm the importance of proven cost-effective computer-dispatching systems for the expansion of existing shared-ride taxi services and the creation of large new systems. It also indicates that there is no product currently on the market that is cost-effective for the unsubsidized private operator.

TRANSPORTATION BROKERAGE

A transportation broker provides a clearinghouse between those needing transportation and those providing it. In most cases, the transportation being brokered runs on a fixed schedule (such as line-haul bus or commuter rail) or is already scheduled (such as van pools or car pools). A person needing transportation enters the brokerage with trip origin and destination locations and desired trip start and end times. The broker then attempts to match the transportation request with the available transportation and informs the customer of all reasonable transportation alternatives. This matching can also recognize the requirements of the elderly and handicapped and identify transportation services suited to their special needs. The customer then selects the desired alternative and places a reservation either with the broker or directly with the provider.

The information and control requirements of this type of paratransit service are obviously quite different from the real-time scheduling requirements of dial-a-ride or taxi operations. The broker integrates the services of many different transportation providers and hence must be able to maintain a large data base including capacities, schedules, and fares for each type of service. Many of the customers in such a system are permanent, using the same transportation service on a regular basis. The broker must be able to maintain records of these customers and the resources they use.

In addition to this fairly static information base, the transportation broker must also handle a number of dynamic data flows. For example, if a transportation service is temporarily unavailable (e.g., the van-pool driver is sick or there is a bus strike), the broker must record the unavailability, notify the customers affected, and inform them of alternative services. Conversely, the schedule of a regular customer may temporarily change (e.g., overtime, vacation, or illness), and the broker must both provide different transportation service and attempt to use the transportation resource suddenly made available. Finally, the broker should be able to handle the walk-in customer who needs single-trip transportation. With all of the transportation requests being channeled through a single information center, the broker can also provide nontransportation services such as customer accounting, vehicle maintenance scheduling, and other management information.

Although it is obviously possible to operate such a transportation brokerage manually on a small scale, the benefits to be gained from the use of an automated system are significant:

1. The ability to include more transportation providers in the system,
2. The ability to include a larger number of customers in the system,
3. The ability to locate more customer-provider matches in real time, and
4. The ability to provide support services such as accounting and maintenance scheduling without additional clerical assistance.

Although such an information system could easily be implemented on a minicomputer or a time-sharing computer, it is unlikely that this would be cost-effective for

a small community brokerage. Knoxville, Tennessee, for example, is currently using a large-scale (DEC system 10) time-sharing system to provide on-line inquiry capability into available transportation resources, but has found that the cost prohibits expanding the on-line services to include resource allocation or scheduling. Within the last year, however, a new computer technology has arisen that makes such a system much more cost-effective.

Microcomputers have brought general purpose computing power into a new cost-performance range. A complete computer hardware system capable of providing all of the above functions can now be purchased for less than $10 000. The software for such a system, once developed, could be used by many different transportation brokers.

The first attempt to introduce this new technology is currently under way in Knoxville, where UMTA is sponsoring a project to develop the software and hardware required to support a microcomputer-based information system with all of the capabilities described above. In addition, it will provide some of the van- and car-pool matching capabilities discussed below.

VAN AND CAR POOLS

Van and car pools are perhaps the simplest transportation systems from an information and control standpoint. With the exception of unplanned changes in rider schedules (overtime, medical appointments, and such) and vehicle failures, they are basically static systems. Once a set of riders is firmly established in a given pool, there is normally little interpool movement. The only planned changes are the addition or deletion of riders from the system as a whole or the permanent schedule change of a rider who requires a reassignment to a compatible pool.

The static nature of the system allows the use of well-established information-system techniques with minimal real-time capabilities. A data base consisting of all potential riders and their schedules, preferences (driver versus rider), and other specific requirements, such as smoking versus nonsmoking, must be established first. Then, by using this data base, an initial set of matches can be generated, leaving all unmatched riders in the pool for later comparison with new pool entries. As new riders enter the system and others leave or request revised arrangements, additional scheduling runs are made to generate new matches.

The potential real-time benefits of such an information system are similar to those described above for a transportation brokerage. When short-term schedule changes, vehicle failures, or other disruptions occur, it is desirable for the system to be able to locate an alternative pool with available space. In addition, a real-time capability would allow the immediate entry of requests for new service, service deletions, and reassignments.

There are many available programs, services, and systems for car- and van-pool scheduling. Most of these use medium- to large-scale computer systems, with their associated cost and accessibility characteristics. These programs are normally run periodically in a batch environment and have no capability for revising the matches in response to short-term fluctuations in ridership or schedules. Knoxville and Commuter Computer in California both currently schedule their van pools in this way.

The nature of the computer requirements makes microcomputer technology extremely useful for small-scale operation. Computational requirements for the assignment process are well within the capabilities of the microcomputer, and because the scheduling need not be done in real time, speed is not a central issue. In addition, the availability of a dedicated computer system at such a low cost would allow for the inclusion of additional real-time capabilities.

It is apparent that there is a potential overlap between the transportation brokerage and the van- and car-pool organizer. The pools are potential sources of transportation service for the broker to draw on, and the broker has the capability to provide backup transportation to the pool riders. This overlap indicates the desirability of developing integrated systems that can provide both services. The system being developed for Knoxville is attempting to do just that. It will record pool requests in real time for later scheduling in an off-line mode. It will also use the pools as resources for the provision of transportation service to customers who require a nonscheduled trip.

SUMMARY

The discussion above shows that fairly extensive use of information and control systems is already being made in existing urban transportation systems. The greatest use is in conventional transit and taxi industries for accounting, payroll, and limited management information. In each of these industries, there has thus far been little commonality among the systems of individual operators, but because of legislative requirements, there are now plans to standardize the accounts, records, and reports of those operators receiving federal assistance. This will include most transit operators, but exclude many taxi operators, and underlines the differences in the traditional positions of these industries vis-à-vis the federal government: Transit is subject to extensive federal regulation but also receives substantial federal money for the development and implementation of new techniques; taxis are relatively unaffected by direct federal actions.

In both industries, medium- and large-scale operators recognize that the costs of information systems for these clerical functions are readily justified by the benefits. For many other functions, however, it is still unclear to what extent benefits exist and whether they justify the costs of information systems. In the taxi industry, where the problem of control is important, the cost of implementing an automated system without outside financial assistance and the lack of demonstrated benefits are major reasons for the lack of these systems. A cautious approach is very undestandable for any large taxi company. The traditional manual approach to control of conventional taxi operations certainly keeps control costs to a minimum, and the possible adverse employee reaction to an automated system could well destroy a company whose financial condition was precarious. Why make a major financial commitment for unknown and disputed financial benefits? If computer dispatching is to have any significant impact on the taxi industry, it will more likely come initially through shared-ride services. For shared ride, a stronger federal role can be seen emerging in terms of both technical and financial assistance. Thus, the taxi operator might be shielded from many of the risks during experimentation when the credibility of computer dispatching is being established. After that, its use by conventional taxi operations may seem worthwhile. In terms of encouraging shared-ride operations, funding research and development, and providing financial assistance, federal participation will be the key to wider use of information systems by the taxi industry. Equally clearly, computer control, with its large fixed costs, will be most readily justified for the largest operators. For some of these larger operators, who already use computers for clerical tasks, the marginal

costs of additional computer functions may be low enough to justify the risks of experimentation even though the costs of failure are high.

In the transit industry, which has a special position with respect to federal research and development and the availability of capital assistance and demonstration projects, information systems are being used experimentally in a number of ways. However, the benefits and cost-effectiveness of most of these—passenger information systems, RUCUS, bus control systems, and maintenance control systems—are still in dispute. Full evaluation of these is often very difficult and unsatisfactory because of uncontrollable events in the operating environment, but the UMTA Project Evaluation Program is designed to maximize the information obtained from the experiments, and the inclusion of innovative applications of information systems in the evaluation program would be most valuable.

For dial-a-ride, control technology has been developed and demonstrated with UMTA support, but definite economic benefits have not yet been shown. The economic justification for automated control is, however, being overshadowed by the concern about the economic feasibility of dial-a-ride itself. Actions to improve productivity, such as imposing spatial and temporal constraints on services, are becoming increasingly important, and these actions tend to simplify the control problem, thus decreasing the need for automated control. For small dial-a-ride systems (perhaps fewer than 15 vehicles), manual control is quite effective (with good training), and for much larger systems, either zonal structured service (as in Ann Arbor) or shared-ride taxi service may well be preferred.

In several of these types of use, most strikingly in the area of brokerage and pooling, advances in computer technology and reductions in computer costs are already making a stronger economic argument for automation. However, at present, it has not been proved that many of the more innovative uses of computer technology can provide paratransit with a real economic advantage.

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Management and Organization for Promoting the Use of Paratransit

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Before paratransit organizations can develop, it is necessary to demonstrate their capabilities to the community. This paper presents a strategy for implementing various paratransit services and integrating these services into the community. It also presents some of the philosophical issues on which paratransit programs may be structured. Finally, it suggests an organizational structure that can be used to promote these concepts and appropriate funding levels.

HISTORICAL REVIEW OF PUBLIC TRANSPORTATION

The conditions under which public transportation operates today are entirely different from those under which it operated a century ago. Then, the railroads and trolleys were a quantum jump ahead of their competition (walking, horseback, and carriage) in terms of travel time, comfort, and convenience. In fact, railroads and trolleys were so superior that, even if a rider had to take a longer route or wait for the next train to take advantage of the service, he or she was better off.

At first, the railroad and trolley lines were very profitable and governments used regulation as a taxing device to force the companies to provide street lighting, maintain roads, and give service to low-density nonprofitable areas.

The automobile changed all that. It provided an additional quantum jump ahead in flexibility, time saving, and routing alternatives. Although the automobile was more expensive, it did not have to be driven by a professional driver. It was a do-it-yourself dream. It was not restricted to a single route, and the vehicles were small enough so that they could be adapted to