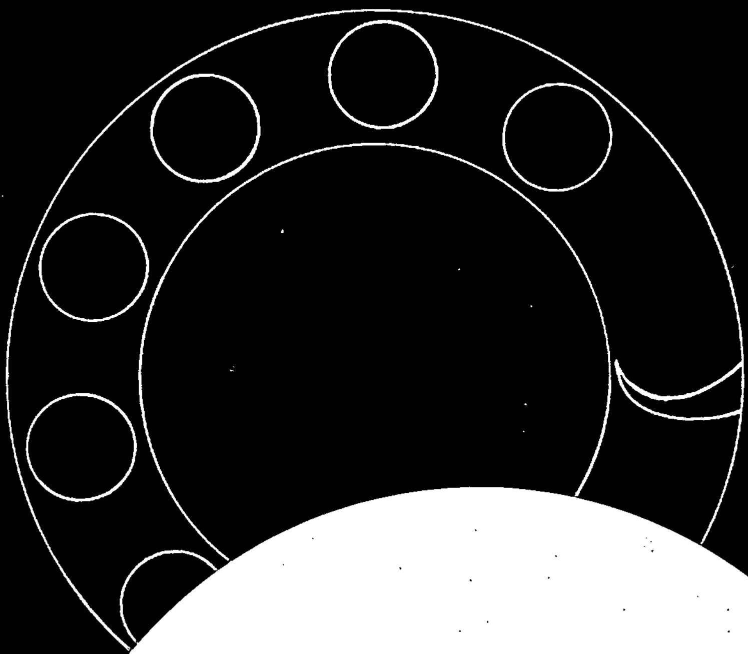

DEMAND-RESPONSIVE TRANSPORTATION

SPECIAL REPORT 147
Transportation Research Board

TRANSPORTATION RESEARCH BOARD 1974

DEMAND-RESPONSIVE TRANSPORTATION

Proceedings of the Fourth Annual International Conference on Demand-Responsive Transportation Systems conducted by the Highway Research Board on October 3-5, 1973, Rochester, New York, and cosponsored by the American Transit Association, Massachusetts Institute of Technology, and Rochester-Genesee Regional Transportation Authority

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INTRODUCTION

Daniel Roos, Massachusetts Institute of Technology

The Fourth International Conference on Demand-Responsive Transportation was held at an important period in the development of these systems. A number of small manually dispatched first-generation systems were successfully installed and operated in the early 1970s. In 1973, the first installations were made of several new second-generation systems. These differed from first-generation systems in the following ways:

1. They were in metropolitan areas rather than small cities;
2. The system consisted of more vehicles and covered a larger area;
3. The system was integrated with existing transit operations in the area; and
4. Automated dispatching aids using digital communications and computers were introduced.

The conference addressed many of the critical questions pertaining to these second-generation systems and reflected on experiences with first-generation systems to determine what had been learned. Those reflections were rather significant not only from the viewpoint of demand-responsive transit but also from the general viewpoint of public transportation.

Demand-responsive transit systems have served as a catalyst to introduce many new approaches in the field of public transportation. They have demonstrated the many different transit markets that exist and the necessity to provide different services for each of those markets. Of particular importance is the role they are playing to serve the needs of the elderly and handicapped. They demonstrated the importance of community participation in the development and implementation of new system concepts.

Marketing, promotion, and new management techniques were essential to the success of these systems. They began to demonstrate how public transportation should be viewed as a system—not as an expanded series of separate services.

Labor, often thought to be opposed to innovation and change, was an important contributor to the success of the systems and worked as a partner with management to adapt to new service requirements. Local communities undertook considerable risk, often implementing systems without any federal financial assistance.

Dial-a-ride had become accepted. No longer was the annual conference a meeting place for "the club" who had originated the concept. There were many new people at the conference—people who wanted to implement these systems. Many of them were not transportation professionals. This was largely a movement of the people and the community—not the transportation professional.

The sponsorship of the 4 conferences gives some indication of the growth and evolution of the demand-responsive concept. The first 2 conferences were sponsored by the Massachusetts Institute of Technology and were primarily oriented toward research and development. The third conference was cosponsored by M.I.T. and the Highway Research Board. This provided broader professional coverage and resulted in the publication of the conference proceedings as HRB Special Report 136.

The Fourth Conference was hosted by the Rochester-Genesee Regional Transportation Authority, which implemented one of the first dial-a-ride systems in Batavia, New York, and implemented a second expanded system in Rochester only 2 months before the conference. The conference was cosponsored by M.I.T., the Transportation Research Board (formerly the Highway Research Board), and, for the first time, the American Transit Association. ATA, recognizing the impact of these systems on transit operations, participated actively in the planning and execution of the conference.

At a time when considerable interest is being directed toward low-capital alternatives, the proceedings of this conference should be beneficial to many groups concerned with demand-responsive transit.

The Fifth Annual International Conference on Demand-Responsive Transportation Systems will be held November 11-13, 1974, at the Oakton Hilton Inn, Oakton, California. Those interested in attending or presenting a paper should write the Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

panel discussion

GROWING DEMAND-RESPONSIVE SYSTEMS IN THE UNITED STATES AND CANADA

W. R. McDougall, Kates, Peat, Marwick and Company, moderator

Several demand-responsive systems that commenced operation 2 or 3 years ago have been considered so successful that they are now undergoing significant expansions; in some cases, they are becoming communitywide systems. These systems and the names of the panelists who discussed them are given below. Panelists were asked to respond to prepared questions as well as those from members of the audience. The questions were not technology oriented in that they did not deal with planning techniques, routing, dispatching systems, and equipment. The intent was to discover how the community views demand-responsive transit service, where systems have been successful, and why they have been successful, not necessarily according to the technicians but according to the people who use the system.

METROPOLITAN TORONTO DIAL-A-BUS

Hugh Clelland, Ontario Ministry of Transportation and Communications, Toronto

The Government of Ontario has the distinction of having launched the oldest operating demand-responsive system in North America. Through its GO Transit operation, Ontario commenced a commuter rail feeder system in the suburban community of Bay Ridges in 1970. That operation has continued to thrive and grow; ridership has steadily climbed every year. Recently operating responsibility was transferred from GO Transit to the municipality of Pickering.

Based on the success of the service in Bay Ridges, other Ontario communities have launched demand-responsive systems, notably Stratford, Kingston, Bramalea, and Ottawa. By far the largest and most ambitious is the system now being implemented by the Toronto Transit Commission and GO Transit in North York. This system will feed line-haul transit and provide internal circulation within a service area containing residents.

Item	Initial System (Bay Ridges)	Expanded System (North York)
Service date	June 1970	October 1973, first phase February 1974, final phase
Population served	13,700	200,000 (total off peak)
Number of vehicles	4	27 (20 off peak)
Average weekday ridership	640 (winter 1972)	5,000 to 6,000 projected
Fare	30 cents	40 cents
Type of service	Commuter rail feeder; many-to-many intraneighborhood, off peak	Subway and route bus feeder, peak; suburban shopping and many-to-many intraneighborhood, off peak

ANN ARBOR TELETRAN

Michael J. Berla, Ann Arbor Transportation Authority

The basis for expanding the Ann Arbor system is success of the dial-a-ride pilot project. Two significant findings were recorded:

1. Transit trip-making in the target neighborhood doubled over previous regular route bus service; and
2. More than half of the dial-a-ride patrons previously used private cars to make the same trip.

The citizens of Ann Arbor voted a 2½-mill property tax in April 1973 to expand the dial-a-ride service from one neighborhood to a citywide Teltran system. The Teltran system is being implemented in phases and will be fully operational in 1974.

Item	Initial System	Expanded System
Service date	September 1971	Summer 1974
Population served	6,500 initial 17,000 final	100,000 (entire community)
Number of vehicles	3	40 dial-a-ride 30 express coaches 5 wheelchair buses
Average weekday ridership	200 initial 375 final	5,000 to 6,000 projected
Fare (adult cash)	60 cents	25 cents
Type of service	Many-to-few neighborhood to downtown and hospitals	Many-to-many citywide

ROCHESTER-GENESEE REGIONAL TRANSIT AUTHORITY DIAL-A-BUS

James E. Reading, Regional Transit Service, Rochester

The Rochester-Genesee Regional Transit Authority has been a leader in advancing the demand-responsive transportation concept. Its first project was a citywide system for Batavia (population 18,000). Based on the ridership response and efficient operation in Batavia, the authority implemented service in part of the Rochester metropolitan area. The new Rochester system employs radio teleprinter communication, which was first successfully demonstrated in Batavia. The present operation in Rochester is considered to be the first step in what will eventually be a much larger system.

Item	Initial System (Batavia)	Expanded System (Greece and northwest Rochester)
Service date	October 1971	August 1973
Population served	18,000	30,000
Number of vehicles	5	7
Average weekday ridership	450 (winter 1972)	230 during 4th week; still growing
Fare (adult cash)	60 cents	$1.00 base fare with discount fare for children and regular subscription service
Type of service	Many-to-many; citywide in small community including home to work and home to school	Home to work and home to school service; feeder for regular route bus; many-to-many; midday service

REGINA TELEBUS

Wallace G. Atkinson, N. D. Lea and Associates, Ltd.

The Regina Telebus project is the most ambitious and successful in North America if ridership is used as a basis for comparison. The original test area is a high-income neighborhood in south Regina, which had failed to attract significant ridership on regular-route buses. Telebus was overwhelmingly successful, doubling transit ridership from the area and simultaneously reducing the operating deficit. Regina Transit has subsequently been expanding the service on a regular basis, adding area and vehicles. Eventually, all outlying neighborhoods in Regina will have Telebus service.

Item	Initial System	Present System	Ultimate System
Service date	September 1971	April 1973	1976
Population	18,000	32,000 peak; 63,000 night	80,000 peak; 120,000 off peak and night
Number of vehicles	7	11	35
Average weekday ridership	1,200	2,000	5,000 projected
Fare	35 cents	35 cents	40 cents
Type of service	Intraneighborhood many-to-many, line transit feeder		

REASONS FOR EXPANSION

QUESTION: What specific findings from your test or pilot system led to the decision to expand? By what criteria has your system been judged successful? Is the community as a whole involved?

BERLA: The two most important, specific findings from the Ann Arbor pilot dial-a-ride project were (a) transit ridership approximately doubled in the area where the project was first operated (a relatively high-income, high-automobile-ownership area) and (b) approximately 50 percent of the trips were diverted from automobiles. In the absence of dial-a-ride, 18 percent would have driven their automobiles and another 32 percent would have been driven as passengers. Our situation required 2 major decisions: one by the Ann Arbor Transportation Authority to propose that the system be expanded and the second by the public to vote at a general election where the millage was on the ballot in the form of a permanent charter amendment. The crudest measure of community involvement is that 61 percent of those who voted in the Ann Arbor general election on April 2, 1973, voted in favor of a charter amendment that had the effect of raising local taxes by 17 percent for public transportation.

CLELLAND: Our decision to expand was based on the successful operating experience in Bay Ridges and the ability to service a population of approximately 14,000. The overwhelming success of our provincially sponsored commuter rail network in the Toronto area, changing transportation demands, and public acceptance of innovations in the transit field led to a provincially sponsored transit funding policy. This was introduced approximately 2 years ago, and since that time the subsidizing of municipal operating deficits made the acceptance of dial-a-bus as an innovative transit system much more attractive to local governments. The operating deficit is subsidized to the extent of 50 percent.

READING: The Batavia system started 2 years ago this month. A 3-bus, dial-a-bus system replaced a 2-bus, fixed-route system. The fixed-route system had a 25-cent fare; the dial-a-bus system had a basic adult fare of 60 cents. There was almost an immediate 30 percent increase in riding. Besides the dial-a-bus system, we also own and operate a school bus system. Both have home-to-work and home-to-school and return subscription service. There is no subsidy whatsoever. The community is totally involved. The retailing community, the senior citizens, the very young, the young without automobiles, all ages without automobiles have made it accepted by the community of 18,000 people in a $5\frac{1}{2}$-square-mile area.

ATKINSON: In Regina, we found that dial-a-bus works and can be operated by the existing transit staff. It doubled transit usage in the low-density area where it was first installed. We found that it could be used as a community planning tool, not unlike the streetcar operations in earlier days, but most important we found that public reaction to the personalized service was enthusiastic. A better level of service can be provided for the same dollar investment and, in some cases, there were marginal savings in the subsidy required. Approximately 40 percent of the city population has access to service in the evening hours, a smaller percentage in the off-peak day hours, and a smaller percentage in the peak. The Regina strategy has been to provide different levels of service in different hours of the day and expand the system slowly.

IMPROVEMENTS BASED ON EXPERIENCE

QUESTION: In what specific areas did you learn from your mistakes in the test system? What corrective actions have been taken?

ATKINSON: We made 2 big mistakes in Regina. One was in locating stations for transferring to the fixed-route system in residential area. We received unpleasant reactions from the community. If dial-a-bus is used as a feeder system, the transfer stations should be located in a corner park or in areas where residents are not disturbed because, even if they get better service, they like the better service in front of somebody else's home. The other was with regard to information service. You just cannot underestimate the amount of telephone answering service and the amount of information that you have to give to the public. We also did not keep political decision-makers sufficiently informed of what we were doing.

READING: I do not think any mistakes were made in Batavia. We did learn that there is no vehicle being produced today that can be applied to this kind of service. Many other operators have encountered the same difficulty. Also, we found that we could improve on the digital communication system used in Batavia for dispatching vehicles. About 3 years ago, we attempted to get federal demonstration funds for a program here in Rochester; that attempt failed and delayed our start about 2 years.

CLELLAND: I agree with the comments about the vehicle. In Ontario, we have researched the industry trying to find what we would call a dial-a-bus vehicle. We have finally developed a prototype. The Bay Ridges system serves a commuter rail station; passenger pickups to the station are dispatcher-controlled, but the number of passengers from the station is an unknown. The 11-passenger Ford Econoline van had insufficient capacity to handle the return trips; we should have had a van that seated 15 to 20 passengers. We also recognized that we could have made the driver's life easier by eliminating the selling of tickets and making change. In the Toronto Metro project, we are advocating exact cash fare. For a small community of 14,000 people we had a 2-week driver-dispatcher training program, but feel 1 week would have been enough. As the dispatching system becomes more sophisticated, the time for that training naturally has to increase.

BERLA: With regard to locating transfer points, I noticed that one of the transfer points in the Ann Arbor system is going to be located across the street from the house of the former mayor, who was instrumental in helping to bring about a favorable public climate for the system. He is going to be put in an interesting situation when the buses begin stopping in front of his house: Is he for it or against it when the crunch comes? On the question of size of feeder vehicles, it seems to me that there is a trade-off between productivity and level of service. Larger vehicles, obviously, have better potential productivity but also longer tour times. With 10-passenger vehicles, we have already a number of complaints from people who are dropped off last. We made no major mistakes or problems in the pilot system, but one thing we learned was that dial-a-ride ought to be integrated into a total system; for it to work as an add-on is difficult. The public gets confused about the service and whether service is related to where they live. A sufficient share of the initial budget should be devoted to marketing, by which I mean transmitting information to potential users. I am amazed at the number of times an individual who is not "into" transit needs the same message in a number of different ways before he or she understands the options that are available.

ALTERNATIVES CONSIDERED AND ROLE OF SYSTEM SELECTED

QUESTION: What alternatives to demand-responsive service were considered for your expanded system? How does the demand-responsive service fit into the overall public transport system in your community? What role does it fill? What other systems are used in conjunction with it?

BERLA: We looked at 2 alternatives to a demand-responsive system: One of them was a capital-intensive PRT system, and the other an expanded line-haul system. We discarded the PRT system because we do not think that we have enough density and enough corridors. We do think there is a role for PRT in certain specified corridors in the city, however, and we are hopeful of getting some support from the state to plan such a project. We would like to move ahead on that but not as a whole system. In terms of the options of either expanding the line-haul system or going to a demand-responsive system, our judgment was that in a city like Ann Arbor, which is a relatively affluent community with a high automobile ownership rate per household, a significant number of people will not be pried out of their cars by anything except a very highly personalized service. So, putting money into a line-haul system would not generate the demand and the ridership.

The Teltran system will be an integrated demand-responsive system, the major features of which will be door-to-door neighborhood feeder service, coordinated transfer to express buses operating principally on radial lines, and a subscription service that we hope will cover many of the work trips and school trips. The system will change very drastically over time basically in the size and number of zones. The largest number of zones will be at peak hours. The system will adapt by time of day, by day of week, and probably by month of year. At certain times of the day it will be a many-to-many, single-zone, dial-a-ride system; at other times a single-transfer, dial-a-ride to dial-a-ride system; and at peak times a coordinated-transfer dial-a-ride or feeder-bus to express-bus system.

CLELLAND: In Kingston, Stratford, Bramalea, Bay Ridges, and Ottawa, the dial-a-bus role is primarily as a feeder service. The new service just initiated in Ottawa has some trunk-line feeder service also. In Toronto, dial-a-bus will provide feeder service to the fixed-route bus and subway systems. As far as the alternatives to dial-a-bus, I believe that all of the systems which have been implemented resulted from transit studies. We considered fixed-route and demand-responsive systems and selected the higher level of service, recognizing the higher cost associated with it.

READING: The dial-a-bus system in Rochester is a part of the regular transit system which is called the Regional Transit Service (RTS), but at the present time is a sort of an add-on system. We hope that eventually it will become a totally integrated part of the system. Other systems that are used in conjunction with dial-a-bus are subscription service and a feeder service to the regular route service. We looked at other alternatives because of our experience in Batavia.

ATKINSON: The Regina Telebus system is now fully integrated with the existing transit service. It is a local service, about 11 percent many-to-many, about 35 percent many-to-few, and about 45 percent transferring to downtown. At several points it also feeds fixed-route services. We tried fixed-route services and found that the deficit in low-density areas varied from $1 to $2 per passenger. Telebus reduced the deficit to about 40 cents per passenger.

USE OF RESEARCH

QUESTION: A great deal of federal and nonfederal money has been invested in research and development of demand-responsive transportation, and a considerable amount of money can be spent on transportation studies that precede implementation of new transportation systems. What was the role of previous research and development in designing the individual systems that you are responsible for? How extensive a study was conducted before the system was implemented?

BERLA: We did not do a great deal of studying before we implemented our pilot system; but that was a demonstration system, and frankly I think that is the most valuable kind of research to do, that is, do research on a small-scale system in place. A great deal of design work was done by our consultants before that system was implemented, and a great deal more design work has been done and is being done on the Teltran system. I am skeptical about the utility of spending large amounts of resources on paper studies. Demand-responsive transportation has proved itself to be feasible, and characteristics, costs, levels of service, and so forth are by now quite well-known. My preference in this sort of thing is to do it.

CLELLAND: In the Bay Ridges experiment, we did not do a study; the decision was made to implement the service. Some in-house evaluation was done of area size, density, zone size, and vehicle requirements; but within approximately 3 months from the time we received the approval to proceed from the conceptual plan, service was implemented. Since then, all systems that have materialized in Ontario have resulted from transit needs studies. And this, we feel, has given each municipality an opportunity to review the options of transit services in their particular areas, to choose the type of service they would like, and to evaluate the cost involved for the various alternatives.

McDOUGALL: From the point of view of one who does studies for demand-responsive systems, typically the study is not a feasibility study but a preliminary design study. The preliminary design study is, in most cases, a low-budget study in which an estimate is made of costs, expected revenues, vehicle requirements, personnel requirements, and so on. Based on that study, a decision is made. If the system is to be implemented, that requires more detailed design, hiring people, tendering for vehicles, and so on.

READING: It helps to have knowledgeable consultants, and we were fortunate in Batavia and in Rochester to have retained M.I.T. researchers to do our preimplementation study and market research work.

ATKINSON: The initial research that was done served mainly to give us courage to go ahead in the job. We drew heavily from the problems of the Ontario experiments, and we took courage from the Mansfield, Ohio, project, which had to be the smallest demand-responsive system in the world, but it showed that it could be done. We had a minimal feasibility study done, and after getting experience with the system we identified some deficiencies. The big deficiencies are management controls. We monitored these systems fairly well, but we have not been able to translate the monitoring information into a control system loop so that management can look at it each week and see that the system is actually dynamic. Expanding these systems is easy, but contracting them in off-peak hours or in summer is difficult.

M.I.T. researchers have done a tremendous amount of work on potential computer programs for large cities, and we have some small manual systems and some systems that provide computer assistance with the paper work. But, at the moment, there is nothing in between, and there is a real need for more research on how one gets from the small manual system to the large "unmanual" system. There is a shortage of research on land-based communications. The Bell system researchers have not become involved in these kinds of programs to determine whether their equipment might have application to this service; we suspect that they probably have some that does. In addition, research is needed on high-speed paper-handling systems. So there are some very good areas of research, and I would suggest that consultants to the newer systems might be of more help in undertaking this research than in trying to design a detailed system, which is going to be changed by the staff as soon as it is operating anyway. The most acceptable arrangement for the latter is for the consultants to work with the existing staff; in that way the consultants learn from the system and the staff is trained so that when the consultant leaves the system does not collapse.

FUNDING, FARES, AND COSTS

QUESTION: What are the operating and capital funding sources for your system? What is the fare? Is there any research money being used to implement or evaluate your system? What has been the financial performance of the demand-responsive service in relation to the performance of the rest of the system?

ATKINSON: The initial experiment in Regina was funded partly by the city and the province and partly by the federal government for planning, engineering, monitoring design, and so on. The city provided all operating funds and capital equipment. Now that the experimental portion is over, the system is financed entirely by the city. The city expects to get some assistance from the province, but the province (Saskatchewan) has not yet established a cost-sharing policy. The fixed-route system in Regina is subsidized by approximately 10 cents per passenger. For 8 million annual passengers, the subsidy amounts to about $800,000. The Telebus system is subsidized by approximately 40 cents per passenger.

READING: The dial-a-bus system in Rochester is not subsidized except by the regular Regional Transit Service bus rider, but that is not really true because the regular bus company is losing money itself. The system started by the use of retained earnings for capital purposes or by the use of equipment leased for a monthly charge. Both systems are losing money at the present time, but patronage is increasing on the dial-a-bus system and decreasing on the regular bus system. When the 2 systems are integrated, we hope we can reverse the trend to a degree, but we have informed the authority that some form of operating assistance is absolutely necessary to the continuation of the RTS operation.

CLELLAND: The provincial government of Ontario has 3 forms of transit subsidy. The first one applies to municipal transit needs studies for which the province pays 75 percent and the municipality pays 25 percent of the cost. We have been promoting these studies primarily to try to improve the operating deficits and naturally the system design and level of service. This work has been carried out mainly by consultants in short time periods that normally range between 6 weeks and 2 months. We also cover operating deficits, and funds can be allocated in 2 ways. We will cover 50 percent of the operating deficit, not to exceed amounts derived by the following formulas: $1/capita for the first 10,000 and $3/capita for the remainder plus 5 cents/revenue passenger, up to a maximum of 50 percent of the operating deficit. We cover the cost of capital equipment to the extent of 75 percent or a maximum based on an annual formula of $2/capita for the first 150,000 and $3/capita for the remainder. The fares of the 5 operating dial-a-bus services in Ontario range from 30 cents in Bay Ridges to 50 cents in Ottawa. However, Ottawa offers a 5-cent discount rate during off-peak periods and a 20 percent discount if the patron prebooks for 5 consecutive days (those patrons are also allowed unlimited rides on the system during that week). Toronto Metro will have an exact-fare system and similar incentives for prebooking. The provincial government offers monitoring services to these municipalities to obtain ongoing statistical information regarding passengers carried. We expect to expand this information to include detailed information on operating costs.

BERLA: The basic cash fare in Ann Arbor is 25 cents for a one-way trip, including such transfers as are required. A personal, unlimited service pass is $10/month, and a special kind of a pass that we call a family pass is $15/month. Any number of occupants in the same household can use the family pass to make the same trip from the same origin to the same destination together. A 50 percent discount on any of those fares is given to senior citizens and to persons who are in low-income families. The system has required approximately a 50 percent subsidy that came from the general revenues of the city until June 1973. We estimate that the system will require approximately an 80 to 85 percent subsidy, of which 75 percent or about $1½ million out of a total $2 million budget for the first year of full operation will come from the new local earmarked millage tax. Seven to 10 percent will come from state funding under a new state half-cent gasoline tax, which is available for urban transportation in Michigan, and the remainder will come from fares. The dial-a-ride experiment indicated that on a per-trip basis, dial-a-ride trips cost approximately twice as much as line-haul trips. However, I believe that the bottom-line relation between fare revenues and total cost is becoming a less important performance criterion; at least we have found that to be true in Ann Arbor. I think citizens have become much more sophisticated about asking what costs really mean. They are ready to move away from questions about how much subsidy is required to keep a system running to questions about social, environmental, and land use costs, and how they fit into the picture. That is why these kinds of questions may be a bit limited for systems where expansion is contemplated.

QUESTION: Will the expanded fares have a negative effect on ridership? If not, why not? If so, how can that be overcome and ridership increased?

READING: We have no way of measuring the impact because we started with a $1 fare, graded down for subscription service and for multiple riding. As I mentioned earlier, the second person in a family or the second person in a group can ride for 25 cents. However, the fare was set at $1 because nobody has ever ascertained how much a person will pay for demand-responsive transportation. We felt that it would be better to lower the fare if we had to than to raise it. We anticipate the probability of lowering the fare sometime in the future.

CLELLAND: In Bay Ridges, we set the original fare at 25 cents and gave a discount to those who purchased tickets. We wanted as many riders as we could possibly get, and we certainly did not want to deter them because of fare structure. After a year of operation we increased the fare to 30 cents. We predicted a 3 percent decrease in ridership, but that never materialized. As a matter of fact, the same rate of increase has been maintained during the past 18 months.

BERLA: I can give you just a couple of observations on fare elasticity based on a comparison of similar numbers of operating days in September 1972 and in September 1973. The dial-a-ride fare in September 1973 was 25 cents, down 58 percent from the 60 cents it was in September 1972. Ridership was up about 48 percent for 16 comparable operating days. Revenue was down by a little less than 20 percent. On the line-haul system, the fare was reduced 28 percent from 35 to 25 cents. Ridership was up about 23 percent, and average daily revenue was up about 15 percent.

McDOUGALL: The basic principle here is that people are certainly, within quite a reasonable spread, willing to pay for the service provided. We thought, for example, in Bramalea, which is essentially a working-class community, that a 35-cent fare might be a little steep and people might be scared away. That did not turn out to be the case at all, and people are paying 35 cents to ride from a point just off a corner of the main regional shopping center into the shopping center, just about 2,000 feet away.

BERLA: We probably would have preferred to set our fare higher than we did. Frankly, we made a political judgment that the chances of the millage issue passing would be favorably affected by establishing a low fare. We were able to say that, with this millage that we are asking from the city at large, people would be able to use the system for approximately, say, $200 per year on a family basis or $60 per year on an individual basis. I would feel more comfortable had we set fares somewhat higher, because I think we would have greater ability to respond to demand levels that may turn out to be considerably higher than we predicted.

SYSTEM OPERATION

QUESTION: One of the striking characteristics of a demand-responsive system is that a vehicle will have a few passengers on board midway in a trip and will receive a message to pick up somebody else. How frequently does this happen? What is the average number of deviations per vehicle trip?

ATKINSON: In the morning rush hours, it is impossible to deviate a vehicle that has already left for its tour because that would simply put everybody off schedule from their expected pickup time. In off-peak hours, generally on a 30-minute vehicle tour, no deviations are made 10 or 15 minutes after the tour starts.

READING: For our morning subscription service, we do not deviate, but for the afternoon service we do deviate to pick up and drop off passengers in the regular route of the vehicle tour. At other times, we only deviate a vehicle for additional pickups or drop-offs when they are enroute to current origins and destinations and do not require the vehicle to backtrack or go off the route.

ATKINSON: I should explain that we are talking about a tour pattern, not a route. The patterns for subscriber service, of course, are almost the same each day unless there has been a last minute change. Different drivers may also follow a slightly different pickup order. Patterns in off-peak periods can be quite random.

READING: A difference that needs to be understood between the systems in Regina and Rochester is that in Regina they have regular tours that meet scheduled buses.

QUESTION: How does one define the trade-off between a large area or a small area, between waiting time, between run times, between fares, and so on?

ATKINSON: We tend to try to maximize productivity within the preselected constraints of what the vehicle tour time is. You could set up service standards, but, first, you have to find out what the goals of the community are. You then establish levels of service, A, B, or C, and calculate the per capita cost. We did this for one project. Based on the modal split, $6/capita provided level A, $30/capita provided level B, and $150/capita provided an almost automobile-free situation. The community then decides what it can afford, and the manager must work within those constraints and operate as effective a system as possible within the preselected service level.

BERLA: People in Ann Arbor do not like to wait more than 15 minutes. If you tell people the waiting times are 25 minutes, they will say, "No thank you, we'll find another way." People in Ann Arbor do not like to be on a bus more than about 35 minutes. If you give a level of service that calls for people to ride longer than 45 minutes, they will use their cars. We use these guidelines in determining the size of our service sectors, vehicle tour times, and dispatching principles.

REGULATIONS

QUESTION: What government and regulatory approvals were required to implement your system?

CLELLAND: In Ontario, there were 2 different areas: the demonstration projects—Bay Ridges and the Toronto Metro project—and municipal projects. In Toronto, the approval of the local government was obtained. Because the Toronto Transit Commission was asked to be the operator, the approval came through relatively easily. In Bay Ridges, only local municipal approval was required. This also applied in the 4 municipally operated systems.

McDOUGALL: The capital subsidies, the study subsidies, and so on that the provincial government provides to municipalities required a change in what was originally called the Highway Improvement Act and is now called the Public Transportation and Highway Improvement Act. The essential change in that act was to provide for provincial government subsidy to municipalities.

READING: The town of Greece, the city of Rochester, and the county of Monroe had to be informed of our plans for dial-a-bus. The legislation that created the transit authority did not give to it any authority. It had the authority to carry out its functions, but not if a town or municipality or any kind of local government opposed it. Therefore, it had to get the approval of the town of Greece, the city of Rochester, and the county of Monroe before implementing the dial-a-bus system. In Batavia, the authority bought a private company and continued the operation but with a change in service.

ATKINSON: Local approvals are required for carriers; and, of course, the license for the radio system in Regina is issued by the federal government.

DIVERTED AND NEW TRIP-MAKERS

QUESTION: Who are the patrons of demand-responsive service? Has it diverted passengers from other forms of public transit and private cars, or has it induced new trip-making? Does your system include any specific disincentives to private automobile use?

BERLA: Most of our riders are female. We also have many school children, principally because of the local characteristics of the pilot project. Most of the trip diversion was from automobiles, either passengers or drivers. Two 1972 surveys showed about 11 percent diversion from the regular line-haul bus system and 12 percent diversion from cabs. In 1971, the cab companies initiated a suit to enjoin the city from operating the system. That suit was dismissed, and the dismissal was upheld on appeal. When we began major expansion, I expected that the local taxi operators would strongly oppose it. Such was not the case, and I understand that in general the taxi industry thinks that if anything dial-a-ride has generated trips for them. People will use a bus to go to a shopping point, but feel they need a cab to go home.

CLELLAND: In Bay Ridges, we were somewhat disappointed with the statistical data we obtained in trying to indicate or recognize the diverted trips from taxis. The only positive result of diverted trips was that 2 small operators went out of business; we know there were trips diverted. There was little comparison with regular buses because, of course, no buses had previously operated in the system except a 2-month experiment tried several years before. For the Toronto Metro project, we will conduct presurvey analysis of present ridership. (I should explain that the Toronto Metro will supplement existing fixed-route services.) We want to get some idea of how many trips are diverted from fixed routes to demand-responsive service. The market area we are trying to reach is the sections approximately 1,000 feet beyond the major arterials where the fixed-route buses operate. The fixed-route service runs on a good system of 1½-mile major arterial streets. We are trying to reach the pockets of poor service areas in between. We are trying to get some cooperation from the taxi industry to monitor its fares for 2 months to see how we affect the industry. With regard to incentives, we have tried to relate fare structure to the perceived cost of the automobile trip. The average trip from the Metro area is about 14 miles, and we have attempted to relate the fare structure to this. The fares are 40 cents both peak and off-peak. There will be no integration with the present Toronto Transit Commission subway service, which has a fare of 25 cents. However, the combined fares compare favorably with the cost of operating an automobile over that distance.

READING: In Batavia, there has been no indication that it has diverted or in any way hurt the taxicab company. Some car pools have been eliminated that took children to school and people to and from work. In Rochester, we have had no calls or complaints or demands on the part of the taxicab companies that we should get out of the business. As a matter of fact, the wife of a taxicab driver indicated that she was going to use the service, and the owner of the largest taxicab company in the service area has subscribed for his children to take dial-a-bus to and from school. There has been little effect on ridership on the regular route; some people are using dial-a-bus to get to and from the regular routes, which take them on into downtown Rochester. Although we have the highest dial-a-bus fare in the United States ($1 each direction), with subscription service, additional people within a family group can ride from one point for 25 cents each. With regular service, additional people in a group can ride for an additional quarter, up to a maximum of 4, so that 5 people can travel for $2. Then it starts all over again, resulting in a fare of 40 cents, which is the basic adult fare on our regular service.

ATKINSON: In Regina, approximately 51 percent of the riders were using the fixed-route system that was already in the area, 11 percent were driving their cars, 13 percent were chauffered passengers—children being driven to school and noncar owners being driven about, 9 percent were traveling by taxi, 10 percent were walking, and 6 percent were unable to make any particular trips before the Telebus service began. The city of Regina both licenses the taxi system and operates the transit system so that there is some control, and there was some good dialogue with the taxi companies, which after all provide public transportation. The point is that, if automobile ownership is reduced, all forms of public transportation benefit, both taxi and transit. The incentive to use the system in Regina is simply low fares and good service.

QUESTION: In a study of the feasibility of a system, how are estimates made of the potential ridership?

McDOUGALL: There is no fool-proof way; the best method is the rule-of-thumb method based on a comparison of the social, economic, and development characteristics of the city or municipality in question with those of other municipalities that have had demand-responsive systems operating for a period of time. We did this recently in Bramalea, which is northwest of metropolitan Toronto and has about 30,000 people, a small industrial base, and a regional shopping center. We estimated that the 6-bus system we designed would carry 1,000 passengers per day by the end of the year. In fact, it carried 1,500 passengers per day at the end of 3 weeks. So that does not say too much for our ability to estimate patronage. Several attempts have been made to take attitude surveys and try to estimate some levels of the potential impact. The problem is that people are asked whether they will use a service with which they have had no experience.

ROOS: One of the real problems is that many of these systems have a market share by mode of, say, 1 to 5 percent. If estimates are off by 1 percent, the size of the system may be off by a factor of 2. This is really a critical problem for small-scale systems. We do have a reasonably good handle on what might be called the "initial site selection," that is, what portion of a large area has the best characteristics for demand-responsive service. I think there is little to gain by trying to obtain really accurate ridership figures; but, on the other hand, spending time on determining what areas you should go into and what areas you should not go into is well worthwhile.

DISPATCHING

QUESTION: Are you planning to employ automated dispatching or digital communications in your expanded system? If so, how?

ATKINSON: In Regina, we quickly got into trouble because of the high demand for service and the high percentage of subscription riders—as many as 45 percent of the inbound morning riders. Three clerks were required to handle the records. A computer program was then written to handle the subscriber file, and we discovered that it could be used as a dispatching aid. At the moment, the computer file is updated overnight, and the orders are printed for the drivers the following morning. There is no reason, of course, why the computer file could not be updated hourly or half hourly; and, because the pickups are sequenced in order of pickup, it is possible to insert into the subscriber list the demand calls and thus have a computer-assisted dispatching system. We learned that the human computer was very efficient in decision-making and the mechanical computer was most useful to handle the high volume of paper work and to eliminate some of the drudgery. I think the computer costs are a fraction of what the manual labor costs would be to handle a very high subscriber file. For the expanded system, teleprinters are being examined as are the experiences in the United States, but there are no immediate plans to implement any further aids until about 1975, mainly because of a lack of financing.

READING: The Batavia system uses a manual system throughout. We experimented with a digital communications operation, but found it to be too expensive and not really necessary for a system of that size. But that experiment helped in the development of the Rochester system. The operators are trained keypunch operators and are equipped with headsets so that both hands are free. The information goes immediately into keypunch cards, which then go to the dispatcher, who makes mental decisions as to which vehicle will make the pickup and in what order pickups will be made. The cards go into a card reader and the information is digitally transmitted to the vehicles and printed out, giving the driver the location of the people to be picked up, where they are to be dropped off, the order of the pickups and drop-offs, and the fare to be charged. When the system is expanded, we expect to use the computer for dispatching.

CLELLAND: In our Toronto Metro project, we will require some computer assistance in our dispatching office because we will be serving a population of approximately 70,000 people during the rush hour. There will be 27 in-service vehicles during that period of time. This is a 3-year demonstration project, which is funded 100 percent by the provincial government. During these 3 years, our intention is to test out dispatching techniques, primarily in the transmission of data from the computer-assist programs. The computer system will edit, store, and sort reservation requests into trip order and produce dispatch listings of pickup requests sorted by street and street number. It will also help to prevent overloading a vehicle and provide a means by which vehicle loading levels may be monitored and the upper limits for loading changed. The system operates on a time-shared mode in the ministry's IBM 360/65 computer through telephone connected terminals in the dispatch office. A second IBM 370/158 computer will provide a dual computer configuration that is necessary for a reliable computer dispatching system. The justification for a computer-based system arises not from any substantial cost savings but from the greater achievement in dealing with increasingly complex problems that attend larger demand-responsive operations and that make manual dispatching increasingly complicated and difficult. We do not plan to install digital or transmitting teleprinter facilities on vehicles until after we become operational.

BERLA: Our present system is manually dispatched by a voice communications link. As we move toward a full citywide system we will have digital links with some sort of computer printout or other numeric display on the vehicle.

MANAGEMENT, STAFF, AND OPERATORS

QUESTION: How have you organized your staff hiring and training program? Have special qualifications been set? What type of special management capability is required?

BERLA: Immediately after our local vote for an expanded system, the Ann Arbor Transportation Authority determined that we had to have an executive director who would have full responsibility for the operation of the system including staffing and training. The authority is in the process of moving away from detailed interference in operating decisions. We are doing that partly on our own motivation, and partly with a good deal of guidance on how to disentangle gracefully from our executive director. He is willing to point out to us decision-making areas that are rightfully his rather than ours. That has been a great help, and I think it will continue to be.

READING: The director of advertising and public relations of the Regional Transit Service (RTS) was transferred to the Rochester-Genesee Regional Transit Authority, where he was given full responsibility for the marketing effort of the dial-a-bus system. Robert Aex, the person most responsible for the development of the Batavia dial-a-bus system, is the executive director of the authority. RTS is responsible for the actual operation of the system. The chief dispatcher came up through our scheduling department to radio dispatch. He is a young man, bright and intelligent, who has the ability and capability of going on to even bigger things. He is doing an excellent job. His assistant and the chief telephone operator also came from our scheduling department. A third person in the control center was hired from the outside and trained in the cardpunch machine and telephone headset operation. All of these people received exactly the same initial training as the bus operators receive. We have 365 regular bus operators who pick the job of dial-a-bus. These highly professional, trained bus drivers periodically pick the work they want on the basis of their seniority with the company. And 12 dial-a-bus runs were gone by the time the twenty-sixth driver in seniority had picked; obviously, it is regarded as highly desirable work. Because they are professional operators, drivers do not need any intensive training, except in the geographics of the area such as where the dead-end streets are and how to find the addresses. They have actually redone a map, which is the best map available anywhere of this particular area.

ATKINSON: Gerry McAdoo is the general manager of the Regina system, and he says that the transit manager must be optimistic and enthusiastic. There is no way that optimism and enthusiasm can be transmitted to the staff if they are lacking in the leadership. It is easy to get a government grant and to write a training program, make 10,000 copies, and distribute them to every system in Canada and the United States. But such a program is sterile. What is needed is to have people who are involved in all aspects of the system planning and feeding back to the management their day-to-day problems. The best way to do this is to sit down with them for a couple of hours and just listen. I think that is the most successful way to bring staff along. Start out with a nucleus and through optimistic and enthusiastic management and supervisory teams you eventually have enough people trained to run a large system.

QUESTION: How do you propose to make a manager account for the decision he has made?

BERLA: I think it comes down to setting management objectives between the authority and the management and then testing whether they have been met. One measurement is how well the system is maintaining its budget; another is how well the schedule is maintained in terms of staging. If there are some efforts to develop ridership growth targets, then surveillance should be maintained on those. There are also the areas of public relations and staff relations—what the public image of the system is and how the manager is interacting with the employees.

QUESTION: That describes a process of evaluating the person or persons in charge of the project. The question is, How do you hold a person accountable in a project corporation in which he or she has no personal investment in the system other than career or professional status?

BERLA: That is the ultimate sanction, and all authorities are going to have to use it. Our director's job is on the line, and that is understood by all parties; it was, in fact, a major subject of all preselection interviews.

READING: No transit manager or system would last very long if the public did not like the service that was being provided. The management contract system, of course, builds in incentive bonuses for efficient operation. But, because of the focus of attention on transit today, the transit manager is being looked at through a microscope in many cities.

QUESTION: Have any systems experienced problems with labor restrictions?

ATKINSON: Some of the Canadian systems have actually been able to get sort of a "moratorium" on bending some of the rules and regulations that are agreed to with the unions. The city of Ottawa has the most notable arrangement: a 12-month moratorium on having to negotiate in detail each little change in the regulations. In Regina, the union adopted a "wait-and-see" position for a year. It prefers, of course, to have fairly decent shifts, but is willing to go along with 2 and 3 splits. If the union helps out in this way by not being suspicious of what might happen in the future, the system will go much better.

READING: In Rochester, we have had few problems with the union. We agreed at the outset that all provisions in the contract would prevail in our dealing. We have had no difficulty working out splits because they fall within the provisions of our labor agreement. We did ask the union (and it cooperated fully) to allow those operators who initially picked the dial-a-bus operation to stay on it through 2 picks so that at the end of 3 or 4 months we would not have a new group of operators and disruption to the service. There is no indication on the part of the drivers that they want to relinquish the dial-a-bus pick. They like it and enjoy the opportunities that it has given them.

CLELLAND: In Toronto, the unions have agreed that drivers will bid on a 12-month assignment for the demonstration project. Of course we were concerned about training fixed-route drivers for demand-responsive service. As for the split-shift arrangement, we are unique in the sense that we serve a population of 70,000 during rush hours and approximately 140,000 during nonrush hours. There are 27 service vehicles during the rush and 20 during the nonrush, so we have minimized split-shift adjustments because of peak demands.

BERLA: Union-imposed constraints have not been a major problem in Ann Arbor, and I do not anticipate that they will be. As a matter of fact, the union was well ahead of management on one issue, that of providing for employees who want to work part time rather than full time. Because ours is a university town, the union felt that a substantial number of people might want to work less than a 40-hour week and wanted to be sure that that flexibility was preserved.

PACKAGE DELIVERY

QUESTION: What has been done to supplement income, say, from package delivery?

READING: In Batavia we have had package delivery service from the time the demand-responsive service started, but it has not grown the way we expected it to. Our business is basically with drug stores, delivering prescriptions from drug stores to homes, and is also with hospitals, delivering hospital supplies and, particularly, blood plasma. We deliver some mail, but had hoped to deliver more from the post office to the firms in the city. We do a considerable business delivering important papers and data tabulations among branches and main offices of banks. Revenue from package delivery is about 10 to 15 percent of the total system revenue, and it could be significantly more.

panel discussion

AUTOMATION IN DISPATCHING DEMAND-RESPONSIVE VEHICLES

Richard H. Shackson, Ford Motor Company, moderator

This discussion is about using the computer directly in the decision-making task. Haddonfield is the only application to demand-responsive transportation. A couple of large taxi fleets have taken this step. The panelists are associated with these systems both in their daily operations and the research and development that led to them.

PANELISTS

Sam Rudofsky, Ford Motor Company and representing Los Angeles Yellow Cab Company
Gordon Thompson, Canadian Marconi
Kenneth R. Roberts, Mitre Corporation
Nigel H. M. Wilson, Massachusetts Institute of Technology

ROLE OF AUTOMATION

QUESTION: What is the exact role of automation in your system?

RUDOFSKY: A few major objectives were achieved by automation: The amount of paper work in dispatching was reduced (the Los Angeles Yellow Cab Company processes approximately 15,000 orders per day); orders in the dispatch center are handled more accurately and faster; and transactions can all be passed into a history file for batch processing at some later time.

THOMPSON: The Diamond Cab Association of Montreal used automation to overcome a number of problems that are peculiar to the taxi industry and to improve the efficiency of the operation. Our main objectives were not so much related to paper problems as to discipline problems. In such a large open-channeled system, piracy (a call intended for one cab taken by another that got there first) is a serious problem. The computer acts as an interface essentially between the dispatcher and the cab operators.

ROBERTS: The computer has 5 main functions. The first one is to assign customers to vehicles—an automation of the scheduler function in Haddonfield. The scheduler was assigned a customer, and he made a specific vehicle assignment. The computer has automated that portion of the manual system completely. The second one, to monitor vehicle location, is a partial dispatcher function. The dispatcher has other functions, but one of the things he is required to know is where his vehicles are. Now the computer keeps track of that. The third is to maintain master files. In the manual system, there was 1 file that contained names of periodic customers. We now maintain 4 or 5 master files (street names and some other things). The fourth is to keep track of operating parameters. The street file contains coordinates and other calculations that are useful during congestion situations with regard to vehicle speed. Also, some other system costs that are used in the scheduling system are based on how busy the system is. And, finally, the computer is used to prepare the transaction file, based on a formalized reporting system, and produce daily reports.

WILSON: The M.I.T. system provides essentially the same working features that Roberts has described for the Haddonfield system. The computer system performs the decision-making role that is performed by the dispatcher in manual systems and is also responsible for the bookkeeping task the dispatcher would normally handle. The way the system operates is that, when the request is received, a telephone operator, seated at a teletype or similar terminal, types in the origin and destination. The computer translates these addresses into coordinates, makes the decision on the best vehicle for that particular passenger, and immediately sends back to the teletype and the telephone operator the expected pickup and delivery times. When a driver makes a stop, he informs the dispatcher, who enters the information through another input device, indicating to the computer that a stop has been made. The computer responds with the next stop for that vehicle, which is transmitted back to the driver. Other functions performed by the computer are automatic billing and allowing different classes of trips to be made at the same time with the same vehicle fleet.

JUSTIFICATION AND PERFORMANCE MEASURES

QUESTION: How was automation justified? Can you identify performance measures that can be used in the evaluation of an automation system? By these measures, has performance been satisfactory?

RUDOFSKY: Quantifying performance benefits that were anticipated and derived is difficult. The amount of paper work in the dispatch center was reduced. In fact, the normal operation has no paper work except for time orders, call-backs, and late orders. Orders are put through faster, and customers wait less. Because of accurate operations, drivers spend less time looking for bad addresses and, most important, pay-miles improved from 47 to 57 percent. (Their objective is still 60 percent, but they are extremely happy with the results so far.) Previously, customers calling in would be queued and have to wait, but now 90 percent of all telephone calls are answered within 45 seconds. The number of orders that are assigned to cabs within 15 minutes improved from 60 to 90 percent. The bottleneck in the dispatch center has been eliminated so that now, with automation and video terminals, orders move from order taker to order sender instantly instead of taking 4 minutes as previously.

THOMPSON: Our main objectives were to improve discipline in 2 main areas: piracy, which causes a lot of trouble, complaints, and dissension among the cab drivers, and favoritism, wherein the dispatcher has a favorite that he always uses on selected driver jobs. These were overcome almost completely with the aid of the computer. Piracy was eliminated by giving the message only to the driver for whom it was intended. And, because the computer assigns the cab to the dispatcher for dispatching, this resolves the matter of favoritism. Because of the number of cabs involved, frequency congestion was another problem that was solved by computer-aided dispatching; the total register dispatch cycle is now down to 12 seconds per cab. Efficiency in loading, a secondary consideration, has improved, measured by the fact that the income of the drivers is up an average of 20 percent with the computer dispatch system.

ROBERTS: Automation was justified, but whether manpower was reduced is not pertinent with respect to our objectives in Haddonfield. We addressed the questions of what is the maximum capability of a manual system and how big should a system be before computer control is needed. We examined wait-and-ride times from 2 points of view: first, with a wide-open computer system to determine whether they would be greater than with the manual system, and, second, with computer controls so that wait-and-ride times were guaranteed by refusing customers if they could not be given a guaranteed time or by bringing more vehicles into service. Computer control provides the capability both to measure and guarantee service, and thus productivity is increased. If a vehicle is going to be out of service downtown for half an hour for a lunch break, with the computer system we can start building up what we call tours or we can accept customers and assign them to that vehicle so that, when the driver reports back in, a load is ready. We also think that the assignment operation gives us higher productivity because of better customer-vehicle assignments when the system is busy. We have, of course, a central-control capability with management control that is a little superior to that under the manual system. And then, the final area that I think we wanted to address was the problem of merging a scatter-gather system with a many-to-many system. In a straight scatter-gather situation, a manual-control system is probably reasonable. A computer-control system is needed for a large, many-to-many, share-cab system, or whatever it may be called. The challenge is to merge these two types of capabilities into a transit system that uses the capabilities when it needs them. That would probably require some type of automatic control.

WILSON: Automation can be justified for the above reasons, which can be summarized as follows: Automation can increase the system productivity, both the passengers carried per vehicle-hour and the passenger-miles per vehicle-mile. It can provide more reliable passenger service through using and closely monitoring guarantees and constraints on service. It can extend the feasible size of the system that can be implemented. You can implement large systems if you have a control center with automated decision-making. For the computer system that uses voice communications between control center and vehicles, manpower reductions are minimal. Some of the decision-making responsibilities are removed from the dispatcher, but the dispatcher must still relay messages to the drivers. With the computer and digital communications, manpower savings will occur when the number of dispatchers is eliminated or reduced. Service measures are important: wait times and travel times. As a result of the increase in reliability we hope to see an increase in ridership. System productivity must also be measured. We are also interested in things relating to the automated function itself, such as times between failure for the computer system, both hardware and software.

QUESTION: What cost-benefit ratio can be attached to automated vehicle monitoring?

RUDOFSKY: The automatic vehicle monitoring system (AVM) will result in better management control of cabs and could improve efficiency. Automation covers only about 50 percent of the operation—receiving customer calls and then dispatching them to cabs. The other part of the operation involves the drivers' picking up customers at hotels and on the streets. So, the cab companies rely to a great extent on the individual cab record to determine how efficiently the cab operates. When I reviewed performances of individual cabs, revenues varied significantly; individual driver earnings ranged from $125 a week to $300 a week. So, I think AVM could serve as a management tool for providing better control over cabs, especially since a major portion of the cab activity does not originate in the dispatch center.

WILSON: We have done simulation experiments on automatic vehicle monitoring. It improves vehicle productivity about 5 or 10 percent; it decreases costs about 5 to 10 percent, excluding the cost of the AVM system itself. Whether it is worth using depends on the cost of the system.

COSTS

QUESTION: What did your installation cost in terms of both time and money?

RUDOFSKY: The equipment was delivered to the Los Angeles Yellow Cab Company January 1971; the major part of the software and hardware debugging was done at the factory prior to delivery. Not until November 1971, approximately 10 months later, was the programming complete and the company on the air for a few hours a day. Three months later, February 1972, the company was on line approximately 90 percent of the time. Even then numerous shortcomings were recognized, and a program rework was undertaken. That took another 4 months; by May 1972, the system was operating relatively reliably and satisfactorily. The Los Angeles Yellow Cab Company intended to pay for the system by monthly rentals after the equipment was delivered, debugged, and accepted. National Cash Register was the successful bidder. The whole system, both software and hardware, was provided by a single vendor.

The cost is $6,000 a month rental for the real-time system (there is a separate system used for batch processing and performance analysis). The telephone system is a key part of the operation, and an Automatic Call Distribution System is rented from the Bell Telephone Company for $1,700 a month.

THOMPSON: We purchased the computer, but we did the complete job otherwise as far as the software, radio, and interface are concerned. However, from the time that we finally came to an agreement, it took 1 year until we had operating hardware—slightly more than a year because the end of 1 year occurred during the Christmas period, and that is not a good time to interrupt taxi operations. A large part of the debugging was done throughout the design. The program writing was going on in parallel with design; and about 2 months after the installation, the major part of the debugging was complete. However, we learned that taxi drivers are quite ingenious when it comes to beating a system, and they found ways that showed up as much as 10 months after the system was in operation (for which we had to alter the program and system). The project was financed by the Canadian Marconi Company on a rental-purchase arrangement. The automation part cost something on the order of $100,000.

ROBERTS: Haddonfield is a federally funded experiment with some state participation. The experiment is funded to the extent that we can operate the system at no fare for the duration and still not spend the money. The state of New Jersey is the local sponsor and purchased the vehicles. The local bus company supplies the drivers, and Mitre Corporation is an UMTA consultant and is implementing the computer control, which is the second phase of the experiment. We use a 2500 minicomputer with a substantial amount of software and have implemented primarily the M.I.T. concept in machine language. A team of 5 people worked a year on implementation, and the system is now turned on for a substantial amount of time. Software implementation is being done by Mitre, but the experiment as a whole has several groups involved. We have, of course, used a substantial amount of vendor-supplied software, which also was worked into the system during that time period. We have had a normal amount of computer downtime. Debugging is an ongoing effort. The basic computer rental price is about $2,500 a month, plus $5,000 for a maintenance contract, which I heartily recommend.

WILSON: If we look at the research and development effort that took place at M.I.T., we can identify 3 distinct phases that led to the development of the real-time control system. First was the development of the assignment and control algorithms. The second was the development of the simulation model capability within which these assignment algorithms could be tested and the overall economic feasibility of the system investigated. The third was the development from that simulation model of a real-time control system. Bear in mind that this was part of a much larger research and development effort on dial-a-ride going on at M.I.T. The overall time to complete all 3 phases was about 3 years, and the total amount of effort put into them was about 7 man-years: 1 man-year on the development of the assignment or control algorithms; 3 man-years on the simulation model development, testing, and debugging; and 3 man-years on the development, testing, and debugging of the real-time control system. We developed a couple of different real-time control systems that operated on different machines and different operating systems. We made the decision to go to a real-time control system from the simulation model; this enables us to develop a system quite rapidly and inexpensively. We were able to use existing operating systems. We used high-level programming languages, and this again was intentional to give us the flexibility when the system was used to modify the assignment algorithms and to modify the real-time control system rapidly as the demonstration was proceeding.

The overall initial development effort was funded by the Urban Mass Transportation Administration. The total project cost was $1.4 million and included many other aspects over and above the assignment algorithms, simulation model, and real-time control systems. The cost of the assignment algorithms, simulation model development and testing, and real-time control system development and testing was approximately $400,000. Additional efforts would be required to get from where we are now with our real-time control system to actually using it in a given environment. Those efforts would be principally related to tailoring the system to the individual service area and to the individual hardware configuration and software configuration under which it would be operating. The entire system was developed by M.I.T. with a minimum of full-time research staff. On the software development, we had one full-time researcher, and the remainder of the staff was composed of faculty members and graduate students working part time.

QUESTION: What is the marginal cost for computer automation? If the first system has been installed, has the second one also? How much additional cost and effort are required to tailor this technique to other specific applications?

RUDOFSKY: Unless the second system is almost an exact duplicate, a major portion of the costs are going to be repeated, e.g., street files of specific cities. Hardware need not change if one is willing to copy someone else's operating system. The problem is that, after the first system is completed, debugged, and operating, many new devices become interesting and tempting for the succeeding implementation. I also doubt that 2 cab management groups would set up the same target for an automation program.

ROBERTS: We would only have to redo the street name file to move the Haddonfield system to another location.

WILSON: I think about 80 percent of the costs would be nonrecurring from one system to another, but some significant things would have to be done. One involves the street network coding, as Roberts mentioned. Another involves travel time prediction, which may be specific to a given service area. A third involves paying attention to and persuading the dispatching staff and the drivers so that the system responds to what they want it to do. That may require making changes in the input and output messages and degree of control given the dispatcher and possibly the driver in certain situations. It is more than just relaying messages; additional capabilities may be needed in a given situation. The fourth involves the computer system in the second area, which is probably different from the system that the software was designed for. Software changes may be necessary to accommodate the machine.

RUDOFSKY: The Yellow Cab Company would like to expand its system and to automate the process of assigning orders to the cabs. However, the company finds itself in a rather awkward position; the computer is totally saturated. To expand would require a totally new computer. Of course, a lot of the software and a lot of the programming are already done and would be transferable. (The entire street file is in the computer, and the address of every order is checked to determine whether it is valid.)

STAFF AND USER ATTITUDES

QUESTION: How are people taken into consideration? For those systems that have operating experience, what has been the reaction of both staff and users to the employment of automation?

RUDOFSKY: The Los Angeles Yellow Cab Company has used automation more in the interest of customer-dispatch center relations than of dispatch center-cab driver relations. The drivers hardly realize that an automatic system exists, and that is of little concern to the company since there is a 295 percent turnover of drivers per year. Automation did have a great impact on the dispatch center. There was no resistance, just skepticism. That disappeared after the system had been in use for about 18 months. The amount of manpower saved in the dispatch center almost paid for the system. The customers are also quite happy with it. Phone calls are answered promptly, and cabs arrive at their doors in much better time. Training, too, is easier. The order takers have video terminals and keyboards and type in the addresses. The order senders interface directly with the cab drivers, and their operation has become much simpler. Previously it took months to train a very efficient and effective order sender, but now they are up to maximum efficiency in about a month.

THOMPSON: I think there are 3 groups that have different reactions: the cab drivers, the dispatchers, and management. The cab driver was faced with an entirely different situation because he was used to hearing everything on his particular channel so that he got to the point where he did not hear anything except what was directed to him. As a matter of fact, he could not initiate anything except his own car identification and address; he could not pick up the mike and talk to anybody. Inititially, there was some adverse reaction to this quiet condition. Although the computer sends back an acknowledgment, he worried that he might have missed it, that he was being ignored, or that his radio was not working. The drivers have now developed initial confidence in the system, and their problems seem to be over. The dispatchers are the ones that benefit most. They had a rough job with an open-channel situation in which everyone was clammering for a call. This is an orderly operation for the dispatcher. The computer stores the incoming calls from the taxi waiting to be registered. The dispatcher tells the driver what address to go to, and all he ever hears is the voice of a cab driver who has to ask for information. Management, of course, benefits from having better working conditions and management information.

ROBERTS: The users in the computer control system are required to furnish fairly complete origin and destination information for many-to-many service. For scatter service, users do not call but merely board a vehicle and the driver arranges the drop-off location. This is a result of the particular control strategy that assigns the customer to a vehicle confined in a central location. We discourage boarding by people who have not called (except in the case of scatter service). The drivers have had to adapt to the computer control system in central areas. They now have less advance knowledge; they are given only their next stop or perhaps their next few stops. It is not advantageous to give drivers too many stops ahead because they will be modified or reshuffled by the computer up to the last minute. We discourage reshuffling of stops on the street by the driver because we are going on a synchronization procedure to update pickup and drop-off times. The impact on the control staff has been minimal. They recognize that when we reach a high level of activity they would not be able to manage a manual system.

WILSON: Users are primarily interested in the service they receive. If a manual control system has options that a computer system does not have, such as flagging a vehicle down, extra people getting on at a stop, or not having to call in at a main activity center when they board a vehicle, then users will perceive the computer system as effectively restricting their options. If, on the other hand, they receive more reliable service, low wait times, and lower travel times, then they would obviously be more in favor of computerization. Both the Mitre and the M.I.T. systems transfer full decision-making responsibility to the computer. Other systems give partial control and decision-making power to the driver or the dispatcher in certain instances. There is a need for exploring these options as well as the full computerized control system. For instance, the computer in general will not have current detailed knowledge of the street system or congestion on the street system; the driver will have that information, and the dispatcher also will have that information to some extent. Where several stops are quite close together the driver, knowing the local street pattern and the local situation with respect to congestion, is in a better position to decide on the optimal sequence of making those stops. I think a mix of computer and manual control techniques is desirable.

QUESTION: Under full computer control, what procedure is followed to modify a vehicle tour if the driver picks up passengers who have not called in? Explain scatter-gather and its operation difficulties under automation.

ROBERTS: We use the term scatter for the one-to-many situation, such as from an activity center or a transfer point from another transportation facility. For example, at the Lindenwold station, vehicles with zone numbers on them pull into the station and are boarded by customers who do not need to call in but can look on a map at the station to find the zone they are in. The driver has a preprinted map on which he marks their stops and somehow works out a drop-off sequence. We worked these into the computer system by putting a customer in called Mr. Dispatch who starts at the station and is dropped off somewhere near the far limits of that zone. The gather, of course, is the opposite situation. That is, the driver picks up regular customers in the morning and takes them to the station. He is given a list of the predetermined pickups. Because the gather tours are early in the morning, the probability that they will need to be merged with the many-to-many tours is minimal because we can, in most cases, let a vehicle work a pickup tour first and then put it under computer-controlled many-to-many service because people tend to go to work before other people do most other things. In the afternoon, scatter tours from the station, say, have to be handled in conjunction with regular many-to-many passengers. The difficulty in computer controlling scatter tours is that people who get off the train want to go as quickly as possible and not be delayed by a sorting sequence. The second difficulty is that the algorithm was not designed for this situation. Further, there is no guarantee that if this service were put into the algorithm it would be improved. Handling these tours manually saves the imposition on the control center and saves all the communication. It does mean, of course, that these transactions are not in the system. Those who want many-to-many service should all call in so there is a full record. That has to be established as a policy. The problem then is how to identify people who did not call. This is no problem at a home address, but there is one at an activity center. The driver cannot separate those who have called from those who have not because everybody will say they called.

QUESTION: What actually happens when the vehicle pulls up at a shopping center stop and there are 3 people who placed orders and 3 others who did not? Does the driver allow them all to get on?

ROBERTS: The driver will then call the control center—in effect, make the call for the people. We try to discourage the driver's having to act as an intermediary between the customers and the control center to schedule trips. The driver has to make a distinction between a situation when the vehicle is operating on the many-to-many mode where there is a requirement that people call and a situation when the vehicle is operating in the scatter-gather, many-to-one, or one-to-many mode where there is no requirement. And, one thing you cannot do is say to the person, Are you a many-to-many or a many-to-one?

EXTENT OF AUTOMATION AND BACKUP SYSTEM

QUESTION: What do you do when the computer fails? What backup is provided for the primary automation? How does this affect the choice of hardware?

RUDOFSKY: When the computer crashes, the system resorts to the original situation. The dispatch center still has the old telephone operator's patchboard and phones, still has a conveyor belt that distributes handwritten orders, and still has the order takers and dispatchers to operate the system manually. Because we reduced personnel in the dispatch center when we automated, the problem is having enough people when the backup system is needed. Another shortcoming is that transactions are not placed in the automated history file. Because this is an important part of the total system, the handwritten orders are punched and replaced in the history file later. Back-up memory is included in the system to retrieve all back orders during the transition. The old equipment formerly used for the manual system is intact and is being retained for the backup mode.

THOMPSON: We did not provide for any backup for the automated function. It was difficult to sell the system to the customer, and it would have been more difficult if we had discussed the problems in reverting to the manual system for short periods of time because of breakdown or maintenance. We have a system for switching to manual operation in the event of failure, but we do lose the information that is stored in the computer as far as the registration of vehicles in particular locations and, of course, the costs of the transactions that take place at that time.

WILSON: In the event of a computer failure, the current state of all vehicles is punched out by the machine, and the dispatcher sequences the stop for each vehicle and sets up the current and projected activity for each vehicle as a sequence of punched cards. The telephone operator moves from teletype to card punch and continues to take requests and punch them on cards that are handed to the dispatcher for decisions. At any point in time, there is a current set of assignments that have been made by the dispatcher. When the computer starts again the cards are read into the machine. Obviously the level of service is degraded in manual backup. I would not want to see the system restricted to the capacity of a manual system operating under computer control. We have to be able to handle more people by computer to justify it, and we have to acknowledge that when the system fails we must go to less reliable service and perhaps reject some requests during that period of time.

QUESTION: What happens to files of dispatches during a failure?
RUDOFSKY: We have a backup memory for the pending file, which is under the control of another computer. When the computer fails, we can pull out the active files and go to the manual system. However, there is always a common link somewhere; and if the common link is not available, we lose the orders.
ROBERTS: We have a restart capability that automatically takes care of the power situation. The problem is that, when the machine stops, we never know how long the downtime will be, so we initiate the manual backup immediately. If the system starts in 5 minutes, we have not lost much.

FUTURE PLANS

QUESTION: What are your plans for the future?
WILSON: Our approach at M.I.T. is to try to define what functions the computer control system should perform, what functions the driver should perform, and what functions the dispatcher should perform. In this sort of environment, the type of computer control system we think should be implemented is one with a high-level language, i.e., something like FORTRAN under existing operating systems that can be easily modified at low costs. When we have a feel for what the optimal or effective characteristics of the computer control system should be, we can then move to a customized low-cost control system with a simpler language, e.g., a second-generation computer control system.
RUDOFSKY: The cab companies are anticipating some funds from the U.S. Department of Transportation. The Los Angeles Yellow Cab Company is hoping for an allocation of about $200,000, but has some future plans in case the funding is not forthcoming. The company is looking at a dial-a-ride application for cabs, especially in the off-peak hours. The cab companies are also looking at Automatic Vehicle Monitoring to better control cabs. They also are considering the applicability of data communications between the cab and the dispatch center.
WILSON: I think one obvious area of future development is the implementation of a computer-digital system. We might then see what manpower savings are achievable by using a more fully automated system than the computer voice system. In the research and development stages of dial-a-ride, we conceived of a computer voice system coming before computer digital systems. It turns out that the first automated system is a manual digital system, which is not entirely what we would have expected 4 or 5 years ago.

panel discussion

DEMAND-RESPONSIVE TRANSPORTATION FOR THE ELDERLY AND HANDICAPPED

Albert J. Sobey, Booz-Allen Applied Research, moderator

The need to aid the handicapped, the aged, and other people who are patrons of our systems proved to be of more interest to those attending the conference than the organizers had anticipated. Panelists were first asked to describe the activities in which they are involved and then to respond to prepared questions.

PANELISTS

John Kent, RRC International
Herbert Bauer, General Motors Research Laboratories
Jeanne Fitzgerald, Visiting Nurse Association of Detroit
Jim Mateyka, Booz-Allen Applied Research
Wayman D. Palmer, Toledo Department of Community Development

ACTIVITIES OF PANELISTS

KENT: RRC has been the project consultant for the Valley Transit District in Connecticut to design and implement a transit program in an area where virtually none existed before. The project is funded by the Urban Mass Transportation Administration, the state of Connecticut, and 4 municipalities that joined together to form the Valley Transit District. The project's objectives are

1. To enable riders to select from 3 kinds of transit services depending on their particular needs and their location within the community;
2. To provide transit services by allowing vehicles to shift from one service mode to another based on rider demand and thereby to make a maximum use of the facilities;
3. To develop a fare structure that allows for equitable charges to the rider based on the actual cost of providing the transit service;
4. To evaluate and develop the necessary modifications to transit vehicles to make them more accessible to the elderly and the handicapped; and
5. To develop the methods and techniques necessary to encourage the use of public transportation services by health and social service agencies.

Although this project is expected to serve the transportation needs of the general public, it was initiated for the elderly and handicapped because the communities felt they were in the greatest need of transportation services. The response has been overwhelming, and the transit district is planning to double the size of its fleet. Fare collection is now done by the use of credit cards.

The Valley Region is in the center of a triangle formed by Waterbury, New Haven, and Bridgeport, Connecticut. The 56-square-mile area has a population of 116,000, with densities of about 3,000 population per square mile. The density decreases toward the outskirts of the region.

There are 3 levels of transit service: a scheduled shuttle that runs along the north-south spine of the area; a rental bus that is used by groups and agencies, particularly by health and social agencies, for group ridership; and demand-responsive service.

The scheduled service has the lowest fares: 10 to 25 cents, based on distance. The route has 2 portions that run through the low-income areas and the business districts. There is no transfer, but a passenger pays a second time in effect if he or she moves from one area to the other. The rental bus is used for any purpose by various groups. The demand-responsive bus system operates much the way most of the others do except that credit cards, or B cards, are used when passengers get on and off. This gives us very substantial data on the operation of the system for management purposes. The Twin Coach TC 25 gasoline-engine vehicles were selected because of their durability and because they can move up and down hills fairly easily. We still need a better vehicle developed for this kind of service.

We modified the vehicles substantially to provide better access. The entrance has been widened considerably. When the doors open, handrails and an additional step are brought out. This has enabled us to put 7-in. risers on the vehicle, which has pleased the elderly and handicapped. Those that are ambulatory can move in and out comfortably. We have put a rail on the sides of the platform, and passengers have indicated that they feel quite secure on it as it moves them rapidly up and into the vehicle.

We put in wider seats with headrests and package racks at the side and end. The aisleway is wider than normal. Three seats can fold up when we need to accommodate the handicapped, but then are available for use by the general public.

On the shuttle service the general public pays a cash fare. However, handicapped people who use the demand-responsive system and group riders are issued credit cards. Passengers insert the cards when they get on and off. In addition, the driver pushes zone buttons as he moves from one zone to the next. This information is taped on board the vehicle and then transferred each evening to the computer. The cost of the ride is split among the individuals on board the vehicle and is directly related to the distance. We are also able to implement other fare policies, such as shared fare. In this case the passenger, in addition to inserting his credit card in the slot, pushes a fare share button. We then bill the agency monthly for its share and the individual for his.

BAUER: I am a research psychologist by training, and I am also an engineering psychologist. That automatically divides my interest in the area of handicapped and elderly into 2 categories: (a) the soft area, that is, their attitudes, perceptions, and needs and the extent to which those needs are met; and (b) the human factors engineering or the equipment design associated with the transit system so that the design is appropriate to the needs of the elderly and the handicapped.

FITZGERALD: I am not an engineer and never heard of the term "demand-responsive transportation" until a month before the conference when I became involved with the Ford Motor Company transportation research department. I am a nurse, and my viewpoints and approach are completely different from the design system approach.

I look at the aged and the handicapped from the perspective of what I have seen their needs to be. For 5 or 6 years I was involved in delivery of personal help and support services. I am now working with the Visiting Nurse Association of Detroit to develop a program to add new services. One of our targets is the Michigan Medicare system. Michigan has about 30,000 people in nursing homes. At least 40 percent of them are "basic care" patients, which means they do not need skilled nursing care but have been relegated to institutional care for the remainder of their lives because services are not available in the community to meet some of their basic needs. It is amazing how important transportation services could be in keeping those individuals out of institutions. We have developed a set of services, including housekeeping and nursing visits, handyman calls, and referrals to the new Title VII nutrition projects, which are being developed.

The importance of transportation in developing Title VII projects is also interesting. Any community center that provides meals must also provide transportation. An arbitrary decision has been made that no more than 10 percent of the meals that are prepared at any center can be home delivered (the intent is to get older persons out of their homes and back into the community).

MATEYKA: I am the engineer in charge of safety and human factors engineering on the Transbus Program, which is a $25 million design competition to develop a standard 40-foot transit bus by the late 1970s. There are 26.5 million elderly and handicapped people in the United States according to the 1970 census. Of these, 13,390 are handicapped, and more than 20 million are over 65 years of age. There is some overlap in the distribution; about half of the handicapped are over 65. The wide range of impairments—visual, hearing, and mobility—leads to some difficulties when one is designing a vehicle to meet the needs of everyone who is not institutionalized. According to the U.S. Department of Transportation, 56 percent of the elderly and handicapped are in urban areas. Seventy percent of these, or 10.4 million people, do not drive automobiles, and this is the target population for any transit system or service. Of these 10.4 million people, 60 percent have transit available within 2 blocks of their residences. The remaining 4.2 million do not and would be candidates for demand-responsive service.

PALMER: In Toledo, we have been involved in the development of a demand-responsive system as a subsystem of the regional transit authority and also of another subsystem to support recreational programs for physically and emotionally handicapped people. As component portions of our model cities program were designed, transportation problems were readily identified. Not unlike the companies in many other communities, our private bus company at that point was near its demise: Service was down, scheduling was poor, and equipment was inadequate. We had many citizens who were handicapped either physically or emotionally and almost all were handicapped economically. Our system was designed, therefore, as much to meet sociological needs as to meet economical needs. We started our dial-a-bus system through a neighborhood-based corporation during a period in which the city was in a transition from a privately operated public transportation company to a regional transit authority. Later that system became a part of the regional transit authority and is now operating 2 kinds of service: (a) fixed-route service within the model neighborhood area for which a 10-cent fare is charged to those who are not classified as handicapped or elderly or who are not on some form of public assistance and (b) a demand-response service that operates on a 4-hour scheduling basis after calls are received. When a substantial recreational program was developed for senior citizens and for the physically and emotionally handicapped, a special transportation need was created that the regional transit authority could not serve. However, through the cooperation of local industry, we secured 4 specially equipped vehicles to serve these recreational needs. Two are equipped with a side-lift apparatus for taking those on and off who are not ambulatory. Special safety features are built into the buses for protection of the handicapped.

VEHICLE DESIGN

QUESTION: What are the needs of the elderly and handicapped with regard to vehicle design?

BAUER: The most obvious barrier to travel by the handicapped and the elderly is economics. Even if transit is available within 2 blocks of one's residence, it might as well not be if one cannot afford to use it.

There is also the psychological barrier to travel by the handicapped and the elderly. They have a great fear of being assaulted and not being able to ward off an attack; they have a concern about being in crowds and not being able to maintain their positions within a crowd; and they have a fear of getting lost on the transit system. Many of us who are neither elderly nor handicapped would also have difficulty getting around on a strange transit system. Even schedules and maps do not always help. I used to have a sort of hobby that when I was in a new town, I would try going from point A to point B by bus. I have since given it up. I had the advantage that if I really got lost I could always take a taxicab. But the elderly, the handicapped, and the economically deprived are not able to do that. So, they worry about getting lost on the system, and they are not eager to ask strangers or bus drivers for help or advice. There are not many communities where a person can ask a bus driver a series of questions. The driver may be running late or in a hurry or tired or at the end of the run, and he or she is impatient with anyone asking all kinds of questions that may sound dumb but are important to the rider.

There are many physical barriers associated with vehicle design. Just an added step reduces what is perhaps one of the biggest barriers to the aged and the handicapped, and that is the distance from the ground to that first step on the bus. We have spent many hours with engineers discussing this problem. To reduce that distance to the point where it is easily negotiated is difficult. General Motors Corporation has developed a rapid transit experimental vehicle that has been called a "kneeling" bus. That is, by the use of hydraulics, the front of the bus is lowered and then raised up again to reduce the height of the first step. There are also problems with signs, handholds, and grab rails.

We have recognized and listed all of these problems, but I see very little being done toward solutions.

MATEYKA: I would like to use the Transbus Program as a reference point to discuss what can be done and what should be done in the design of a new vehicle. Much of the Transbus technology is applicable to small demand-responsive buses. I will start by describing the old buses. The lighting level is low, and one can barely see what the vehicle looks like. It is usually dirty because it is not designed for easy cleaning. The seat backs are low; seating is cramped. A number of the grab rails are in the wrong place; they are made of stainless steel and present some safety hazard. The windows are relatively small—too low for a tall standee. The steps are steep, with 10-in. risers inside the vehicle and a 14-in. step to the ground (that far exceeds the 7-in. steps in homes). The step well is poorly lighted, and the curb area is not lighted at all from the bus.

On one version of the new Transbus, the lighting level is vastly increased, and the seat backs are much higher. The grab rail is soft, pliable plastic and is above the shoulder of the seated passenger. The seats are slanted back so that one can pass down the aisle, using handholds from seat back to seat back. The ambulatory handicapped or elderly person must have this kind of support inside of the vehicle. The seats are cantilevered from the wall, and no legs are underneath so that the floor area is completely free. The windows are large, and the smallest seated passenger and the largest standing passenger can easily see outside. An audio system is built in for use in announcing the next stop. There is a single 7-in. step within the vehicle; the distance from the bus to the curb is less than 7 in. The floor surfacing is either carpeting or a skid-free rubber material.

Within the Transbus Program, there is a special contest to design a vehicle to accommodate the elderly and handicapped, taking into account getting an individual in a wheelchair on and off the bus. Three companies have entered the competition.

The AM General bus requires an interfacing platform on the street and would be used in a large urban area. It integrates with an overall system that provides more information and amenities to the passenger because the problem cannot necessarily be solved by vehicle design alone. There are a number of physical barriers at the stop. The bus can be lowered from 20 to 17 in. to align with the platform height. As the bus comes to a stop, a level platform slides out through the open doors, and entering or exiting the bus is as simple as going through a doorway—and the doorway is 40 in. wide, providing plenty of clearance. Hand rails are built into the inside of the door.

The General Motors bus rolls up to the curb, lowers to about 17 in., using its kneeling feature. There is a single large platform, and normal-service people would step up to the large platform and then step up one 7 in. step into the bus. Because the bus is so low, this large platform can be lowered and raised quite easily with a very simple mechanism. A number of retaining devices are built in the lift mechanism itself so that there is no problem with sliding or rolling off.

The Rohr Industries bus has an even lower floor height; this 40-ft bus is only 13 in. off the ground. The ramp projects out from the bus only 3 ft and is used where there are curbs. To meet the architectural barrier standard for proper ramp angle, that ramp would have to be 20 ft long on an existing transit coach with a 34-in. floor.

QUESTION: How do you prevent an elderly or handicapped person from being turned over if he or she is in a wheelchair, stepped on, or crowded in, particularly during the rush-hour period? Is the bus being designed so that there are special locations on the bus for the handicapped?

MATEYKA: In a crowded situation, how do you make sure that the elderly or handicapped individual has a safe ride? The system must have the capability to deploy a ramp or something from the vehicle. And, all of the systems deploy outward. If there is limited visibility in twilight or in the early morning hours, the vehicle must have floodlights to illuminate the area around the stop. Both the ramp and the intensity from the light will tend to move people back from the curb to allow the handicapped person to enter. Beyond that, the problems are operational. Inside the bus, the individual comes up through the central area behind the fare box. The seats directly behind the inward-facing seats either fold up or are removed in that standee area. Some hold-down devices are required.

BAUER: To equip all of the 58,000 urban transit buses to remove barriers to wheelchairs in getting on and off, the Urban Mass Transportation Administration has estimated that it would cost about $5,000 per bus or $250 million.

QUESTION: We have 2 choices: One is to adapt the present service to use by the handicapped and the other is to provide separate service or accommodations. What effect will providing service to the handicapped on the normal operations have with regard to delays and trip time?

FITZGERALD: This raises the question of where the driver's responsibility ends. Does he go to the door of the bus to help a person on? Does he go into the house? Does he go up the stairs? Does he go into the apartment? What are the extra kinds of services that some of these people need? Is this a responsibility of the transportation system, or must there be some kind of support service? There is then the problem of delay time. If the driver must provide support services, does this cut down on the number of people that he can carry? What about those who are already waiting in the vehicle? I cannot answer these questions, but I am glad to know that I am not the only one who has asked them.

KENT: One of the criteria of demand-responsive transportation is to guarantee pickup and delivery times. You cannot readily do this if you mix normal ambulatory persons with severely handicapped, quasi-ambulatory, wheelchair patients. Perhaps we need a demand-responsive service that is specifically designed for handicapped persons and another service that has a more flexible schedule for others.

QUESTION: The Transbus design is supposed to reflect the next generation of commuter buses. There are provisions in the Transbus to accommodate the nonambulatory handicapped. The question is, Can the transit industry accommodate wheelchairs on regularly scheduled commuter services and still maintain a schedule?

KENT: We certainly cannot now satisfactorily accommodate handicapped people in normal fixed-route service. We are making progress, but we have a long way to go.

MATEYKA: For regular service on an arterial route, about 7 or 8 percent of the time, the bus is at a stop. On a 40-minute route, 3 minutes of time is spent at the stop. If 10 individuals in wheelchairs boarded at the stops, the bus would run 10 or 15 percent slower than it normally would.

SERVICE

QUESTION: What specific services can demand-responsive transportation provide?

FITZGERALD: In addition to transporting the elderly and the handicapped for medical purposes, for social and welfare services, and for recreational activities, demand-responsive transportation can aid in their socialization. We are increasingly concentrating housing for the elderly in transit-functional areas, and there is a need for socialization outside of that elderly housing. Demand-responsive systems can help meet that need.

KENT: We are using demand-responsive transportation to take services to people: public health nurses, homemakers, and homemaker aides. We also handle blood plasma batch delivery and similar medical services.

FITZGERALD: Demand-responsive transportation is a completely different thing for the engineer, for me, and for those who are handicapped or aged. There is, of course, a common denominator: the vehicle. But, the being transported itself is the important thing for an older or a handicapped person who perhaps is socially isolated. A social system develops in the act of being transported, and it becomes more than a ride. And the driver becomes more than just a bus driver. He or she is someone for that individual to relate to. You can see the social system develop in the way the passengers on a vehicle form a subcommunity or a subsocial system.

There are also different levels of needs for this kind of transportation for older and disabled people. There are different kinds of dependencies. In Ann Arbor, about 11 percent of the riders are 65 and over. They do not need anything more special than a normal dial-a-ride system. Yet for others, there are different levels of need. Those who have sensory impairment or vision and hearing problems may not be able to take trips by themselves all the time. They may not be sure where they are going, and, once there, may be afraid of getting off. A project in Cleveland uses transportation aides, someone who travels with the aged or handicapped individuals and helps bridge the gap between their homes and communities that they are not too familiar with.

PALMER: There are other kinds of special needs; one deals with the variableness of schedules for fixed-route variations. One of the problems we have encountered is the flexibility that is built into routing. We may have a service point that is 2 blocks off of the predetermined route. The user of the service cannot negotiate that 2-block area, and the system does not allow for detours so that there can be door-to-door delivery.

QUESTION: Why then is the federal government spending $25 million on hardware before it spends a couple of million to determine whether there is a demand for this service and whether that money would be better spent for a special service in large metropolitan areas where 3 or 4 vehicles could serve the whole metropolitan area?

MATEYKA: The basic design of the Transbus, which we should have done a long time ago, replaces the 1958 new-look design, which everybody recognized was not going to attract anybody back to transit. The primary concept in designing the vehicle was to incorporate features that would make the bus safer, more comfortable, and more attractive. The design also meets the needs of the elderly and the handicapped, particularly the ambulatory elderly and handicapped; the vehicle is a great deal more comfortable and easier for everybody to use. Features such as wider doors and lower steps, which are fundamental to any bus configuration with or without the handicap lift, are the kinds of things that will cut time on routes by as much as 5 and 10 percent, and that is money in the bank. The other aspect of designing for the handicapped is a significant safety benefit that can be translated into dollars. Tripping on stairways and other types of things now account for about 15 or 20 percent of the total claims bill, and these will be reduced significantly. As a result of the design for the handicapped, there are features that should speed the transit service and make it safer and, therefore, less costly.

QUESTION: In the Connecticut project, which is in an area that has 80,000 people, one of the 6 vehicles has equipment on it to allow wheelchairs and severely handicapped people to get on easily. There is space on that vehicle for 3 wheelchairs, but to date, the service has not been extensively used. Why has it not been used? Is it because people need a lot of encouragement to use it, or are they afraid to use it?

KENT: The 3 tie-down positions are increasingly used. We can tie down more in the center of the vehicle if necessary, but we have not had to do so. One of the major problems is that many people in wheelchairs cannot get out of their houses or into other buildings because of steps.

QUESTION: There are many architectural barriers and walls for people in wheelchairs. Nobody in a wheelchair can get anywhere near the city hall in my hometown because of the steps. Sports auditoriums, theatres, certain shopping centers, and restaurants have barriers. It is nice to get people out of their houses and into buses, but will many people be interested if they have nowhere to go other than to ride around town?

BAUER: Transportation does not function independently of the rest of the activities in the community. The elderly and handicapped should not necessarily have to use transit at all if they do not desire to do so. They should be able to get onto the sidewalk in a wheelchair and go to the stores to shop or to other community facilities. That they cannot is certainly one of the shortcomings that we have nationwide.

QUESTION: Does the transit authority or some other agency make the medical assessment of who should use the regular transit service and who requires special service?

KENT: In Connecticut, we rely on the health and social service agencies that normally interface with the elderly, handicapped, or low-income groups. Those agencies know most about the individual through relationships that have already been developed.

RESEARCH AND PLANNING IN DEMAND-RESPONSIVE TRANSPORTATION

Demand, Supply, and Cost Modeling Framework for Demand-Responsive Transportation Systems

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A comprehensive evaluation framework to aid in the implementation of demand-responsive transportation systems is proposed. The framework consists of demand, supply, and cost models that could be applied at general and detailed levels of decision. General-level models use information from existing demand-responsive operations in the United States and Canada. The models provide estimates of expected ridership, vehicle supply, ridership, and cost of operations as a function of system parameters such as population density, fleet size, fare, travel time, and control center requirements. The use of the models to obtain these estimates is exemplified, and their sensitivity to parametric changes is discussed.

Although the number of demand-responsive transportation systems is increasing in the United States and abroad, little is known about the socioeconomic and demographic parameters that affect the usage level of such a system. In addition, little is known about the manner in which this usage level may be translated in terms of system operating parameters such as fleet size, fare, travel times, and control-center staffing. As a result the initial selection of a service area and the operating parameters of a system are arbitrary decisions based on misleading market feasibility studies or superficial inspection of the service area characteristics.

After the system is in service, the operator attempts to reach a desirable level of service by changing the levels of the key system parameters. The operator may lower the fare and increase the fleet size to increase average ridership or may constrain the service area within geographic boundaries to serve high population densities at a higher quality of service—lower waiting and traveling times. Whatever the case, most of these changes would be performed with no detailed knowledge or analysis of what interactions exist among the parameters and how these interactions affect the performance of a system.

Demand, supply, and cost models that were developed for demand-responsive transportation systems are described in this paper. The models are used to derive estimates of expected ridership, vehicle supply, and cost of operations as a function of key system parameters such as density, fleet size, fare, travel time, and control-center personnel requirements. The models were designed to serve as a planning tool to aid in the preliminary evaluation of potential alternatives for implementing a demand-responsive transportation system. They may also be applied for the initial selection and subsequent monitoring of operating parameters.

The set of demand, supply, and cost models presented is an integral part of an evaluation framework that was developed to aid in decision-making at different levels of implementation. The overall evaluation framework is described, and the application of this framework for 2 levels of analysis is exemplified.

The notation used in this paper is defined below.

Notation	Definition
P	Population of service area
A	Service area size, square miles
R	Average daily ridership
H	Average number of operating hours per day
RPP	Average daily ridership divided by service area population
RPM	Average daily ridership divided by service area size
RPH	Average daily ridership divided by number of daily hours of operation
D	Density or population per square mile
V	Average number of daily operating vehicles in system
VH	(V)(H); also V = 3.73 + 0.058VH
$(VH)^1$	Average number of vehicle-hours per month or 28.55(VH)
PS	Average number of total daily passenger seats in operation or (V)(seats per vehicle)
PSH	Passenger seat-hours or (PS)(H)
FA	Average fare charged to a customer
WT	Average waiting time of a customer
RT	Average time of traveling in vehicle
TT	Total trip time or (WT) + (RT)
T	Type of vehicle used where 1 = taxi, 2 = van, 3 = 13- to 20-passenger bus, and 4 = full-sized transit bus
S	Average traveling speed of vehicles, mph
S^1	Type of service, where 1 = many-to-one, 2 = many-to-few, and 3 = many-to-many
R^1	Average weekly ridership or 6.04R
H^1	Average number of operating hours per week or 6.04H
C_{ma}	Monthly cost of management personnel
C_{dt}	Monthly cost of dispatchers and telephonists
C_{sc}	Monthly cost of secretaries and clerks
C_o	Monthly cost of office and garage space
C_t	Monthly cost of telephone
C_{om}	Monthly cost of office maintenance
C_d	Monthly cost of drivers
C_{go}	Monthly cost of gas and oil
C_i	Monthly cost of insurance
C_m	Monthly cost of mechanic
C_s	Monthly cost of miscellaneous supplies
C_r	Monthly ratio maintenance cost
W_{ma}	Wage rate per hour of managers
W_{sc}	Wage rate per hour of secretaries and clerks
W_d	Wage rate per hour of drivers
W_{dt}	Wage rate per hour of dispatchers and telephonists
W_m	Wage rate per hour of mechanics
C_f	Fuel cost per gallon of gas
M_l	Miles driven per gallon of gas

MODEL DESCRIPTION AND INTEGRATION

An integral part of the evaluation of demand-responsive transportation is a modeling framework that can be used to estimate vehicle supply and ridership based on various service parameters and to delineate resultant costs and revenues for any potential demand-responsive operation. These parameters could be used as input to a profit-loss analysis.

Figure 1 shows the manner in which the sets of models interact and integrate to form an evaluative entity. The development of such a framework follows the actual relations that exist among the parameters. For example, the demand for a demand-responsive system is directly dependent on the vehicle supply and inversely related to the fare structure. As the system supply (measured in terms of fleet size or vehicle-hours) increases, the quality of the service (in terms of less waiting time or total trip time) increases and, thus, the demand should increase. However, as the demand increases, it causes a corresponding decrease in service quality that, in turn, causes the total demand to decrease until an equilibrium is achieved between demand and vehicle supply. Similarly, in an aggregate transportation market, as the demand increases, the cost of providing this service increases; but on a local basis, as the fare structure increases, the demand decreases. If the demand is related to both the fare and the supply, indirect relations exist between the fare structure and the vehicle supply, shown in Figure 1 as a dotted line.

Similar relations exist among system demand, supply, and cost of operations. An increase in vehicle supply and ridership causes an increase in control staff requirements—which affects both capital requirements and operating costs of the system. In addition, miscellaneous incomes that may be obtained from a demand-responsive operation may affect fare levels and, thus, the ultimate profit or loss.

The demand, supply, and cost models provide mathematical descriptions of these major relations. The demand model provides estimates of daily ridership for any given service area as a function of the socioeconomic characteristics of the area and the system variables. The supply model relates a service quality index (such as fleet size and fleet-hours) to other interacting parameters, such as ridership, waiting time, and travel time. Similarly, the cost models relate capital and operating costs as a function of ridership and vehicle supply. The cost and income analysis (based on fares, marketing, rents) leads to the profit-loss analysis.

The applications of these models can be integrated into an optimization procedure to determine the combinations of parameters that would provide maximum revenue or minimum operating costs (1). For example, the analyst could determine the vehicle supply, operating hours, and fare structure that would generate the highest level of ridership at a given quality of service at minimum operating costs.

To aid in decisions regarding the implementation of a demand-responsive transportation system, the modeling framework should be developed for at least 2 levels of analysis. These are designated as general and detailed levels of analysis in terms of their potential applications, the models that may be developed, and the analytical techniques and data sources that may be used (Table 1).

For the general level, models are developed to provide estimates of demand, supply, and costs for a preliminary evaluation and screening of alternatives. The models not only identify the best service areas for system implementation but also may be used for establishing initial parameters for the operation of the systems. Information from diverse demand-responsive operations in the United States and Canada was used as input for this analysis.

The models developed for the detailed level of analysis are designed to give more accurate and detailed information applicable to a specific service area or ongoing operation. Since ridership and vehicle supply relations are expressed as functions of time of day and origin-destination, decisions can be made as to vehicle routing and scheduling, hours of operation, and arrangement of parameters to meet local conditions. The general models will be more closely related to the socioeconomic profile of the user and nonuser and the attributes of the specific system. Onboard and household surveys from an existing operation should be used as a data source for this modeling effort.

Figure 1. Evaluation framework for demand-responsive transportation systems.

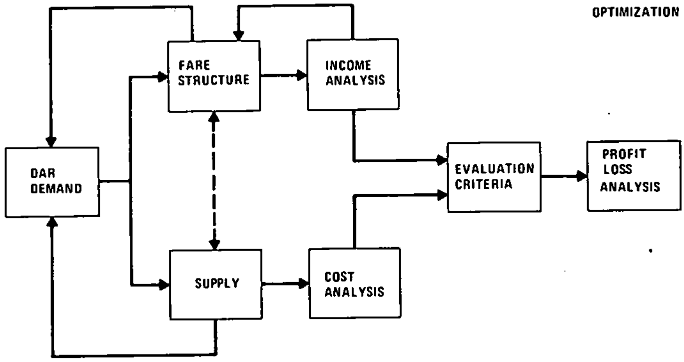


Table 1. General and detailed levels of analysis.

Level	Applications	Models	Analytical Techniques	Data Sources
General (macro)	Preliminary evaluation and screening of alternatives Service area identification index Project ranking Setting of initial operating parameters	Demand, supply, cost Aggregate analysis	Correlation-regression Factor analysis Graphical analysis Response surface optimization	Questionnaire, United States and Canada Census files
Detailed (micro)	Accurate and detail analysis Operational decisions Daily-weekly variations Vehicle routing and scheduling User-nonuser profile Arrangement of parameters	Demand, supply, cost Multiattribute discriminant Utility relations Operational relations	Correlation-regression Clustering and discriminant analysis Utility theory Rating and ranking Response surface optimization	Haddonfield Demonstration, onboard and household surveys

Table 2. Summary of demand-responsive transportation systems.

Service Area	Population	Area (sq mi)	Density	Type of Service	Nature of Service
Little Rock, Arkansas	132,500	53.0	2,500	Taxi-based share-ride	Many-to-many
Davenport, Iowa	100,000	30.0	33	Taxi-based share-ride	Many-to-many
Hicksville, New York	48,075	6.8	7,070	Taxi-based city wide	Many-to-many, many-to-one
Haddonfield, New Jersey	27,481	8.1	3,393	Bus-based city wide	Many-to-many, many-to-one
Columbia, Maryland	18,000	28.0	643	Bus-based city wide	Many-to-few, fixed-route
Buffalo, New York	53,860	3.0	17,953	Bus-based Model Cities	Many-to-many
Batavia, New York	18,000	4.3	4,186	Bus-based city wide	Many-to-many
Ann Arbor, Michigan	10,000	2.3	4,348	Bus-based city wide	Many-to-many
Detroit, Michigan	108,000	9.5	11,368	Bus-based Model Cities	Many-to-many
Columbus, Ohio	37,000	2.5	14,800	Bus-based Model Cities	Many-to-many
Toledo, Ohio	10,000	3.5	2,857	Bus-based Model Cities	Route deviation
La Habra, California	43,000	6.3	6,825	Bus-based	Route deviation
Regina, Saskatchewan	49,000	7.5	6,533	Bus-based feeder service	Many-to-few, many-to-one
Bay Ridges, Ontario	14,000	4.0	3,500	Bus-based feeder service	Many-to-one, many-to-many
Kingston, Ontario	59,000	64.0	922	Bus-based feeder service	Many-to-one
Stratford, Ontario	35,000	7.0	5,000	Bus-based feeder service	Many-to-one

The application of the modeling framework at both the general and detailed levels provides a set of planning tools to deal with all the major elements of system implementation. As a first step in the development of this framework, the results of the general models are presented.

METHOD OF STUDY

Operations of Demand-Responsive Transportation Systems

To obtain the necessary data to develop the general evaluation models, a complete inventory was needed of the operating parameters of existing demand-responsive systems and of the socioeconomic characteristics of the populations of the service areas. The stratification of system parameters was obtained from findings described in numerous reports and professional journals (2, 3, 4, 5, 6) and from questionnaires sent to the managers of existing demand-responsive transit systems.

Table 2 gives a list of the 16 sites from which completed questionnaires were obtained. Because of data reduction problems, complete information was not obtained from all the sites. Therefore, data on operations in Kingston, Stratford, and Hicksville were not included in the models. The models presented will be updated as information is obtained from these and other new significant demand-responsive operations.

A detailed description of these sites is found in other reports and will not be given here, but variability in the data sources is noted. Information was obtained from 3 taxi-based systems and 13 bus-based systems. Service areas vary from about 3 to 65 square miles, and service area population varies from 10,000 to 130,000 people. Four of the sites are in Canada and operate mostly as many-to-one feeder services. Of the remaining 12 American sites, 4 were restricted to Model Cities areas and 8 were providing citywide service. Most of these 12 sites provide many-to-many service.

The following major data items were requested in the questionnaires sent to the 16 sites:

1. Competition, major trip generators, and service objectives—(a) type and extent of competition within the service area, including public, private, and special systems, (b) fare structure of other systems, (c) special trip generators or peculiarities of the service area warranting specific treatment, and (d) service objectives and the degree of attainment of these objectives;
2. Demand and supply—(a) type of service being provided, (b) number and type of vehicles and available passenger seats, (c) average ridership, waiting time, riding time, and vehicle-hours for an average weekday and for Saturday and Sunday, and (d) peak-hour ridership; and
3. Economics—(a) capital costs of equipment (vehicles and communications) and basis of acquisition, (b) cost of support facilities, operating personnel, miscellaneous maintenance, office equipment, and taxes, and (c) annual total revenues from fares, leases, advertisements, and other miscellaneous items.

Model Building and Applications

The data items were reduced to perform a correlation and stepwise multiple linear regression analysis to develop 3 basic types of models:

1. A demand model relating variations of the ridership parameters (daily ridership, ridership-persons, ridership-square miles, ridership-hours of operation) with key operating parameters (population, area, fare, wait time, fleet size, hours of operation);
2. A supply model in which either total trip time or fleet size is expressed as a function of the other parameters, including daily ridership; and

3. A cost model relating each major cost component of a demand-responsive system to the estimated levels of ridership and vehicle supply.

After development of these 3 models, they were solved simultaneously to obtain the best estimates of daily ridership, vehicle supply, and monthly revenue and cost.

The procedure used to obtain the estimates can also be used in the application of the models to any particular area. Since each regression equation represents the best estimate of the dependent variable for given values of travel time, density, service type, and fare, demand and supply equations were solved simultaneously to obtain estimates of ridership and fleet size. The monthly revenue curve was then generated by multiplying the average number of days of operation per month by the estimated daily ridership and the corresponding average fare.

Since most of the cost component equations relate individual costs of a demand-responsive system to ridership and fleet size, the total monthly cost of the system was obtained by adding all the individual costs of the systems obtained after substituting the estimated values of ridership and fleet size.

Curves showing the interaction among the variables were also developed to determine the sensitivity of ridership and fleet size to changes in other parameters.

MODEL RESULTS

Demand, Supply, and Cost Models

A summary of the set of equations developed is given in Table 3. In terms of statistical efficiency, all equations were highly significant and yielded estimates that compared favorably with the observations. Most of the correlation coefficients were larger than 0.90; only one was as low as 0.70.

Four types of ridership equations and 2 types of supply equations were developed. The supply equation, in which total trip time is the dependent variable, was developed to enable potential operators to establish system parameters according to the desirable service level. For example, an operator who wanted to ensure that the level of service (i.e., total waiting and riding time) does not exceed 30 minutes could determine the best combination of ridership, vehicle-hours, and density required.

The 12 cost equations are expressed in terms of the major cost elements, excluding the capital cost of the vehicles, radios, and antenna. The capitalization of these costs can be attained according to normal economic procedures, which take into consideration the service life of the vehicles, the market interest rate, and so on. These costs should, of course, be added to the total operating costs obtained from the cost equations.

The equations can be expressed as multidimensional plots or nomographs. This transformation allows the equations to be used with ease and the relative effect of each variable to be apparent. A nomograph for the estimation of ridership per hour of operation is shown in Figure 2. For a service area of 50,000 people, a fleet size of 100 passenger-seats per day and a fare of $0.80, 27 riders/hour of operation is expected. A nomograph for the estimation of vehicle supply is shown in Figure 3. This nomograph will give the best estimate of the number of vehicles required in an operation for different levels of population density, area size, trip time, ridership, and type of service.

Figures 4 and 5 show the cost equation curves. These curves were designed to show the relative contribution of each component of the operating costs; for general use, they could also be translated into nomographs. This is particularly true of the labor costs, which are a function of 2 or more variables, including variations in wage rate.

The costs related to the control center (Fig. 4) illustrate the relative importance of the costs for telephonists, dispatchers, and managers as compared with the remaining costs. For the systems surveyed, costs related to the control center amount to 20 per-

Table 3. Demand, supply, and cost equations.

Type	Equation	Correlation Coefficient
Demand		
Daily ridership	$R = -238.9 + 0.072D + 23.3V + 0.161PSH$	0.99
Ridership/persons	$RPP = 0.00793 - 0.01638FA + 0.00012PS + 0.0000036D$	0.92
Ridership/square mile	$RPM = -51.9 + 0.06D + 1.6V - 145.4FA$	0.87
Ridership/hour	$RPH = 22.6 + 0.0009P + 0.187PS - 72.0FA$	0.94
Supply		
Travel time	$TT = 3.01 + 0.014R - 0.027VH + 0.002D + 3.6S^1$	0.84
Vehicles	$V = -4.68 - 0.23TT + 0.012R + 0.70A + 0.0008D + 1.18S^1$	0.94
Control-center-related costs		
Management	$C_{mm} = (0.224 + 0.0019R)\ 170\ W_{mm}$	0.92
Dispatchers—telephonists	$C_{dt} = (1.48 + 0.04H' + 0.0002R')\ 170\ W_{dt}$	0.70
Secretaries—clerks	$C_{sc} = (0.001R)\ 170\ W_{sc}$	0.92
Office—garage	$C_o = 129.66 + 0.50R$	0.94
Telephone	$C_t = 28.05 + 0.513R$	0.92
Office maintenance	$C_{om} = -35.41 + 0.393R$	0.91
Vehicle-related costs		
Drivers	$C_d = (VH)'\ W_d$	NA
Gas and oil	$C_{go} = (VH)'\ SC_f/(MI)$	NA
Insurance	$C_i = -1318 + 117V + 471T$	0.80
Mechanics	$C_m = (-69.25 + 1.38VH + 32.39T)\ W_m$	0.92
Miscellaneous supplies	$C_s = -204 + 7VH + 10T$	0.92
Radio maintenance	$C_r = 67.4 + 4.61V$	0.93

Figure 2. Nomograph for estimating ridership per hour of operation.

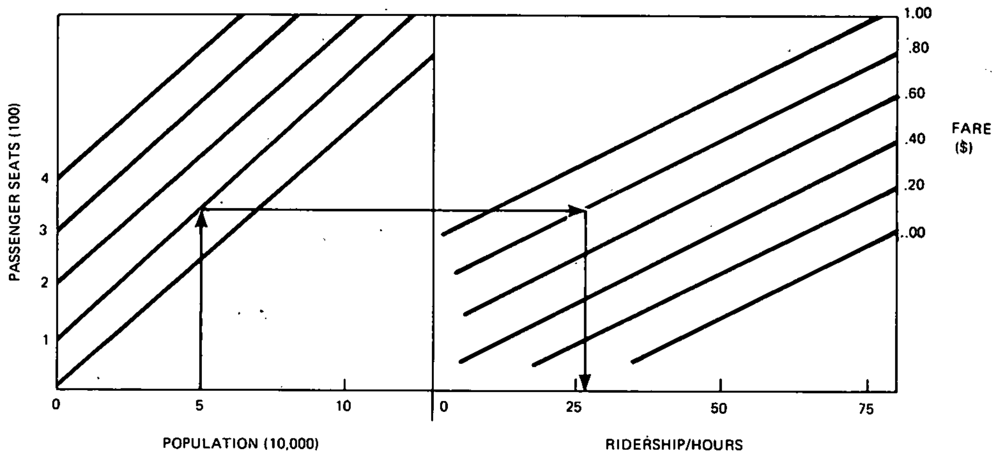


Figure 3. Nomograph for estimating vehicle supply.

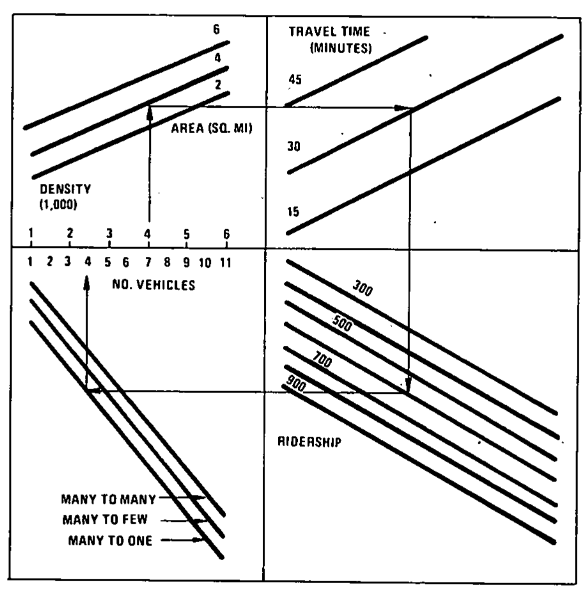


Figure 4. Control-center-related costs versus ridership.

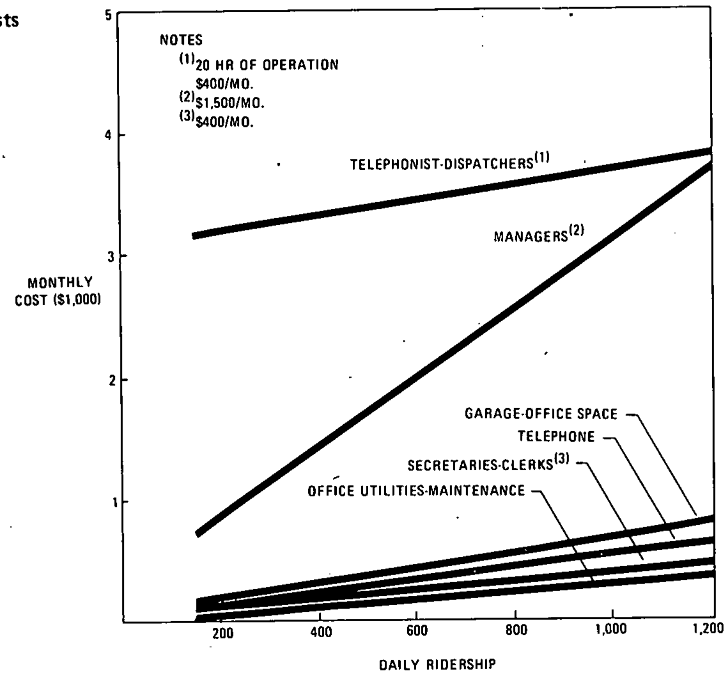
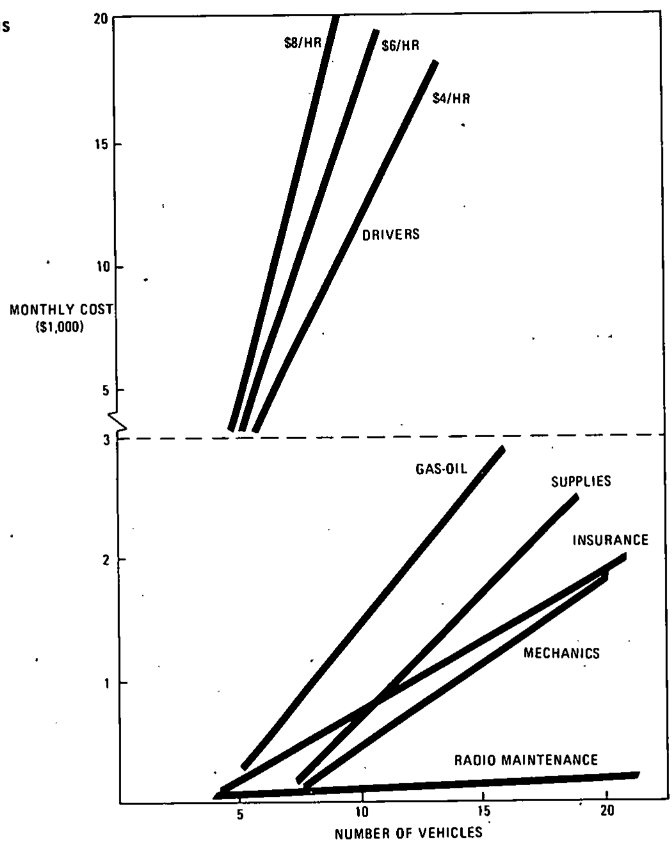


Figure 5. Vehicle-related costs versus fleet size.



cent of the total cost of implementing and operating a demand-responsive transportation system. Of this, the cost of telephonists, dispatchers, and managers amounts to 15 percent of the total cost.

Each element in the vehicle-related costs (except radio maintenance) increases significantly with an increase in the number of operating vehicles per day (Fig. 5). However, the drivers are the most expensive element, amounting to about 60 percent of the total costs. The remaining vehicle-related costs amount to another 15 percent of the total costs. The remaining 5 percent of the costs are capital costs for the purchase of vehicles, radios, and other control-center equipment.

Illustration and Sensitivity Analysis

The demand and supply equations were solved simultaneously to illustrate the model results and the sensitivity of these results to changes in system parameters. Except as noted, the following assumptions can be made:

Item	Assumption
Population	32,000
Service area, square miles	8
Density, people/square mile	4,000
Service	Many-to-many
Vans, 4-year life, 8 percent interest (no salvage value)	$8,000
Radios, 6-year life, 8 percent interest (no salvage value)	$500
Antenna, 6-year life, 8 percent interest (no salvage value)	$5,000
Wage rates/hour	
Drivers	$5
Mechanics	$5
Wage rates/month	
Dispatchers and telephonists	$600
Secretaries	$500
Managers	$1,500

Effects of Fare and Travel Time

Figures 6 and 7 show the expected ridership and vehicle supply for the previously stated assumptions as functions of fare and total trip time. Daily ridership decreases significantly with an increase in fare and decreases slightly with an increase in total trip time. For example, for a decrease in travel time of 30 minutes, the ridership increases by approximately 200/day. This increase in ridership necessitates an increase of 8 vehicles, which affects the cost of operation significantly. The interaction of these 2 variables is shown in Figure 8.

Figures 9 and 10 show monthly revenue and costs as functions of fare and trip time. The revenue and cost curves reflect the functional relations existing among the operating parameters. That is, as fare increases, revenue increases to an optimum point, after which ridership begins to decrease. As shown in Figure 10, low fares result in high ridership, which requires a large fleet and high monthly costs. Levels of ridership, supply, and monthly costs have been delineated for 3 fare values corresponding to values of optimum revenue.

Figure 11 shows a comparison of revenue and costs for a trip time of 30 minutes and the previously stated assumptions. An additional cost curve is shown relating the effect of reductions in wage rates on the total monthly cost. The curve for the low wage rates was obtained by using the following values:

Figure 6. Effect of fare and travel time on daily ridership.

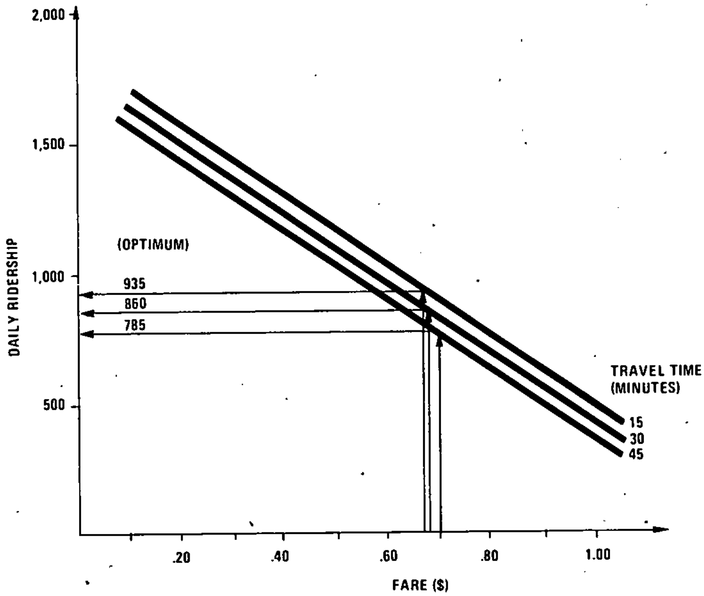


Figure 7. Effect of fare and travel time on fleet size.

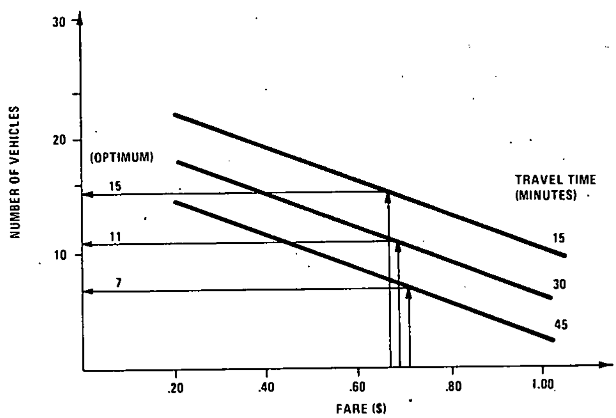


Figure 8. Effect of fleet size and travel time on daily ridership.

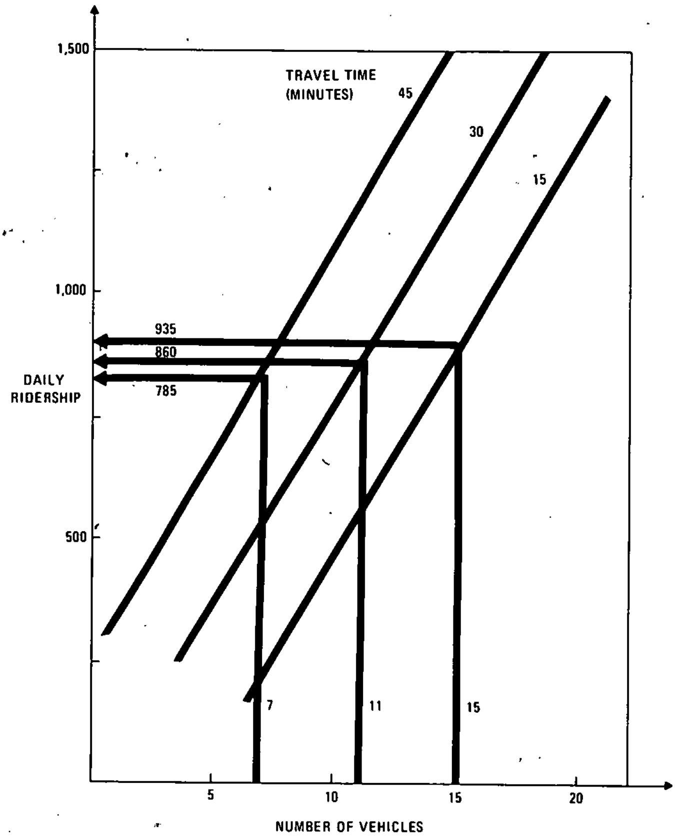


Figure 9. Monthly revenue as a function of fare and travel time.

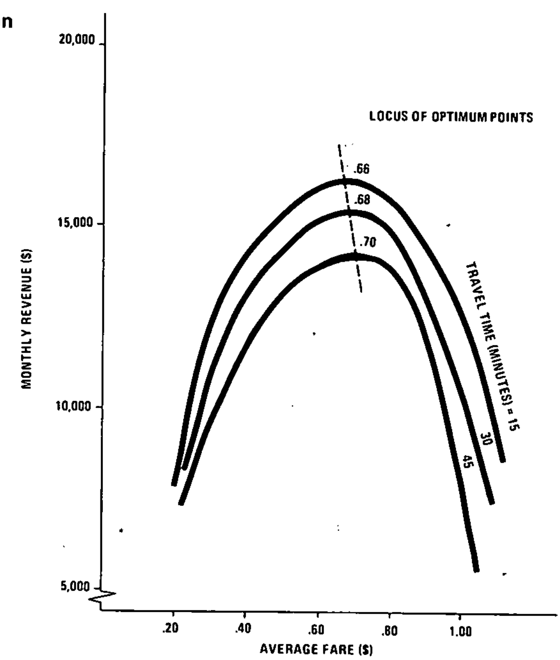


Figure 10. Monthly cost as a function of fare and travel time.

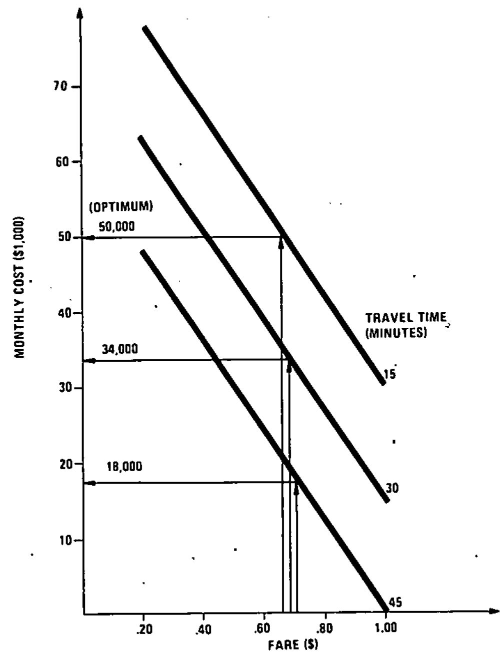
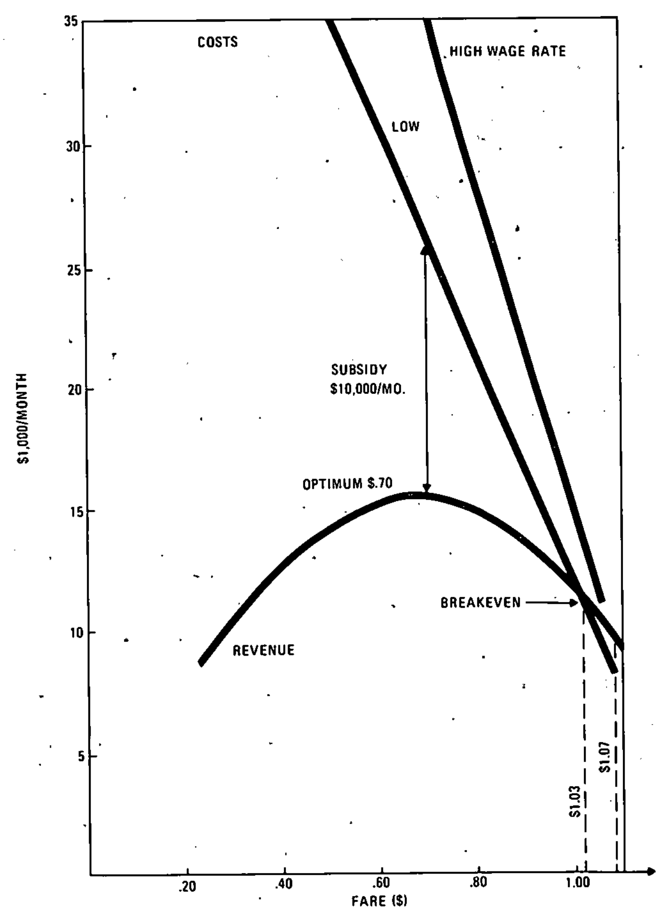


Figure 11. Comparison of monthly revenues and costs.



Item	Value
Wage rates/hour	
Drivers	$3.50
Mechanics	$3.50
Wage rates/month	
Dispatchers and telephonists	$500
Secretaries	$500
Managers	$1,000

The point of optimum revenue obviously does not correspond to minimum operating costs. If the objective is to operate at low subsidy or profitable levels, high fares must be charged and will result in low ridership, low vehicle supply, and thus a low level of service. Low fares result in high ridership, large vehicle supply, and thus a high level of service.

The optimum revenue of $15,000/month is obtained by charging $0.70/ride (Fig. 11). This results in a monthly cost of $25,000 or $10,000 of required subsidy or external incomes. Break-even conditions occur at a fare of about $1.03/person. A final factor to note from Figure 11 is the sensitivity of the costs to changes in wage rates. A decrease in wage rates reduces the subsidy level by half at optimum conditions, but reduces the break-even fare level by only $0.04. Thus, the effect of decreased wage rates is much more significant at lower fare levels because these low fares result in incrementally higher ridership and vehicle supply levels.

Effects of Fare and Density

An important factor in the implementation of a demand-responsive transportation system is the population density of the service area under consideration. As shown in Figures 12 through 15, for a trip time of 30 minutes and the aforementioned assumptions, population density has a high correlation with levels of ridership, vehicle supply, revenues, and costs. For example, at a fare of $0.60, an increase in density of 2,000 people/square mile results in an additional 1,200 riders/day, which requires 14 additional vehicles for service. The monthly revenue increase from the fare box is approximately $36,000, and the costs increase about $52,000.

Because all the system parameters increase significantly with an increase in population density, care should be used in the selection of a service area. The optimum revenue curves are shifted to a higher fare level as population density increases. This causes break-even conditions to occur at prohibitive fare levels. Therefore, under certain circumstances, depending on the desired level of service to be attained, to operate in areas having lower population densities might be propitious in order to keep system size and cost at a minimum.

Consideration for Future Applications

Those who are considering implementing a demand-responsive transportation system and who desire to use these models for preliminary evaluation and selection of system parameters should be aware of the limitations of the models and the types of adjustments needed to account for local conditions.

In terms of specific limitations, the models were developed by using a statistical analysis of existing demand-responsive transportation systems, which differ in terms of demographic characteristics and types of operation. Therefore, the analysis attempts to account not for direct cause and effect relations among the variables but for true functional relations. Estimates obtained from these equations should be used in light of the peculiarities of the study areas used for analysis. For example, ridership estimates of more than 1,000 obtained from a large fleet size and high fares usually refer to a taxi-based operation.

Figure 12. Effect of fare and density on daily ridership.

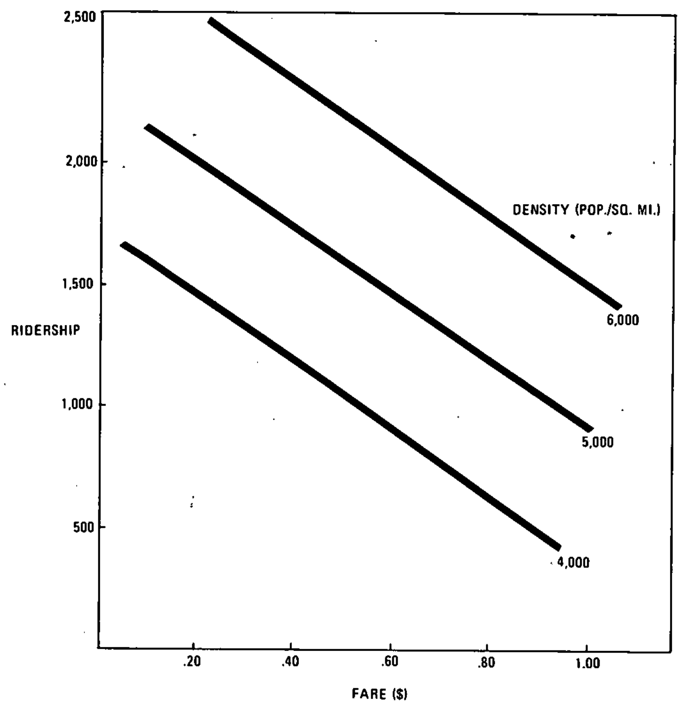


Figure 13. Effect of fare and density on fleet size.

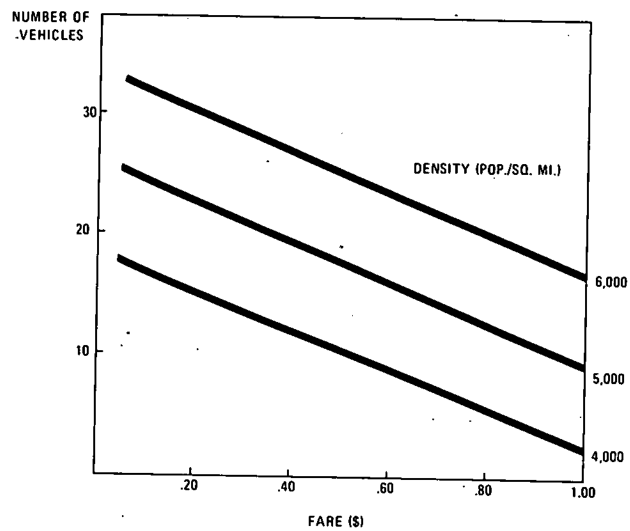


Figure 14. Monthly revenue as a function of fare and density.

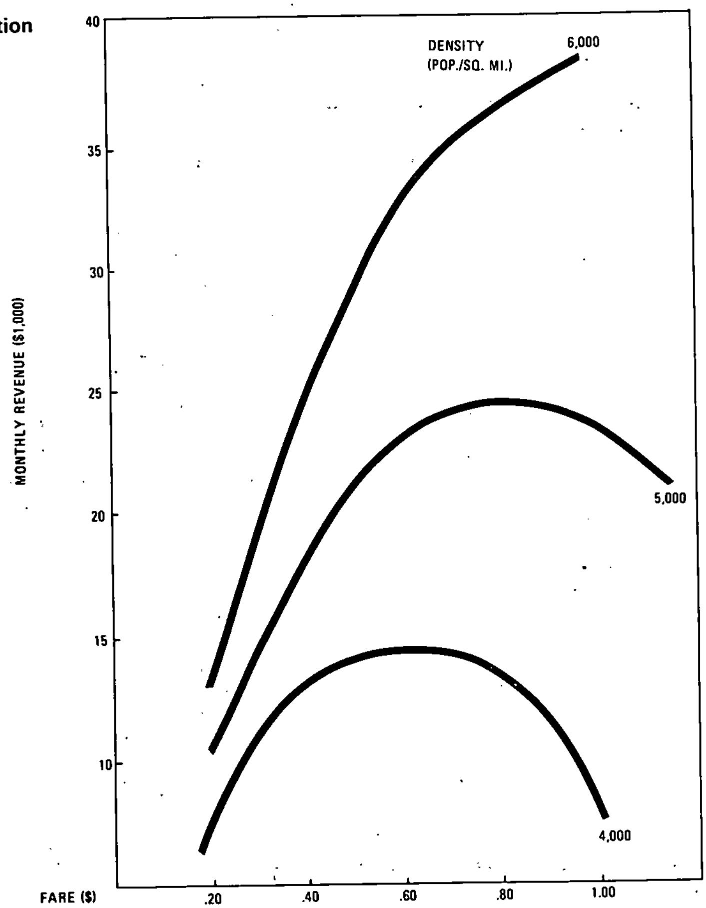
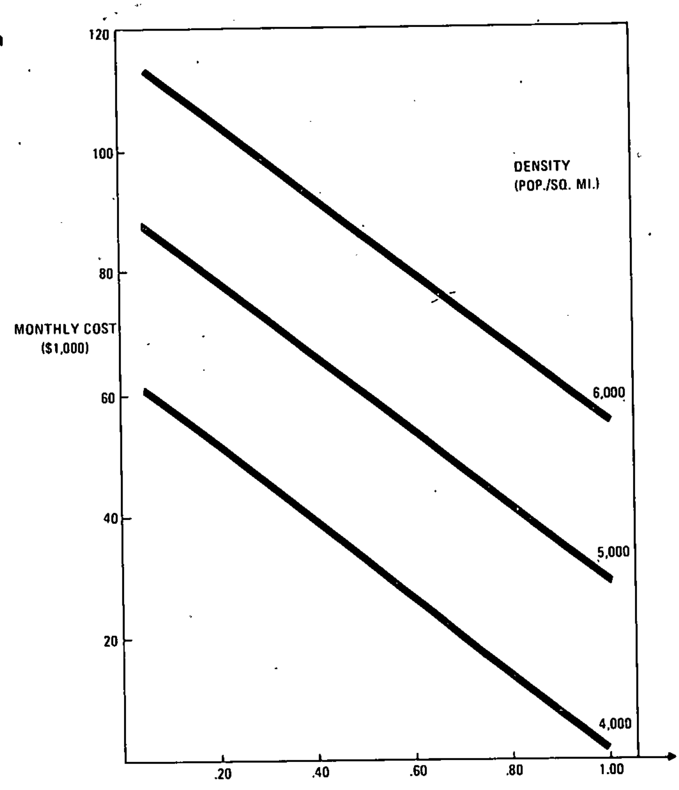


Figure 15. Monthly cost as a function of fare and density.



The models also do not reflect unique demographic, social, and economic characteristics of the community and of the potential users of the system. The only measure of socioeconomic level used in the models was the total population of the service area, the size, and thus the density. Therefore, although the models can be applied to any specific area to obtain estimates of expected ridership, on the basis of aggregate indexes, no mechanism in the models accounts for specific individuals (the poor, the aged) who have a strong propensity to use the system.

Within the context of these limitations, analysis of the models has shown that significant relations exist among ridership, vehicle supply, and various demographic and system parameters. Similarly, significant relations exist among operating costs, ridership, and vehicle supply. That is, even at the general level, where ridership data are expressed on an average daily basis, significant statistical relations exist among parameters.

To apply the equations effectively, the analyst should be aware of these limitations and make adjustments based on the following considerations:

1. Is there a high percentage of residents with a propensity (percentage over 55, under 20, unlicensed) to use a demand-responsive system?
2. Is there a large trip generator, such as a shopping center, high-speed line station, hospital, or schools, that would affect the incidence of ridership?
3. What other transportation modes are available within the area, and what percentage and type of market do they capture?
4. Is it possible to allocate services to institutions, such as day care centers and senior citizens' homes?
5. According to the traffic-generating characteristics of the area, at what daily hours is it better to operate modes such as many-to-many or many-to-one?
6. Is there a potential to offset the cost of operating a system in the service area by supplementing fare-box revenue by paying low wages to operators or providing package delivery?

CONCLUSIONS AND RECOMMENDATIONS

A comprehensive evaluation framework to aid in the implementation of demand-responsive transportation systems has been proposed. The framework consists of demand, supply, and cost models that could be applied at general and detailed levels of decision. General-level models were developed by using information from existing demand-responsive operations in the United States and Canada. The application and sensitivity of the models to key system parameters were also illustrated.

It was concluded that the set of demand, supply, and cost models fulfilled the objectives of the general level of analysis. These 3 models can be used as planning tools to aid in the preliminary evaluation of potential alternatives for implementing a demand-responsive transportation system. They may also be used for the initial selection and subsequent monitoring of operating parameters. The models perform these functions by providing estimates of expected ridership, vehicle supply, revenue, and cost of operations as a function of system parameters such as population density, fleet size, fare, travel time, and control-center requirements.

The research in demand, supply, and revenue-cost modeling for a demand-responsive transportation system is in its infancy. This study could be expanded to improve analysis at the general level or to develop more accurate and widely applicable models for decisions at the detailed level. Critical research areas regarding the modeling of demand-responsive systems include

1. Expansion of the general models by incorporating demographic and socioeconomic indexes to better represent the tendency of the residents of given areas to the system;
2. Development of models that will accurately reflect differences in operating systems and modes such as bus-based versus taxi-based and many-to-many versus many-

to-one and that will account for other variations in usage such as average weekday, Saturday, and Sunday travel;

3. Development of demand and supply models for detailed analysis that are behavioristically oriented and, thus, sensitive to profiles of users and nonusers and their attitudes toward the system's attributes; and

4. Development of an optimization procedure that will integrate the demand, supply, and cost models to identify operating parameters that will maximize ridership, give the most favorable arrangement of vehicle supply, and minimize cost of operation.

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Analytic Model for Predicting Dial-A-Ride System Performance

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Previous development work on dial-a-ride (DAR) has focused principally on defining the supply side of the system. Detailed computer simulation models that have been developed at M.I.T. and the Ford Motor Company (1, 2) relate the quality of service to the number of vehicles operating and the level and distribution of demand for the service. At the early stages of development and investigation of the general potential of the system, this was appropriate because detailed and realistic simulation was necessary to determine these fundamentals of operation. During this phase, different assignment algorithms were tested and, for the best set, calculations were developed between level of service as a key output measure and number of vehicles, vehicle speed, pickup and delivery time, ridership, and distribution of ridership as key input parameters. This basis that was then formed for detailed costing of DAR systems related cost per vehicle, cost per operator-hour, control costs, and operating costs to important output measures such as cost per passenger trip and cost per passenger-mile.

At this stage the supply side of the system was quite well defined, and the analyst was able to make reliable statements such as, "If a dial-a-ride system is to be implemented to serve 200 passengers per hour at a mean level of service of 2.5 in a 10 square mile area, then x vehicles will be required and the average cost per trip will be y." This was clearly an important step in establishing feasibility of the concept, but it did not include the demand side of the picture. Work on the demand side has been much more limited, and until now no model has been developed that includes both the demand and the supply sides. This paper presents such a model, which is designed so that a transit planner can quickly and inexpensively explore a variety of design and policy options for a proposed dial-a-ride system.

The model predicts the equilibrium operation of a dial-a-ride system and the outputs, including gross and net revenue, total cost, total ridership, and quality of service, that the designer is most concerned with when configuring a system. Equilibrium is computed by 3 components: supply model, cost model, and demand model (3). The supply model is an analytic model that is based on the operation of the system and has been calibrated with simulation model experiments. This enables a much less expensive supply model to be used that retains much of the accuracy of the full simulation. The model requires a minimal data base, which is generally available in any metropolitan area, and no significant additional data must be collected.

This equilibrium model for the first time allows a transit planner to test a wide range of service areas, vehicle fleet sizes, and fare policies to select the best set of options for given objectives, which may be couched in terms of realizing a net revenue, providing a given quality of service, or attaining a given level of ridership. Relations such as the effect of fare on ridership and net revenue and of fleet size on service level and ridership can now be explored in given areas by using the proposed equilibrium model.

Table 1 gives the exogenous and endogenous variables in each submodel as well as the notation that is used for these variables.

SUPPLY MODEL

The supply model considers each passenger's trip to consist of 2 parts: a wait time, t_w, and a travel time, t_T. Each vehicle is modeled as a queue. Passengers arrive at the queue at the moment they are picked up and leave the queue when they are dropped off at their destinations. While on board, they wait in the queue to be served, and the average in-vehicle time, t_T, is their average time in queue.

The rate at which a vehicle can serve a passenger depends on the time needed for a passenger to board and exit from the vehicle, t_E and t_P respectively, and the average distance between stops, D. Although on the average each demand served results in 2 stops, one of these is to pick up passengers and can, therefore, be ignored for model-

Table 1. Model variables.

Variable	Notation	Exogenous or Endogenous	Models in Which Variables Appear		
			Supply	Demand	Cost
Average vehicle speed	SPEED	Exogenous	x		x
Average trip length	L	Exogenous	x	x	
Total time of service per day	T	Exogenous	x	x	x
Factor input prices	—	Exogenous			x
Size of service area	AREA	Exogenous	x		
Total daily internal trips in service area during DAR operating time	GENR	Exogenous		x	
Vehicle boarding time	t_p	Exogenous	x	x	x
Vehicle exit time	t_E	Exogenous	x	x	x
DAR modal split	MS	Endogenous	x	x	x
DAR fare	f	Exogenous		x	x
Vehicle fleet size	v	Exogenous	x	x	x
Average DAR wait time	t_w	Endogenous	x	x	
Average DAR travel time	t_T	Endogenous	x	x	
Automobile access time	CART	Exogenous		x	
Daily net cost of DAR	TC	Endogenous			x

ing the travel time component of a trip. Therefore, the average time needed to serve a passenger, $1/\mu$, is

$$\frac{1}{\mu} = \frac{D}{SPEED} + t_E + t_P \quad (1)$$

The value of D will clearly be a function of a number of variables, including the pattern of origins and destinations in the service area, the dispatching algorithm, and size of the service area. However, this problem was greatly simplified by treating D as a linear function of the average trip length and the rate at which demands arrive at the vehicle. Simulations were run, and the results were used to estimate an equation for D by using ordinary least squares. The results are

$$\begin{array}{rccc} D = & 1.109 & + \ 0.036L & - \ 6.12\lambda \\ & (0.109) & (0.056) & (0.737) \\ & (10.162) & (5.483) & (-8.299) \end{array} \quad (2)$$

$R^2 = 0.877$, and $F(2, 15) = 53.513$. The coefficient of L is positive, reflecting the difficulty associated with creating efficient tours when a service area is characterized by long trips. The variable λ reflects the average number of origin-destination pairs available for putting together tours and, therefore, has a negative coefficient indicating lower interstop distances with higher demand rates per vehicle.

If values of λ and μ are measured in the same units, in this case demands serviced per minute, a number of possible queuing models can be applied to predict the travel time, t_T. The simulation results were used to test the M/M/1 and the M/G/1 queues. Both models tended to underpredict travel times for highly congested systems. However, in general the M/M/1 model resulted in predictions that better matched the simulated data. Furthermore, the M/G/1 specification requires a prediction of the variance of the service rate. Therefore, the M/M/1 model shown in Eq. 3 was selected.

$$t_T = \frac{1}{\mu - \lambda} \quad (3)$$

Even though the model underpredicted travel time for certain dial-a-ride systems, the range of model validity was relatively well defined. It was found that, unless Eq. 4 held, the model was likely to be seriously in error. Equations 2 and 6 were solved by using only simulated data within the range of model validity.

$$8.82\lambda - v/AREA \leq 0.250 \quad (4)$$

The wait time could in theory be treated as a queue. However, a much simpler method was used in the supply model to reduce the complexity of the equilibration process.

Given the value of the average in-vehicle travel time t_T and the exogenously determined average trip length, it is possible to determine an average effective velocity, V_{EFF}, in any given direction. This velocity corresponds to the effective rate at which a vehicle moves along a tour toward any passenger's destination. The wait-time equation simply assumes that the same effective velocity applies to a vehicle moving to pick up a passenger as to a vehicle heading toward a passenger's destination. If the average distance from the vehicle to a demand is L^W, then the expected wait time, t_W, can be expressed as

$$t_W = \frac{L^W}{V_{EFF}} = \frac{L^W}{L} t_T \quad (5)$$

As with D, an equation for L^W was developed by using the results of the simulation runs. Equation 6 presents the results of this estimation. The vehicle density, v/AREA, reflects how far from the demand's origin a vehicle is likely to be. The demand density, λv/AREA, reflects the degree of system congestion that is likely to make assignment of a very close vehicle to be inefficient. As expected, both coefficients have the proper sign.

$$L^{w} = \underset{\substack{(0.104)\\(15.613)}}{1.622} + \underset{\substack{(1.227)\\(4.061)}}{4.98\lambda v/AREA} - \underset{\substack{(0.140)\\(-6.386)}}{0.892\, v/AREA} \qquad (6)$$

$R^2 = 0.753$, and $F(2, 15) = 22.829$.

DEMAND MODEL

Because there are few comprehensive data about the demand for dial-a-ride services, a relatively simple incremental demand model was selected (4). This model assumes that total daily travel within the service area is fixed and that DAR modal split, MS, is a function of only the expected wait time, t_w, the fare, f, and the ratio of DAR travel time to that of automobile travel time, TTR. It is assumed that a base-point modal split, MS°, is known, which corresponds to a base wait time, t_w°, a base fare, f°, and a base travel-time ratio, TTR°. Given this base point, the demand model is

$$MS = MS^\circ \left[e_w \left(\frac{t_w - t_w^\circ}{t_w^\circ} \right) + e_{TTR} \left(\frac{TTR - TTR^\circ}{TTR^\circ} \right) + e_f \left(\frac{f - f^\circ}{f^\circ} \right) \right] \qquad (7)$$

where e_w is the elasticity of modal split with respect to wait time, e_{TTR} is the elasticity of modal split with respect to the travel time, and e_f is the elasticity of modal split with respect to fare.

The base point of 2 percent modal split for a wait time of 15 minutes, a fare of $0.60, and a travel-time ratio of 2.0 were used based on the records for early months of operation in the autumn of 1971 in Batavia, New York.

The elasticities selected were derived from the attitudinal survey by Golob and Gustafson (5). They derived a set of demand curves that in light of existing operational experience gives modal-split values that are far too high (6). However, the elasticities implied by those curves seem quite reasonable for DAR demand. These elasticities are

$$e_w = -0.3;\ e_{TTR} = -0.3;\ e_f = -1.1 \qquad (8)$$

The wait-time elasticity is somewhat lower than that usually used for demand analysis and is roughly equal to travel-time ratio elasticity. This probably reflects the fact that dial-a-ride passengers generally wait in their homes rather than in a transit station. The fare elasticity is quite high, perhaps reflecting the high proportion of low-income, elderly, and young persons using dial-a-ride service.

Automobile out-of-vehicle time, denoted as CART, was assumed to be 2 minutes. Average vehicle speed for automobile travel was assumed to be equal to that for dial-a-ride.

EQUILIBRIUM

At equilibrium, Eqs. 1 through 7 are all satisfied simultaneously. This condition, after substantial algebraic manipulation, results in the following polynomial equation of the endogenous variable λ.

$$\left[a_1 \text{ SPEED} + \frac{a_2 d_1}{q_1} + \frac{a_2 a_4 \text{ SPEED}}{q_1} + \frac{a_3 \ell_1 d_1}{L} + \frac{a_3 \ell_1 a_4 \text{SPEED}}{L}\right]$$
$$+ \left[-a_1 d_1 - a_1 a_4 \text{ SPEED} + \frac{a_2 d_2}{q_1} + \frac{a_3 \ell_1 d_2}{L} + \frac{a_3 \ell_2 d_2}{L} + \frac{a_3 \ell_2 a_4 \text{ SPEED}}{L} - \text{SPEED}\right] \lambda$$
$$+ \left[-a_1 d_2 + \frac{a_3 \ell_2 d_2}{L} + d_1 + a_4 \text{ SPEED}\right] \lambda^2 + d_2 \lambda^3 = 0 \qquad (9)$$

where

$$a_1 = \frac{\text{GENR}}{v} \text{MS}^{\circ} \left[1 - e_{TTR} - e_w + e_f \left(\frac{f - f^{\circ}}{f^{\circ}}\right)\right];$$
$$a_2 = \frac{\text{GENR}}{v} \text{MS}^{\circ} \frac{e_{TTR}}{\text{TTR}^{\circ}};$$
$$a_3 = \frac{\text{GENR}}{v} \text{MS}^{\circ} \frac{e_w}{t_w^{\circ}};$$
$$a_4 = t_t + t_o \text{; and}$$
$$q_1 = \frac{L}{\text{SPEED}} + \text{CART}.$$

Equations 2 and 6 have been simplified so that

$$D = d_1 + d_2 \lambda$$
$$L^w = \ell_1 + \ell_2 \lambda \qquad (10)$$

The positive, real solution of this third-order polynomial in λ, the demand arrival rate, can then be used to determine the travel time and wait time directly from the supply model equations.

NET COST MODEL

To predict the net cost of service requires that both costs and revenues be calculated. The DAR system was assumed to be computer dispatched by the use of available minicomputer technology. Costs were considered in 4 general categories:

1. Customer communications (handling and processing incoming calls for service),
2. Vehicle operation (capital and operating costs),
3. Dispatching (computer rental, space), and
4. Overhead.

The 4 categories were further disaggregated into space, labor, phone rental, and other requirements. Wage rates for various job categories and other factor input prices were taken from a number of sources and represent reasonable values for a typical northeastern city with unionized labor.

In the cost analysis, true demand-responsive service was assumed to operate only during off-peak hours and more efficient subscription bus service was assumed to operate during the peak hours. Thus, a portion of total cost was allocated to peak-hour service. Similarly, only a typical weekday was modeled, and a portion of fixed costs was allocated to weekend and holiday DAR service.

Revenues were calculated from the demand arrival rate. However, on the average each demand corresponds to slightly more than 1 passenger; therefore, 1.1 passengers per demand were used.

MODEL RESULTS

The model was used in a hypothetical parametric test case in which a range of sensitivity analyses was performed by systematically varying average trip length, size of service area, demand elasticities, base modal splits, fares, and vehicle fleet sizes. The model was used successfully to analyze several thousand different configurations and demonstrated the complex interrelations between design parameters.

For systems characterized by both high fares and high fare elasticities, no positive equilibrium solution could be found, probably because the incremental demand model is inadequate at fares or service times that are much larger or smaller than the base values.

Occasionally, when high fare-high fare elasticity systems resulted in a positive equilibrium solution, the results were completely unreasonable in that dial-a-ride travel time was less than that for automobile travel time. However, these systems were a small fraction of the thousands of configurations tested and were generally characterized by input values far beyond the range over which the supply model was calibrated. The development of a much larger data set on which more sophisticated expressions for L^w and D could be calibrated might eliminate much of this difficulty.

No dial-a-ride system examined resulted in a profitable operation. This is consistent with existing operational experience and seems reasonable when one considers that only the off-peak hours were considered. Efficient peak-hour subscription bus service for work trips would probably offset at least some of this deficit.

CONCLUSION

The need for effective dial-a-ride system planning tools other than expensive, supply-oriented simulation will become more acute as more and more small communities consider the implementation of dial-a-ride service. Analytic models that capture both supply and demand effects within an equilibrium framework offer an alternative that can aid the design process in small communities and be used in conjunction with simulation in large-scale planning problems. Although still untested in an actual design problem, the model presented in this paper seems to offer reasonable potential for meeting an important planning need.

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Technique For Selecting Operating Characteristics of Demand-Actuated Bus Systems

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As the number of applications of demand-actuated public transit systems increases, careful consideration must be given to the selection of operating policies. It is not sufficient to merely determine that a demand-actuated system is better than a fixed-time operation. We should also attempt to select those operating characteristics that result in the optimal benefit to the user, operator, and community. In this paper, we explore the effect of several variables on the economic and service characteristics of demand-actuated systems. Comparative tables and charts describe a process for selecting the "best" system for prescribed service areas and potential demand. The variables include scheduling dynamics and routing dynamics. The selection criteria include user statistics such as ride time and waiting time and operator statistics such as total capital cost, operating-hours, and vehicle productivity. The selection of a system will necessitate a trade-off between service and operating costs, and techniques for formalizing these decisions and results of applying these techniques are presented.

The term "demand responsive" has many meanings. In a sense, bus systems in major cities are demand responsive. That is, as the demand has decreased through the years, the frequency of service and route coverage has responded to that demand.

If we want to more accurately characterize demand-responsive systems, we would define attributes to which they respond: average ridership and the response period, probably measured in years. This type of system provides good service if demand is relatively high and requires frequent service if both short- and long-term variations in demand are small. This may result in short periods of crowded buses and then periods of underuse of buses, but probably not to the extent that changes in operating policies are warranted.

However, as the average demand decreases, continued use of these attributes for scheduling and routing leads to either infrequent service or low bus use. The former means poor service as viewed by the user, and the latter results in an uneconomic operation.

To overcome this dichotomy in the face of decreasing patronage, analytical and empirical studies have been conducted. These studies use instantaneous or short-term demands for scheduling and routing as opposed to long-term averages. In this way, they avoid the long wait time associated with bus systems responding to long-term averages and yet maintain a higher level of bus use. As the demand increases or the variation in demand decreases, these advantages decrease. Since the cost is inherently greater for managing demand systems than for managing the existing system, we must understand the precise level of demand that warrants one or the other of these systems.

Because there are policy variations in the operation of demand-actuated systems, the question is one not of defining a single point but of defining a family of curves describing optimal operating policies ranging from instantaneous response to the "fixed-time" response of the existing systems. If we use cost in a general sense to include some combination of user costs and operating costs, this family of curves may appear as shown in Figure 1.

The purpose of this study was to develop and operate a model on a common set of data to produce this family of curves. A second objective was to illustrate the application of this concept for various definitions of cost and to test the sensitivity of these curves to various system parameters.

DEFINITIONS

At the outset, we had to define the characteristics of the various systems to be tested and evaluated.

Table 1 gives a list of demand-actuated public transportation systems. The characteristics of those used in this study are given below. The dynamic system was not tested in this study.

1. The fixed-headway and fixed-route system is based on multiple-passenger vehicles traveling on predetermined routes at prescheduled headways for passenger pickup and delivery. The route and headways for such operations are predetermined from past demand experiences. This type of system now exists in most urban areas.
2. The variable-headway and fixed-route system also uses multiple-passenger vehicles traveling on predetermined routes, but the schedule depends on dispatching criteria. For this study, we used 2 independent criteria: total demands or a specified wait time, whichever occurred first.
3. The fixed-headway and variable-route system is similar to the route-deviation service offered in Mansfield, Ohio. An optimal routing technique is necessary for system operation. To increase the efficiency in computing the optimal routing strategies, high-speed digital computers are necessary.
4. The variable-headway and variable-route (nondynamic) system is the traditional dial-a-ride service. The demands are recorded and analyzed according to their time of calls and spatial locations, and routes and schedules are selected based on the input criteria. The same set of dispatch criteria were used in this case.

SIMULATION MODEL

The simulation model was developed with the capability of replicating the operations of bus systems under various system strategies and collecting the data required for statistical summaries of system performance parameters.

The model is initiated by generating strings of demands (collection and distribution) for each specific area of operation. There is no limit with regard to the size of an area. For larger areas, the model can handle sectoring or splitting of the entire area in segments and can operate the simulated bus systems concurrently in each segment.

The model assumes a central pool of buses from which vehicles are dispatched to any sector on demand. (Different pooling policies are investigated in the sensitivity analysis portions in the study.)

For fixed-route systems, the routes of bus operation are specified; for variable-route systems, the shortest path is used by the model.

The simulation program develops a point-to-point travel distance matrix for the given area under investigation. The distance matrix is then converted to a travel-time matrix by using link travel speeds. The speed of travel can either be used as an average speed or as a function of other parameters.

Input variables include these specific speed parameters, number of sectors to be serviced, pooling policy, fixed headways, dispatch logic, vehicle capacity, and number of available buses.

A demand is considered as a call for service and can consist of either single or multiple passengers; the number of passengers is generated from probability functions with assigned probabilities for 1 passenger, 2 passengers, and so on.

The available buses in the bus pool are serially numbered, and the simulation model always searches for lowest numbered buses for use and will not call for a new bus (though available from the system constraints) so long as there is a bus in the pool that has been used before. Thus, maximum use of each bus is accomplished, and the number of buses required may be determined by specifying large bus pools. That strategy was used in this study.

The capacity of vehicles used in the simulation is an input parameter and must be specified. Capacity is treated as a constraint in making the decision regarding vehicle and passenger service.

The zone number for identification of the activity center is also an input parameter. Thus, multiple-activity centers for various trip purposes are possible.

The mean arrival rate for the area under study is an input. The generation subroutine computes the rider demand on the basis of a preassigned probability distribution. The frequency of collections and distributions is also computed according to probability functions. Thus, the generation of rider demand is completely random (Poisson or any other probability distribution) and is computed for any specified length of time in the model.

The delay at any stop for a bus is a function of the number of passengers involved and whether they are loading or unloading. The model includes separate delay functions for evaluation of travel times. For a given bus stop, the delay is computed on the basis of the number of passengers entering and leaving at that location. This function is set up as a default option in the absence of specific input.

The model requires specific inputs regarding minimum number of passenger demands to warrant dispatching a bus or maximum headway of buses if the specified demand is not registered. These are predetermined in the definition of the system.

The maximum tolerable waiting time for a passenger is also an input to this model. This parameter signifies to some extent the level of service provided to the riders. It also is used to define the limit at which potential riders switch to other means of transportation and are lost in this study. We used 30 minutes as the maximum wait time, after which the call was erased from the demand list.

The general flow chart for the model is shown in Figure 2. The function of each subroutine is described below.

1. The "generate" subroutine generates passenger demands (collection and distribution) with necessary identification information such as origin zone, destination zone, number of passengers in each demand, and absolute clock time of generation.

2. The passenger demand is then separated by sectors and arranged in increasing order of generation time.

3. The model then examines the demand list of each sector at a specified interval of time (5, 10, 15, 20, 30 seconds) and tests the maximum headway constraint and dispatch logic. If neither of the above 2 dispatch triggers is satisfied, the model moves to the next increment of time and tests again. This operation is done concurrently in all sectors. When a dispatch criterion is satisfied, a bus is dispatched with the demand list for the specified sector being serviced.

4. The bus-pool subroutine is activated by 1 of the 2 triggers and searches for a bus with the lowest serial number and sends it to the sector identified.

5. The time of bus dispatch is noted, and a time clock is advanced in each bus to keep a record of tour time. This time clock considers point-to-point travel time from the generated travel-time matrix and also accumulates embarkation and disembarkation times at each service point. This module summarizes bus operating times and bus use statistics.

6. A separate test module keeps track of individual passenger generation time, wait time, riding time, and total travel time. This module summarizes passenger service data after each bus tour and also compiles summary statistics.

The system simulation is performed by the model, and all pertinent statistics of the riders are accumulated. The waiting time at the point of demand, riding time, and total travel time are accumulated by the model and printed for each bus trip. The origin and destination of the riders, their time of generation, waiting time, riding time, and total travel time are printed for each bus trip and also for each segment of the service area as shown in Figure 3.

The mean, maximum, and frequency over a specified limit are accumulated and printed for all statistics. This enables the analyst to take a closer look at the system attributes.

The bus occupancy, the trip time, and the bus utilization are accumulated for the entire simulation period. The first set of printouts consists of a table for each vehicle indicating each tour, number of passengers collected and distributed, and total

Figure 1. Optimal regions for alternative systems.

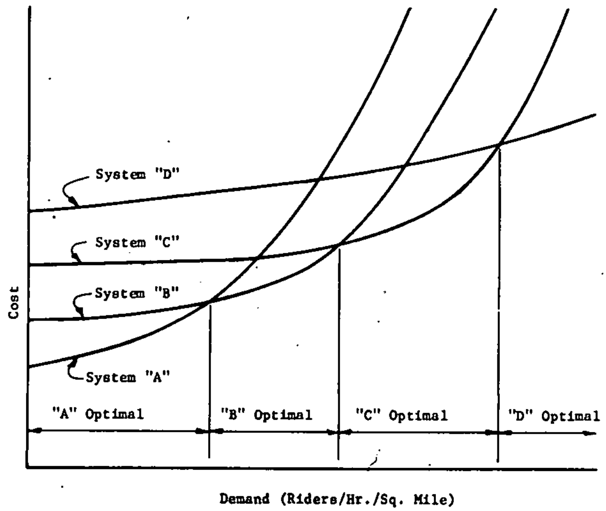


Table 1. Performance criteria levels in hierarchy of demand-actuated bus systems.

System Number	Dispatch Logic	Response to Demand	Route
1	Fixed route and fixed headway (general purpose)	Nonresponsive	Fixed
2	Variable headway and fixed route	Semiresponsive to fixed route	Fixed
3	Fixed headway and variable route	Semiresponsive	Traveling salesman
4	Variable route and variable headway, nondynamic	Fully responsive	Traveling salesman
5	Variable route and variable headway, dynamic	Fully responsive to address	Traveling salesman

Figure 2. Simulation model.

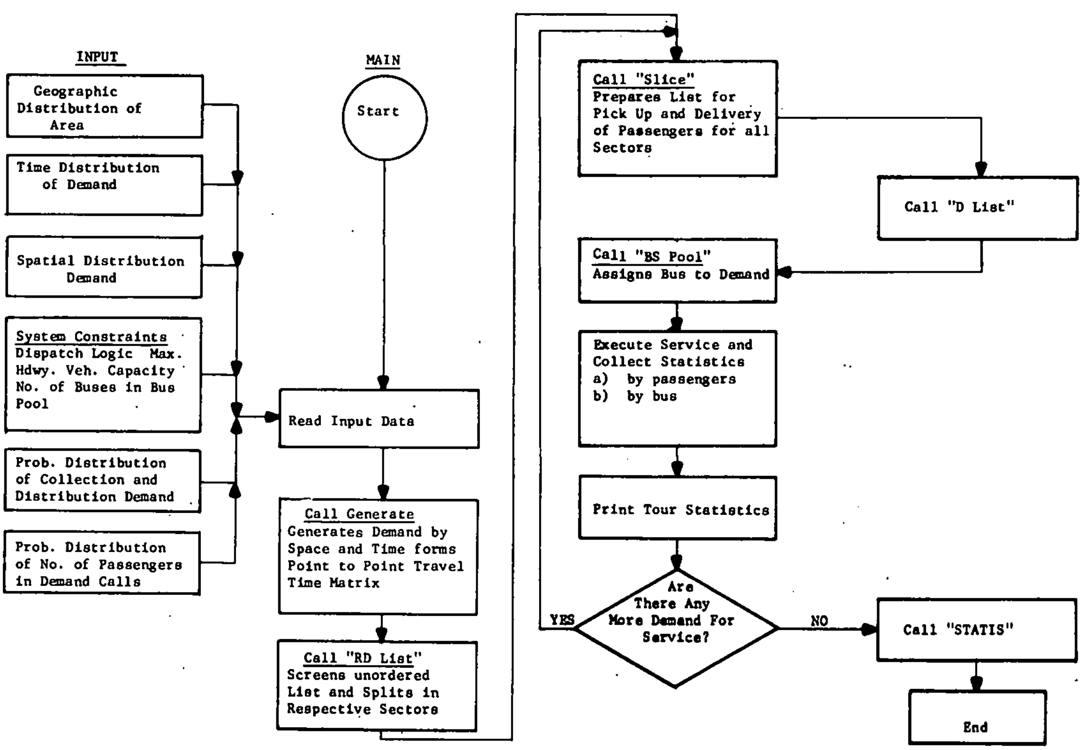


Figure 3. Model output of user statistics.

SECTOR 2 BUS NUMBER 1 LEFT A.C. @ 4.09 MINUTES RETURNED @ 23.02 MIN

TOUR COMPLETION TIME: 18.25 BUS DISTRIBUTED 0 PASS. COLLECTED 5 PASS. IN THE FOLLOW

DEMAND #	DESTI-NATION	ORIGIN	NUMBER PASS.	TIME GEN.	WAIT TIME	RIDE TIME	PASS. TOT. TRAV. TIME
1		33.	1.	0.41	5.76	16.86	22.62
2		73.	2.	3.78	15.37	23.11	38.48
3		139.	2.	0.26	34.62	10.91	45.52

BUS NUMBER 1 EXECUTED 8 TOURS INVOLVING 37 PASSENGERS
TOTAL TIME IN USE = 163.98 MINUTES

TOUR NUMBER	# PASS. DISTRB.	# PASS. COLLCT.	TOTAL TOUR TIME
1	0	5	19.24
2	2	3	19.54
3	1	3	20.25
4	4	1	20.89
5	1	3	21.41
6	0	5	20.04
7	3	2	21.81
8	3	1	20.80

PASSENGER "WAIT-TIME" STATISTICS,

SEGMENTING IS DONE EVERY 60 MINUTES BASED ON GEN.-TIME

	SECTOR #1			SECTOR #2			SECTOR #3		
SEG. #	MEAN	MAX.	OVER 15 MIN.	MEAN	MAX.	OVER 15 MIN.	MEAN	MAX.	OVER 15 MIN.
1	10.37	30.82	7	13.05	27.17	9	14.41	30.12	12
2	9.59	23.53	6	13.53	31.39	12	13.72	28.35	6
3	7.43	24.25	3	9.85	16.79	3	8.45	30.10	4
4	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0

PASSENGER "RIDE-TIME" STATISTICS,
SEGMENTING IS DONE EVERY 60 MINUTES BASED ON GEN.-TIME

	SECTOR #1			SECTOR #2			SECTOR #3		
SEG. #	MEAN	MAX.	OVER 15 MIN.	MEAN	MAX.	OVER 15 MIN.	MEAN	MAX.	OVER 15 MIN.
1	12.55	20.42	10	10.95	17.82	3	10.50	21.22	8
2	8.84	18.17	3	10.05	17.68	5	9.09	17.29	4
3	9.39	17.16	3	9.11	20.55	2	9.92	18.13	4
4	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0

tour time.

The summary statistics for the buses shown in Figure 4 consist of one table for each time segment indicating the number of tours performed by each bus, number of passengers collected and distributed, total tour time, mean tour time, and bus use.

TEST SYSTEM

The street network used in this study was composed of 3 sectors with a common activity center. Each sector is 1 mile square and contains 225 passenger-generation points.

The variable-route system has access to each generation point through a grid network. The fixed-route system, which follows a pattern as shown in Figure 5, makes 20 stops to pick up or drop off passengers. The generated riders walk to the nearest stop for service, and the walking time is included in their waiting time.

Passengers were generated at each of the 225 generation points-sectors by a random generator. Poisson distribution was used to distribute passenger arrivals at each point; the mean value was one of the variables tested.

Before analysis is made of the differences in system performance characteristics produced by the models, the model results must be validated. To do this, we compared the model results over a range of demand densities with actual field experience, as shown in Figure 6. As expected, the existing systems perform better than fixed-time and fixed-route systems, but not so well as an optimally routed demand-actuated system. Figure 6 also shows that the advantages of demand activation decrease with increasing demand.

SYSTEM PERFORMANCE CHARACTERISTICS

Each of the 4 systems was used as the basis for simulation on a fixed data set representing 3 hours of operation at each of several levels of demand. The demand levels tested in the anslysis were 10, 20, 30, 40, 60, 80, and 100 demands per hour per sector.

Both user and operator summary statistics were collected and compared as a method of establishing system performance. These statistics include waiting time, riding time, number of vehicles required, and vehicle productivity.

Figure 7 shows the average wait time per passenger versus the demand per hour per sector for each system. The variable-headway and variable-route system provides the lowest wait time for a demand level below 75/hour/sector. Beyond this level, the fixed-route and variable-headway system has the lowest waiting time, although the variable-headway and variable-route system is quite close. At demand levels beyond 60/hour/sector, the fixed-route and fixed-headway system has almost the same wait-time characteristics as those of the variable-route and variable-headway system. The variable-route and fixed-headway system is clearly not comparable, for it results in a much higher waiting time than that of any other system.

Figure 8 shows the ride-time characteristics of each system. The variable-route and variable-headway system can reduce riding time in the network for all levels of demand tested. Both fixed-route systems yielded very high ride times.

No single system provides the optimal value of each characteristic at all demand levels. However, if the 2 recorded times are added to obtain total travel time, the variable-route and variable-headway system yields the lowest total travel time at all tested levels of demand.

Figure 9 shows that the variable-route and fixed-headway system yields the highest vehicle productivity for all levels of demand. The variable-route and variable-headway system produces a higher productivity than either one of the fixed-route systems for demand levels below 80/hour. Beyond this point, the fixed-route and fixed-headway system shows higher productivity.

Figure 4. Model output of bus statistics.

SEGMENT NUMBER 1   TIME FROM   0.0 MIN. TO   59.99 MIN.

BUS #	NUMBER TOURS	NUMBER PASS. DISTRB	NUMBER PASS. COLLCT	TOTAL PASS. SERVED	TOTAL TOUR TIME	MEAN TOUR TIME	BUS UTILI-ZATION
1	3	2	11	13	50.01	16.67	0.83
2	3	4	5	9	49.18	16.39	0.82
3	2	4	6	10	46.92	23.46	0.78
4	2	6	4	10	46.66	23.33	0.78
5	2	2	7	9	40.75	20.37	0.68
6	2	0	4	4	19.98	9.99	0.33
7	1	3	2	5	21.81	21.81	0.36
8	0	0	0	0	0.0	0.0	0.0

Figure 5. Fixed-route system.

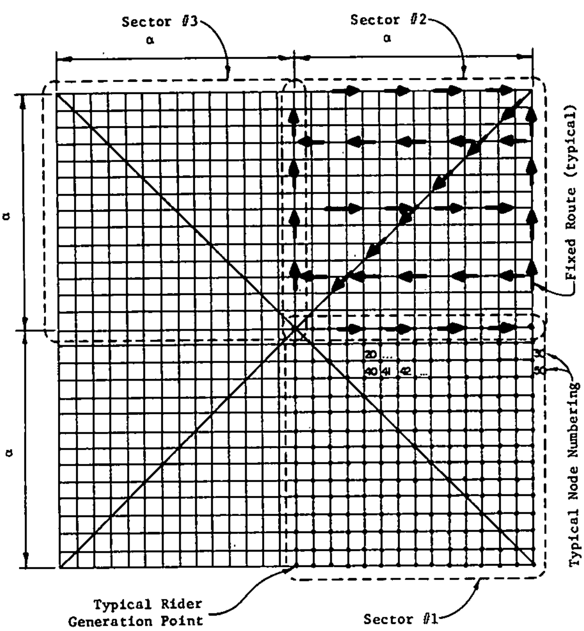


Figure 6. Comparison of productivity of simulated and operating systems.

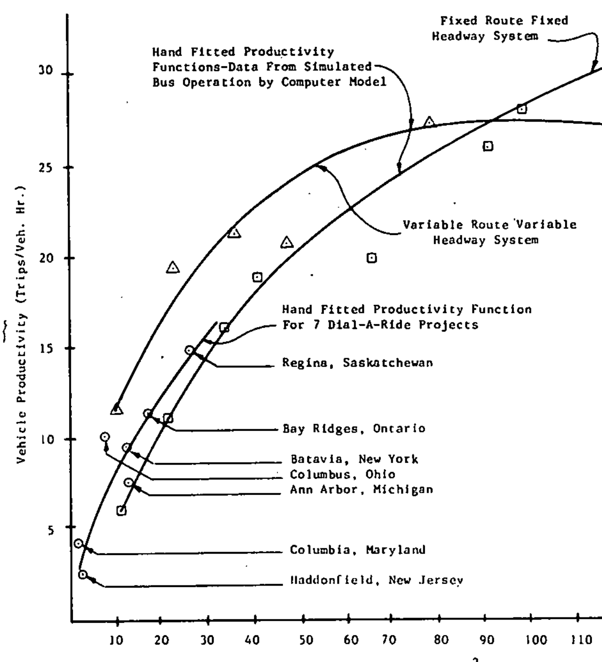


Figure 7. Wait times of 4 systems.

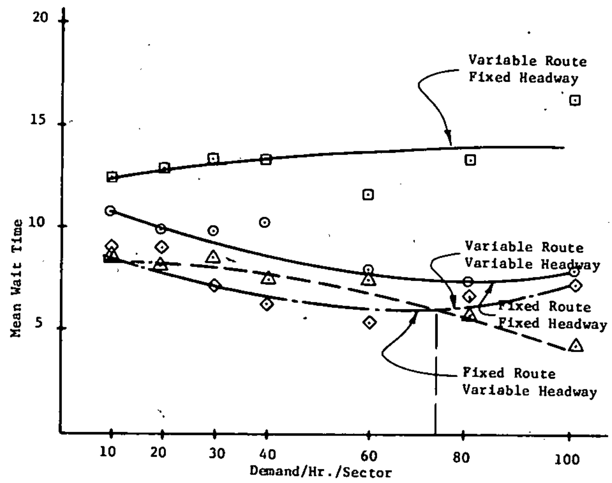


Figure 8. Ride times of 4 systems.

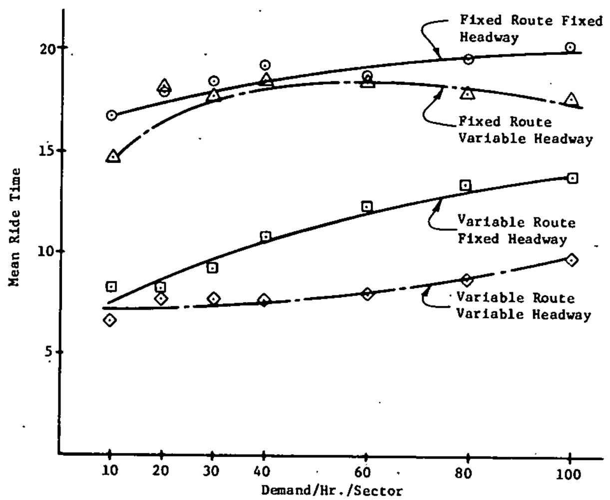


Figure 9. Vehicle productivity of 4 systems.

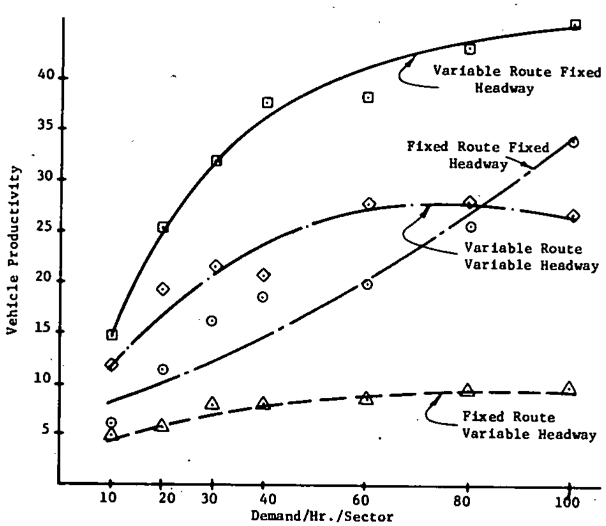


Figure 10 shows the total number of buses required for each system. Because this measure is inversely related to productivity, the variable-route and fixed-headway system has the lowest vehicle requirement for all levels of demand. A similar result is shown in Figure 11 for driver-hours. Again, the variable-route and fixed-headway system results in the lowest driver-hour requirements for all levels of demand. The variable route and variable-headway system has a driver requirement lower than the fixed-route and fixed-headway system in the low-demand sector, but the 2 systems become nearly coincident in the high-demand sector.

Figure 12 shows vehicle-hours of operation. The variable-route and fixed-headway system produces the lowest vehicle-hours of operation among the systems. The variable-route and variable-headway system has a lower vehicle-hour requirement than the fixed-time and fixed-route system up to the demand of 65/hour/sector. These curves and those for driver-hours cross at different demand levels because the variable-route and variable-headway system is a more efficient system when measured by bus use. Therefore, there are fewer idle hours for the bus driver while waiting for the run to start.

SYSTEM EVALUATION AND SELECTION

The primary objective of this study was to generate data to assist in the selection of demand-actuated bus system alternatives. If one were to make the very simple assumption that demand, service, and operating costs are all nonelastic, then the curves shown in the preceding section would suffice. The bus manager who wants to operate a bus system for profit could survey the demand and select the system with the lowest product of vehicle operating time multiplied by cost per hour and capital costs of required buses amortized over their life span. The cost for this bus service could then be compared with a feasible fare.

Similarly, if public transportation were being considered as a public service, a specified level of service as measured by waiting time and ride time could be established, and the system that met these criteria for the projected demand could be selected. The appropriation required for the service could be determined from the bus statistics, and a decision reached by the appropriating body.

There is sufficient evidence, however, to reject this assumption of a nonelastic market. The structure of existing trip-generation and modal-split models used in transportation planning includes a dependent relation among demand, service, and cost. Thus, the problem is not that simple, even if the data are known.

Obviously a trade-off must be made between the user's performance characteristics (wait time, ride time, total travel time) and the transit operating characteristics (number of buses, vehicle-hours of operation, vehicle productivity, bus use). The use of constant unit cost figures for each of these characteristics is unrealistic, for they vary with location and in many cases are quite subjective.

The value of these system attributes depends largely on the goals and policies of the community for which the transit system is being planned. In economic analysis, where the trade-off between intangible and tangible costs needs to be established, the common practice is to use a value scale for both items. This value scale varies depending on the goals of the environment and is often referred to as a utility scale; system alternatives are selected on the basis of their score or utility function. Whether the simple benefit-cost anslysis or the more complex utility analysis is preferred by the analyst, there are 2 common factors in all evaluation techniques:

1. A scaling factor representing the "value" of an incremental change in each of the significant measures of performance, Vi; and
2. A quantitative representation of the change in the magnitude, x_i.

The evaluation models can combine these factors in an additive, multiplicative, or exponential manner. They can be linear or nonlinear, independent or interdependent, and time independent or time dependent.

Figure 10. Bus requirements of 4 systems.

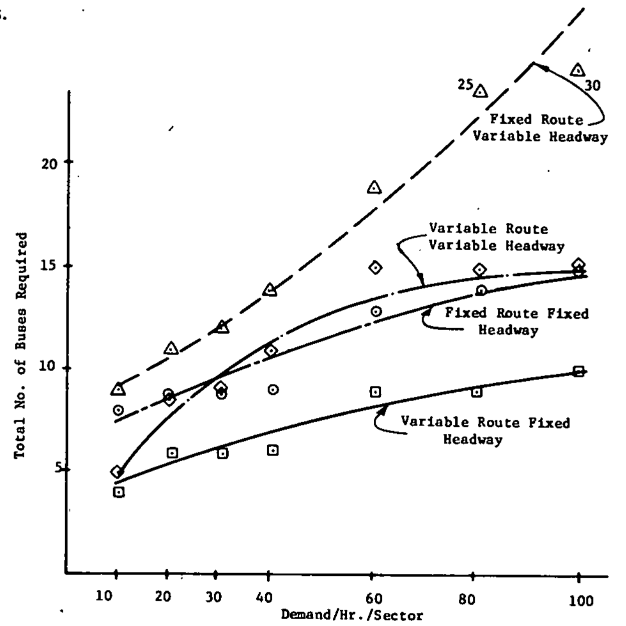


Figure 11. Driver-hour requirements of 4 systems.

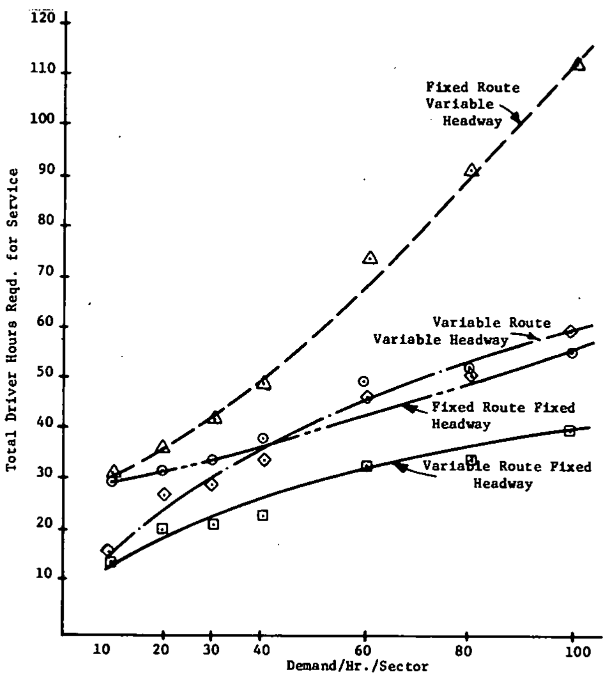


Figure 12. Vehicle-hours of operation of 4 systems.

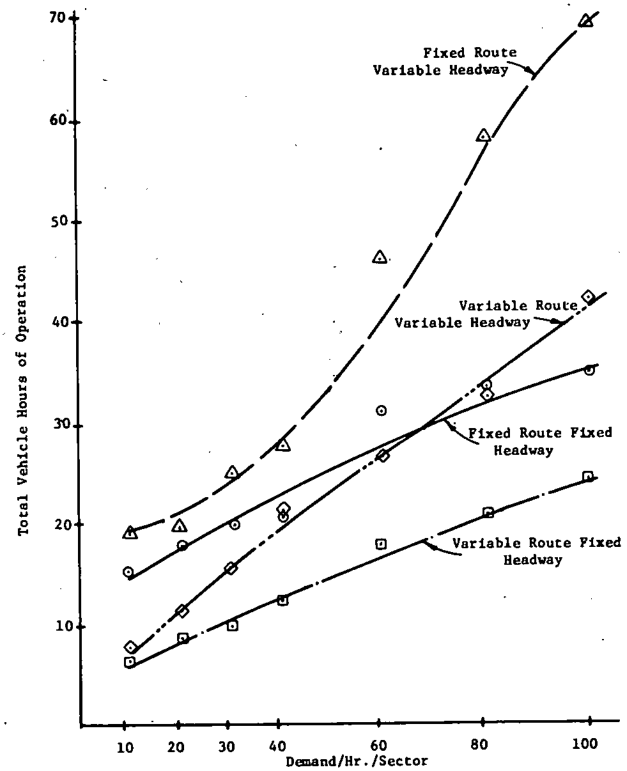
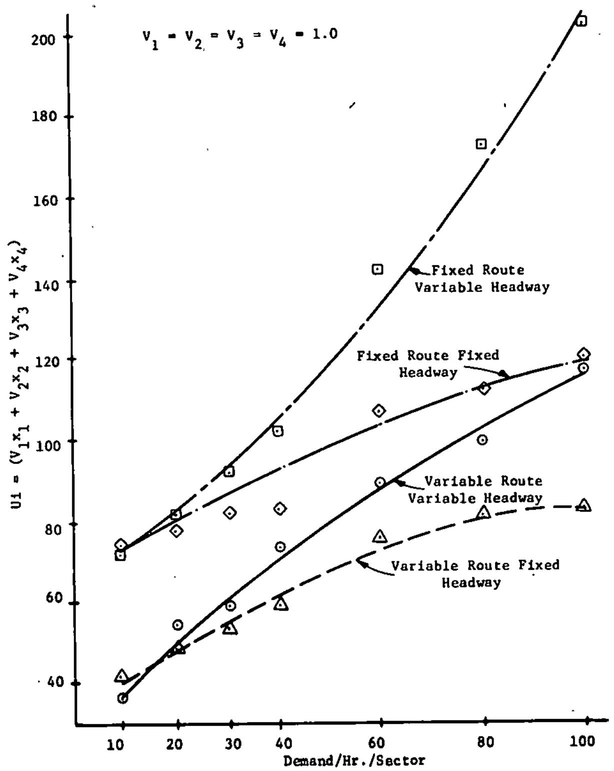


Figure 13. Utility cost functions for all coefficients = 1.



This modeling represents an entire area of study and is beyond the scope of this paper. However, for the purpose of demonstrating the applicability of these model outputs to the evaluation process, a simple additive, linear model is assumed. The scaling factors, V_i, are also assumed, but variations in these values are tested to demonstrate user-oriented, operator-oriented, and system-oriented assumptions. The model structure used is

$$(U_j) = f \text{ (system performance data, policies)}$$

$$U_j = V_1x_1 + V_2x_2 + V_3x_3 + \ldots + V_nx_n$$

where

U_j = utility,
x_i = score of a selected system performance parameter, and
V_i = value coefficient selected in accordance with the goals and policies.

The following variables have been selected to demonstrate the applicability of the methodology of utility cost functions for system alternatives in the selection procedure:

x_1 = mean wait time/passenger,
x_2 = mean ride time/passenger,
x_3 = driver-hours required for service,
x_4 = total vehicle-hours of operation,
V_1 = value coefficient for mean wait time,
V_2 = value coefficient for mean ride time,
V_3 = value coefficient for driver-hours required for service, and
V_4 = value coefficient for vehicle-hours.

Because these parameters all become increasingly undesirable with increasing scores, this model defines the disutility or utility cost, $U_j = V_1x_1 + V_2x_2 + V_3x_3 + V_4x_4$, of each system.

Selection of high-value coefficients for variables x_1 and x_2 (i.e., mean wait and ride time) will result in the selection of a service-oriented operation where passenger service criteria are quite stringent and the nonmonetary benefits of public transportation are given high weights compared to the monetary costs of operation. High-value coefficients for variables x_3 and x_4 (i.e., driver-hours required and vehicle-hours of operation) will lead to the selection of a low-cost operation with greater emphasis on tangible costs than on user benefits. The methodology presented here does not suggest any specific values for these coefficients, but merely demonstrates a procedure that could be used in evaluating alternative systems.

Figure 13 shows the utility cost versus demand density for all 4 systems where the utility coefficients are all equal to 1.0, or there is no bias between user values and operator values. At a very low-demand density (10/hour), the variable-route and variable-headway system results in the lowest utility cost. As the demand increases, the variable-route and fixed-headway operation results in the lowest cost system for demand of more than 20/hour. The fixed-route and fixed-headway system, which results in a high cost at low demand, approaches the variable-route and variable-headway system at approximately 100/hour demand. For low-demand situations characteristic of Columbia, Maryland, or Haddonfield, New Jersey, the variable-route and variable-headway system should be selected if the user and the operator characteristics are considered to be equally important.

Figure 14 shows the utility cost function for coefficients V_1 and V_2 equal to 1 and V_3 and V_4 equal to 3.0. This might be representative of a system with a limited subsidy. In this case, some increase in user costs would be accepted in return for lower operating costs. As a result of this change in the weighting functions, the total user time increased from 15.6 to 20.4 minutes at a demand level of 10/hour, and vehicle-

Figure 14. Utility cost functions for V_1 and $V_2 = 1$ and V_3 and $V_4 = 3$.

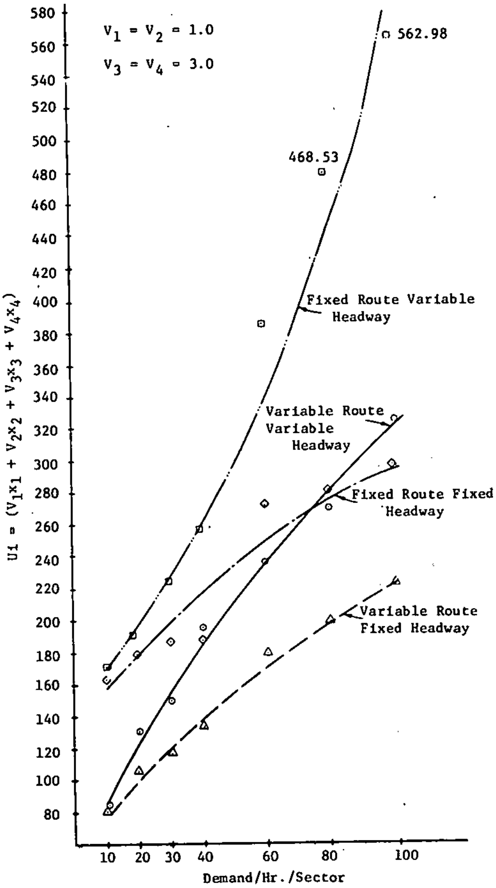
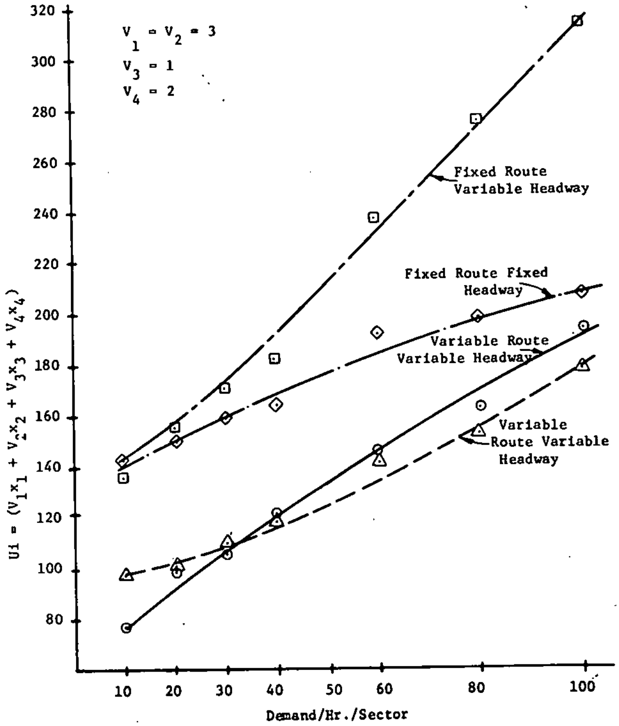


Figure 15. Utility cost functions for V_1 and $V_2 = 3$, $V_3 = 1$, and $V_4 = 2$.



hours of operation was reduced by 18.6 percent, from 7.76 to 6.31 hours. We are equating this 5 minutes of extra travel time to a ½-hour reduction in bus-hours.

At the other extreme, Figure 15 shows a case in which the user characteristics are weighted very heavily. This might be characteristic of a highly subsidized service for a Model Cities neighborhood, in which service is the important factor to be considered. The operating characteristics of the variable-route and variable-headway system are far superior to those of any other system at all levels of demand. In comparison with the normal operation (fixed route and fixed headway) at a demand level of 100/hour, savings in total travel time is 51 percent and the penalty is 17 percent in operating hours.

In addition to system-selection policies, the analyst is also faced with the task of recommending operating policies. In this study, we looked at variations in system characteristics and utility costs as they are implemented by different bus-pooling policies, vehicle-to-sector assignment policies, sector size and network accessibility factors, and variations in demand over time. Time does not permit a discussion of each of these in this paper. However, an example was prepared to demonstrate the effect of matching the system with the demand over time.

Because the demand for bus transit ridership in any area varies with time, such variations in demand must be considered in the system selection process. As we have shown previously, the demand at which any system becomes "better" than other systems depends on the value coefficients. Thus, different systems can be optimal at different times during a typical day's bus operation. The effect of changes in operating system alternatives was demonstrated by a hypothetical passenger demand distribution (Fig. 16). The same decision variables—wait time, ride time, vehicles-hours of operation, and driver-hours required—were used and the value coefficient shown in Figure 14—$V_1 = V_2 = 1.0$ and $V_3 = V_4 = 3.0$—and the utility cost versus demand density were plotted to construct the utility costs of the variable-route and variable-headway system and the fixed-route and fixed-headway system for hourly variations in demand. Table 2 gives the time of demand, demand rate, and utility cost. This information was used to compare 3 alternative operating strategies: variable-route and variable-headway system for the entire period, fixed-route and fixed-headway system for the entire period, and a combination of those 2 systems to achieve minimum total cost. Table 3 gives the results.

This example serves only to illustrate how the results of this study might be used. The difference in cost saving or magnitude of system efficiency can be quite significant in some cases. This depends on the value coefficients selected for evaluation purposes (which really reflect the goals and policies of the community) and the magnitude of the variations in demand.

Other policies, like bus pooling, sector selection, guaranteed pickup time, dispatching logic, and level of service provided, will also influence these numbers. The approach used in this study provides the tools necessary to assess each of these and to bring rationale in the system-selection process.

ACKNOWLEDGMENTS

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Figure 16. Typical distribution of rider demand.

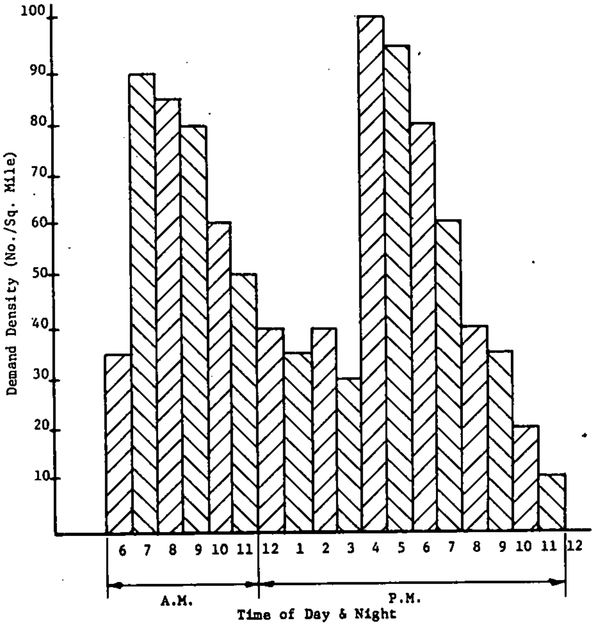

Table 2. Utility costs of alternative systems.

Time	Demand Rate (riders/sq mi)	Variable-Route and Variable-Headway System	Fixed-Route and Fixed-Headway System
6 to 7 a.m.	35	170*	208
7 to 8	90	298	282*
8 to 9	85	284	275*
9 to 10	80	276	272*
10 to 11	60	232*	248
11 to 12	50	210*	233
12 to 1 p.m.	40	182*	217
1 to 2	35	170*	208
2 to 3	40	182*	217
3 to 4	30	155*	198
4 to 5	100	318	292*
5 to 6	95	308	282*
6 to 7	80	376	272*
7 to 8	60	232*	248
8 to 9	40	182*	217
9 to 10	35	170*	208
10 to 11	20	121*	178
11 to 12	10	83*	163

*Optimal system for that hour.

Table 3. Cost and efficiency of systems.

System	Cost	Inefficient (percent)
Variable route and variable headway	3,849	3
Fixed route and fixed headway	4,218	12
Combination of 2 systems	3,754	

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Dial-A-Ride: Opportunity for Managerial Control

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Competent management requires the ability to perceive problems, the ability to conceptualize solutions, and the skill to communicate both the problem and the solution to those responsible for carrying out management directives. It also requires that managers infuse the issue with a sense of urgency so that the solution is implemented. For the most part, public transit has not been managed by these objectives. Rather transit management has been totally absorbed with service, maintenance, and escalating costs. Policy decisions in public transit are often based on inadequate, outdated, or incomplete information or have come too late to reverse system inefficiency. Costs rise, the level of service falls, and patronage drops to levels so low that many operations are in desperate financial situations. And yet transit systems continue to be managed by heirarchical control. Effective management through the control of information flow will reverse this trend. Dial-a-ride transit, with its capability of providing real-time information about system status, is an ideal medium in which innovative management techniques can be tested. This paper explores the opportunities dial-a-ride offers for developing innovative systems for the management, control, and interpretation of information and outlines information flow techniques that can be useful in the optimization of system efficiency.

Dial-a-ride, dial-a-bus, telebus, call-a-bus, demand jitney, computer-aided-routing system, call-a-ride—these are all names for demand-responsive bus systems (1).

The concept combines the door-to-door convenience of the taxi ride with the economics of bus service to create a new approach to transit. The characteristics of this type of service have been adequately described elsewhere, and the achievements of dial-a-ride in Orange County have been outlined (2). Dial-a-ride is a financially feasible system of local public transportation both as a pickup and delivery system in low-density suburban areas and as a tributary system for fixed-route buses on arterial highways. All transportation modes can be integrated with dial-a-ride; this flexibility has prompted the Orange County Transit District to begin planning for the expansion of dial-a-ride from the present experimental unit to 12 or 15 "modules" and 180 vehicles during the next 4 years.

Dial-a-ride is most often proposed as a method of improving the level of service provided by transportation agencies. The large dial-a-ride system planned for Orange County would indeed achieve this goal. However, the potential that dial-a-ride has for improving the management and control of transit organizations has not been previously considered. Moreover, innovative techniques of management may be critical to the ultimate success of such a system.

The emphasis in this paper is on the elements of organizational theory that can make management of public transit more responsive to public needs, more efficient through the control of communication, and more satisfying for employees by establishing reasonable performance goals and allowing them the satisfaction of achieving these goals.

Public transportation is a labor-intensive enterprise, yet too little attention is paid to the enhancement of the individual dignity of operators, whether they be bus drivers, trainmen, or those who help them. Operators are the primary means of public liaison; unless methods are developed that facilitate the development of favorable attitudes toward the traveling public and the sharing with them of management's enthusiasm for the improvement of transit service, then expenditures for capital equipment and a promotional campaign will not benefit service.

Managers of public transit enterprises face a twin dilemma: There are neither widely accepted, explicit goals to attain nor a tangible, identifiable product. Interest groups expect different kinds of achievement: Senior Americans desire ubiquitous service, but they and low-income families expect this service to be paid for from the fare-box rather than by taxes; members of upper income families approve of subsidy payments for commuter service to reduce highway congestion; and transit employees desire security and job satisfaction. Transit enjoys widespread public support, but the reasons for this support differ and are often contradictory. In fact, the highest level of support comes from those least likely to use public transit (3). Furthermore, how can the attitude of people who use and operate the service be changed so that they will express more positive attitudes toward public transit? It is those people, the low- to middle-income blue-collar workers who make limited use of transit and sometimes rely on the system for their livelihood, who defeat transit funding issues (4).

And how can the causes for these negative attitudes be detected early enough for management to recognize that problems exist, to examine the symptoms, and to implement solutions?

Service is the product of transit, but the quality is difficult to measure. Patronage, passengers per mile, operating deficit, and cost per mile are all used to measure effectiveness, but they are weak indicators of the level of consumer satisfaction. They are merely statistics gathered each month; they have meaning for other transit operators, but tell little about the quality of service. More often than not, they are indicators of the numbers of people who have no other choice than to use public transit.

An additional deficiency of these operational statistics is that they do not provide early indicators of service failures. Patrons are lost before management realizes that buses are too crowded, uncomfortable, or not going to the right places or that drivers are surly because they cannot maintain schedules. So many of the problems that deter the public from using public transit result from management's inability to deal with operational problems and to transform public transit into a pleasant experience.

Managing public transit is like managing a restaurant. The quality of the food, like the comfort of the vehicle, is important, but it is also the quality of service that causes patrons to return. The performance of employees who meet the patrons is of critical importance, but the methods available for encouraging and rewarding employees for superior service have not been accentuated.

When definitive goals for an organization cannot be established and when there is no tangible product whose quality can be assessed, it is difficult to improve organizational performance. But monitoring and improving the communication system within the organization can afford the transit manager with a means of controlling and improving the organization.

COMMUNICATIONS

Improvement of communications within an organization can achieve 3 purposes.

1. It can promote harmony by facilitating the sharing of organization goals among all employees, even though these goals may be poorly defined.
2. It can generate favorable opinions toward the organization by employees.
3. It can serve as a feedback mechanism to judge whether desired changes are occurring in response to new managerial directives.

Improving communications within transit organizations is not a simple task. They tend to be large organizations; and the larger they are, the more complex the communication system is. In addition, transit organizations are heirarchically structured. A few in top management attempt to control many operators through foremen and supervisors. Usually communication is from the top down, and little effort is made to monitor feedback. Yet feedback can be critical to making an accurate assessment of system performance.

For the most part, large transit organizations are uncontrolled; they may even be uncontrollable. Operators do not share the aspirations of management; there is often hostility between them for which the passenger suffers, and there is little attention given to developing a feedback system even when genuine attempts are made to improve communications between top management and operators.

Dial-a-ride is a means whereby the communication system can be improved and the level of bus service in communities can be increased. It provides public transit that is built on a 2-way communication system. Furthermore, it is a communication system that management can control.

The flow of information in complex organizations is critical to the attainment of system efficiency. However, many transit administrators have failed to maintain effective lines of communication as their organizations have increased in size. The input-output sequence in dial-a-ride, involving an orderly progression of easily monitored events, provides an excellent medium for examining methods by which information flow can be improved.

Dial-a-ride is a public transportation system made up of a fleet of small vehicles that are radio dispatched. The vehicles operate on city streets with a flexible schedule, responding to requests for transportation as they are received by a central dispatcher. The dispatcher-scheduler combines customer information regarding location, number of riders, and desired pickup time with information regarding vehicle positions, tentative routes, and trip characteristics of other passengers. Using preplanned scheduling and dispatching procedures and a radio communication link to a fleet of small buses, the dispatcher assigns a vehicle to pick up and deliver each customer from origin to destination. The customer is advised of the expected pickup time and, perhaps, the fare and then waits until the vehicle arrives.

A large metal-backed map and magnetic pieces are used in a control center. The magnetic pieces hold trip tickets containing customer trip data—different pieces denoting origins and destinations. When a trip is assigned, colored markers corresponding to the vehicle are placed on both pieces. These markers also serve as pointers to the vehicle's next stop and effectively trace out a tentative route for each vehicle.

When the bus arrives at a stop, the driver notifies the control center, which updates the bus position on the map and in turn notifies the driver of the next stop. The map, therefore, represents quite accurately the true state of the system, i.e., vehicle position, customers on-board, and customers waiting. Given this full view of the system, the control staff can alter tentative routes as necessary to accommodate new trip requests (5).

This orderly process of operation is extended to evaluation of the system. A significant amount of information is available about a number of variables related to the level of service the system is offering.

Most of these variables relate to the measure of time as an indicator of system efficiency. Four means of service quality are used (5, p. 10). Data are derived from time stamps on tickets at the time the call is received, the pickup and delivery times, and the dispatcher's estimate of wait time.

1. Customer wait time is the elapsed time between the receipt of a customer's request for service and the boarding of the vehicle by the customer. (In La Habra, this averages 15 to 20 minutes during off-peaks and as much as 30 to 40 minutes during peaks.)
2. Customer ride time is the elapsed time between boarding and exiting of a vehicle by a customer. (Average travel time in La Habra is 11 minutes.)
3. Level of service is the ratio of customer wait plus ride time to the corresponding automobile travel time for the same trip.
4. Pickup time deviation is the difference between the actual arrival time at a customer's origin and the expected arrival time quoted to the customer when the trip was requested. (In La Habra, actual pickup time averages 2.2 minutes earlier than promised.)

Other methods of determining system efficiency involve comparative analyses between the level of service of dial-a-ride and that of competing modes, in particular the automobile.

LEVEL OF SERVICE AND SYSTEM EFFICIENCY

A key to analyzing the efficiency of dial-a-ride service is to determine its level of service. One way of measuring level of service is to determine the ratio of wait time plus trip length on dial-a-ride to an estimate of the time the same trip would take in an automobile. Dial-a-ride systems normally operate at a ratio of about 3:1; the La Habra system normally operates at this ratio (for example, a 10-minute automobile trip would take 30 minutes on dial-a-ride). A ratio of 3:1 may be considered acceptable. However, assessing the efficiency of a dial-a-ride system solely in terms of level of service can be misleading. Level of service is relatively insensitive to absolute differences in dial-a-ride and automobile trip times, whereas potential users are not likely to be so insensitive. For example, if the dial-a-ride travel time were 5 minutes and corresponding automobile travel time were 1 minute, the resulting level of service of 5 would be acceptable to many users, for the absolute difference is only 4 minutes. If, however, the respective times were increased to 50 minutes and 10 minutes, the level of service would remain at 5, but the absolute time difference would be 40 minutes, which could well be unacceptable to many dial-a-ride users (5, p. 12). Consequently, other variables must also be taken into consideration.

The key factor is wait time (the elapsed time from phone call to actual pickup). In an average system, dial-a-ride wait times are normally 15 to 30 minutes, and travel time may average 11 minutes (as in La Habra). This will vary, depending on time of day, number of vehicles in service, and weather. Under unusual circumstances, wait time can range from 5 minutes (a bus happens to be on the same street when the request for service is received) to an hour (it is a rainy day, or the call was made during the peak period). A reasonable wait time is 20 minutes, and riders who call well in advance of their desired pickup times are usually picked up 1 to 5 minutes prior to the time promised.

Previous analyses have yielded relations between quality of service, demand rate, vehicle supply, and area size (6, 7). For a dial-a-ride system operating in a contiguous service area, the expected effect on wait time plus ride time of changes in area, fleet size, and demand is expressed by

$$T = 2.2\sqrt{A}\left\{1 + \left[\frac{A(0.82 + 0.087D)}{N}\right]^2\right\} \tag{1}$$

where T is the dial-a-ride wait plus ride time, in minutes; A is the size of a square service area, in square miles; D is the demand density rate in terms of trips per square mile per hour; and N is the number of vehicles in service. (The assumption is that trips randomly arrive on time with ends uniformly distributed in the service area. The factor $2.2\sqrt{A}$ represents the automobile, or direct, travel time required to make a trip of average length in the service area at a speed of 15 mph.) Thus, for a given number of vehicles, wait plus ride time varies essentially as the square of demand density rate and the 2.5 power of area.

There are various means by which level of service for any area can be established through negotiation among labor, management, and the public. Improved service can be achieved through increasing labor and capital investment, and lower fares can be charged if the public is willing to accept a lower level of service. But once a level of service is established as a goal, and agreed to by all parties, then there is an objective against which management can assess performance. Any deviation is immediately revealed to both operators and management.

Evaluation is assisted when there are several dial-a-ride modules in operation. Comparative analyses of modules reveal opportunities for systemwide improvement.

SYSTEM PRODUCTIVITY

An important measure in assessing the economic characteristics of a public transportation system is system (or vehicle) productivity, defined here in terms of passengers per vehicle-hour.

In a dial-a-ride system, the upper limits on vehicle productivity are considerably lower than in a fixed-route and fixed-schedule system. In the latter, any increase in demand that does not cause the vehicle capacity to be exceeded causes only a slight delay at a stop and a near linear increase in vehicle productivity (5, p. 13). In a dial-a-ride system, however, each additional user typically generates not only additional vehicle stops, but additional diversions to the stops as well. The effect on vehicle productivity is, therefore, considerably more severe (1, p. 5).

The impact of additional demand is easily assessed in dial-a-ride. Because trip tickets are produced for each demand, documented material for analysis is readily available. The trip ticket, listing origin, destination, number of riders, and estimated pickup time, provides a thorough record of areas where demand is greatest (or minimal). Furthermore, time-stamping of the ticket when the ride request is placed and when the pickup and delivery is made provides continual information to the manager about variations in level of service, vehicle productivity, and employee efficiency (e.g., how well a dispatcher estimates wait time and how well a driver can keep to the schedule). Because a wealth of information is available to the analyst, a high level of system efficiency is much easier to maintain. Real-time information is available to management about the efficiency of the system, and comparative analyses of various parameters of level of service (vehicle productivity versus peak-demand periods versus wait and ride time) can be used to adjust the system operation. Here, the utility of an effective communication and information system is a key to efficient management and control.

For example, the La Habra dial-a-ride operates at 5 to 7 passengers per vehicle-hour, but productivity varies greatly throughout the day. Productivity peaks between 7 and 9 a.m. and again between 2 and 4 p.m. at about 7 passengers/vehicle-hour.

When the actual is compared to the theoretical by using Eq. 1 to solve for productivity, V = DA/N, and the average wait time, ride time, and density rates encountered in La Habra, the result is 5.67 passengers/vehicle-hour. This corresponds fairly well with the 5 to 7 passengers/vehicle-hour actually achieved. Thus, the use of dial-a-ride theory, when combined with empirical knowledge of system or service area characteristics and the data base inherent to dial-a-ride, can provide the manager with a sound basis for decision-making.

Realistic and identifiable system goals (such as a level-of-service ratio of 3:1 and a system productivity factor of 7 to 10 passengers/vehicle-hour) can be established. Constraints on the system such as vehicles/square mile, available manpower, costs, and geographic and demographic characteristics and a real-time data base can be combined to result in the setting of realistic goals that can be defined and given to employees as an incentive to work toward increased efficiency (5, p. 21).

Two factors often compared when transit is planned and its success is assessed are potential or real demand and actual use (patronage).

A common experience in transit is to develop a system in response to public outcries for service only to be astonished at how little the system is used. Marketing considerations aside, the key here is perceptions of service versus the realities of operation. An interest group or city may support the formation of a transit system only to find that a fixed-route, fixed-schedule operation has fallen short of expectations in terms of frequency of service, route alignment, or, simply stated, "taking me when and where I want to go."

Dial-a-ride can respond to this problem—indeed it can avoid the problem altogether—because of the characteristic flexibility in routing and scheduling of a demand-activated system. The only constraints to the innate responsiveness of dial-a-ride are at the managerial level. Given an adequate and reliable fleet, a well-trained labor force, and an adequate operating budget, the responsibility for providing a high level of service rests with how well decisions are made, based on analyses of trip information. Awareness of characteristics of the service area, both geographically and demographically, is also critical. When are the peak periods of demand? Who rides? Where are they going? What is the effect of weather on demand? Should seasonal variations in ridership be considered? Such questions must be answered if the dial-a-ride system is to be a responsive and efficient operation.

A profile of demand is readily available from the record of the trip requests. This profile can be used by management to forecast demand and schedule labor and equipment. Variations in demand can be detected as trip requests exceed anticipated requests, and changes in operation can be broadcast to drivers so that the additional demand can be accommodated. Similarly, if demand is slack, drivers can be diverted to trip-generating areas where the presence of the bus often stimulates demand.

Dial-a-ride can provide information on trips (via tickets) and the characteristics of users and their desires (via communication with drivers). Fixed-route operations do not have the luxury of this information flow, nor are they able to modify operations as easily to accommodate change.

COMPUTER CONTROL

In a small system with less than 12 buses and approximately 50 demands/hour, receiving calls for service and scheduling and dispatching can be handled manually. But in a system of 15 or more buses and as many as 100 demands/hour, the decision-making capacity of the human mind can be exceeded.

Because of the economies of operating a large fleet from a single communication center, automated scheduling and dispatching techniques are attractive. Moreover, a well-refined computer program can make decisions with fewer errors; thus, the efficient use of person-hours and vehicles is maximized and a corresponding higher level of service to the user is provided.

The algorithms for such a system are being developed and tested at the Haddonfield, New Jersey, dial-a-ride demonstration project. But beyond its use in the scheduling and dispatching function, computerization can lead to a more efficient means of compiling and analyzing other system characteristics such as (a) real-time optimization of level-of-service variables (wait and ride time, vehicle productivity); (b) a storage-retrieval information format about fuel consumption, maintenance records, and other vehicle parameters; (c) vehicle-monitoring system in which the "vital signs" of vehicles can be monitored on an ongoing basis; and (d) a "vehicle locater" system tied to the dispatching processor for spontaneous interrogation of vehicle location and a consequent higher level of machine-made trip assignment.

In a single dial-a-ride module, these on-line monitoring characteristics are a luxury. However, when several dial-a-ride modules are integrated as a system, then computerized information files present an opportunity for real-time management of the transportation system.

The La Habra module was established as an experiment to determine costs of operations in Orange County and to enable the Transit District to adapt the techniques learned from the federal demonstration project in Haddonfield, New Jersey. The experiment has provided the district with considerable knowledge as well as operating records on which the costs of expansion can be estimated. During the next 4 years, a countywide dial-a-ride system will be developed incrementally to a fleet of 180 vehicles in 12 to 15 modules. A decision has not yet been made on computerized operation, but an opportunity exists to test in Orange County a medium-sized computerized dial-a-ride system that will integrate local dial-a-ride service with intercommunity bus routes operating on arterial highways. Operating statistics from each module could be interrogated from central control so that real-time management would be possible without interfering with the decentralized autonomy provided for the supervisors of each module. The control would exist through the records of the communications system rather than by personnel supervision. The following are key features of the integrated system:

1. Full integration of all transportation modes to maximize efficiency, provide a superior level of service, and demonstrate a fully integrated system of transit modes in a suburban area;
2. Door-to-door service anywhere in the developed area of the county for nearly a million people;
3. Innovative management by the Transit District of modules operated by both public and private organizations to maintain an incentive to provide a high level of service, to keep costs down, to ensure responsiveness to public needs, and to develop new techniques for controlling a highly refined transportation system;
4. New marketing strategies for increasing ridership of low mobility groups and for penetrating the automobile/commuter market;
5. More efficient use of existing rights-of-way and equipment to minimize costs and optimize present-day technologies;
6. "Transfer of technology" capabilities to develop dial-a-ride as a modular system that can be implemented in communities in need of transit services or new approaches to management and control; and
7. Reduction of pressing ecological and social problems such as excessive pollution, energy consumption, transportation network encroachment on land use, and low mobility of those without cars.

The foundation of the system would include 4 basic elements:

1. Community dial-a-ride services on 180 vehicles at 12 to 15 dial-a-ride nodes connected with the scheduled buses;
2. Intercommunity scheduled buses on both arterials and freeways, the latter stopping at park-ride lots, which will also be served by dial-a-ride;
3. Airport, heliport, commuter railroad, and other transportation modes integrated via the dial-a-ride mode; and
4. An information and control system using computers to provide real-time optimization, to automate dispatching to minimize passenger inconvenience, and to provide

management information for operations analyses and decision-making.

DECENTRALIZATION

Although a centralized system of communication and control is easily monitored, the inherent danger of a centrally controlled system of dial-a-ride modules is that the attributes of personal service that can be offered by transit are overlooked. To ensure that a close association develops between the operator and the patron requires that management of each module be decentralized.

The Orange County Transit District dial-a-ride program will be operated on a local community basis. Each dial-a-ride node will be independently operated, but its services will be integrated with contiguous dial-a-ride nodes and the fixed-route system. The involvement of the local community in dial-a-ride is critical to its success. These dial-a-ride modules can be operated for the district by local operators on a "franchise" basis. The district will provide the equipment, procedures, and supervision, and the local contractor will provide labor and facilities on a cost-plus-fee basis. Cab operators will be logical operating entities, for they have a labor pool and are familiar with the local area and with radio dispatching and scheduling techniques.

Another possibility for the locally based operator is city or interest group cooperatives. If labor can be trained on the job or be largely voluntary or locally subsidized, or all of these, the cost of operation to the district can be minimized to levels equal to or below that of the fixed-route operation.

By decentralizing control over labor and service while supervising and ensuring the overall integration of all dial-a-ride modules into a single, unified system, management can operate an efficient integrated transit system without the penalty of losing contact with the local community.

Module supervisors can operate a small system, maintain a close relation with drivers and dispatchers, and share the aspirations and feelings of staff. If the flow of information is as it should be, this feedback will flow upward for input into the management decision-making process. Another avenue for capturing the opinions of operators is through the resolution of problems that management perceives through comparisons of modules. District employees are freed from most labor-management conflicts and can place emphasis on correcting the causes of dissatisfaction rather than on relieving the symptoms.

A great many employees of large organizations are repelled by the idea that they can only be used to execute, within narrowly defined limits, the orders of management who alone can exercise judgment, imagination, and creativity (8). In transit the continuation of this philosophy has shut the door on a tremendous resource of human talent and alienated the operator on whom the success of public transit depends.

Communications technology can improve decentralization. It makes possible the designation of service areas and levels of performance that operators and management can agree to in advance. With the aid of the computer's storage and retrieval capabilities and the development of standardized formats of analysis, comparisons can be made of levels of service of various dial-a-ride nodes on a daily basis to determine segmental as well as systemwide efficiency. Deficiencies are readily apparent to operators when the modules are small and operators feel that they have a competitive interest in performance. Problems are often corrected through cooperation, and success is shared. Bonus payments can further aid learning through achievement.

Decentralized dial-a-ride modules stimulate communications between participants in the organization at the lowest level of heirarchy. If this communication network can emphasize the achievement of the performance goals established by top management, then a means of resolving the complex communications problems in large organizations is achieved. In this respect, dial-a-ride is as important a management technique as it is an innovation in public transit.

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SPECIAL REPORTS FROM ENGLAND AND SWEDEN

From England

Roger Slevin, Cranfield Institute of Technology, England

Telephone availability in Britain is something like a third of that in the United States. That in itself puts a big question mark on the dial side of dial-a-ride. Lower car availability is equally a problem. In fact, only about 10 percent of our households are in the ideal dial-a-ride market, which is a household with a telephone but without a car, as opposed to the market here, which is with a telephone and without 2 cars. We also have a well-used transit system.

Because of these factors, the demand-responsive transport system that will emerge in Britain will be different from that which is developing here. I suspect there will be a much greater compromise between fixed-route operations and dial-a-ride operations. The densities of our urban areas are something like 5 times higher so that we have a higher density of movement and shorter distances over which people are moving. To have dial-a-ride feed line-haul services in many of our towns would be quite inappropriate. We will probably have the dial-a-ride vehicle provide fast line-haul service into a town center or city center.

Since your last conference on demand-responsive transportation, we had a few experimental services start. One service was a half-baked idea in Abbington that has since died. This was a 2 day a week service mixed with a 5 day a week minibus, fixed-route, fixed-schedule operation.

The second experiment was in Masden, and that has also been close to disaster because of some institutional barriers in Britain. We have a very complex licensing system for any bus operation. The Masden operator was a taxi operator, and he had to protect the existing bus operator by charging a high fare and by not picking up anybody except at doorsteps.

At Harrogate is a different sort of service that has done 2 things: expanded from 5 service areas to 9 and contracted from offering 4 journeys a day to each of the areas to 2. It is the only version of dial-a-ride that is showing anything like the commercial return. It is a specialized shoppers' service, but seems to be answering a need in that particular context.

A fourth service has begun recently in Eastbourne, a coastal town about 60 miles from London. There is heavy commuter travel from there into London by train, and the service is intended primarily to serve the rail station.

Two other proposals, Bristol and East Kilbride in Scotland, have both fallen foul of our traffic commission proceedings.

The experiments that are under way and those under consideration are entirely manual, fixed schedule, but variable route. All of them are many-to-one or many-to-few operations.

The Department of the Environment has asked the Transport and Road Research Laboratory to prepare within the next 4 years an evaluation of the potentials of all various forms of demand-responsive bus services in Britain. The Transport and Road Research Laboratory is sponsoring a small number of experimental services solely with the objective of collecting experimental data. Cranfield Institute of Technology is under contract to the laboratory to assess studies of these experiments.

The first experiment will be established in late 1974 or early 1975 in Harlow New Town. In about 12 months, we expect to start another experiment, probably in an established town; and in about 2 years, offer a many-to-many service in a large suburban area. Sometime during the 4-year contract period, which started in July 1973, we also expect to start a rural operation.

Our research program will evaluate all the system components—vehicles, radios, telephone equipment, and so on—and particularly concentrate on the problems of communication between the passenger and the control, which is going to be far more of a problem in Britain than here. We will also study the market for dial-a-ride services and indeed the market for public transport services in general. We believe there is much more involved than just a share of the market. We must do more in the way of latent demand estimation.

And finally (and something that I have found surprisingly and disturbingly missing here), we will do a thorough social and economic evaluation of the cost and benefits not only to the operator of the services but also to society at large. We have been asked particularly to look at the distribution of these benefits. If they all go to the upper middle classes, it may not be a desirable policy politically for the government to support the idea that dial-a-ride services should be introduced in Britain. The political aspects, I think, will be our biggest problem. My feelings and observations are that political processes here are different and the officeholders prefer not to be bothered with cost-benefit analyses because they would probably disturb the political processes. In Britain, the emphasis seems to be the other way around.

From Sweden

Curt M. Elmberg, Gothenburg Transit Authority, Sweden

I traveled extensively throughout the United States and Canada in 1972 to study demand-responsive systems in Haddonfield, Columbia, Batavia, Bay Ridges, Regina, and Ann Arbor. When I returned to Sweden, I wrote a report that was widely distributed and publicized. In fact, I was called to testify before the Swedish Parliament Transportation Commission, after which the national government suddenly changed policies.

In Gothenburg, we were going to start a feasibility study on the use of dial-a-ride, and the national government offered to contribute some funds to this. That was a complete change of policy in Sweden because the national government has never given a cent to local governments for anything. Although the amount of money given was very limited, the attitude was important. The feasibility study started in April 1973.

Gothenburg is situated on the west coast of Sweden. The city proper has 450,000 people; and the region has 675,000. We have a rather extensive rail rapid transit system; 75 percent of the travel is by rail, and 25 is by bus. Most of the bus routes feed the rail system. However, we do have several bus routes that have demand appropriate to the dial-a-ride concept. Therefore, we have picked 3 areas of different social-economic structure and studied them from many viewpoints. We hope to make a full-scale test in one or all of the areas.

Although Gothenburg is the home of the Volvo factories, Volvo has not been able yet to make a good bus for this type of operation. It is a problem to get good vehicles for this type of operation anywhere in Europe. However, the concept of dial-a-ride is starting to grow and I think that the manufacturers of buses in Europe will respond and produce a good vehicle. Mercedes is perhaps the most appropriate, but has one disadvantage: It is very expensive.

We do have several years of experience with another concept: transporting disabled people. Before 1967, a private enterprise in the city government provided transport service for the disabled people. In late 1966, the city council purchased this private operation. The first question raised was, "What agency should have responsibility for transporting the people?" There were 2 agencies to select: the Transport Authority and the Fire Department (in Sweden, the Fire Department is also responsible for ambulance service). The council selected the Transit Authority, for it had the most knowledge of transporting people.

Today that small operation is quite large. Any citizen who is disabled to the extent that he or she cannot travel on the regular public transport can apply for a permit to use this special service. The cost of the full operation of the special service is borne by the Social and Welfare Administration of the city, and the Transit Authority operates the service. The people apply to the Social and Welfare Administration and must have a physical examination. They are divided into: those who have a regular daily destination, such as to school, to work, or to hospitals and those who have special destinations such as to places of leisure. Those who have permission to use the service are given a certificate, which they have to show to the driver. The city council gives 8 leisure trips a month. For the first years from 1967 to 1970, the service was free. However, the disabled people want to be considered as general citizens and to pay for the service. Since 1970, they have paid the same fare as that on regular transit: 25 cents for adults and 15 cents for children.

In 1972, 720,000 trips were made—120,000 by special vehicles and 600,000 by taxis. The Transit Authority purchases the taxi service, which is used based on a doctor's statement as to whether the applicant must go in a special vehicle or in a taxi. Eighty percent of all the sick go by taxi. The average cost in 1972 for making a trip was $3.00 in taxis and $7.00 in a special vehicle.

We have 40 special vehicles with movable platforms for taking wheelchairs. Thirteen of these are Mercedes, 2 are Volvos, of which one is an ambulance (a few people cannot even sit in a wheelchair, but must lie on a stretcher), and 25 are Peugots. The Peugot is considered the best vehicle because it has such a low floor that the hydraulic, movable platforms are not required; the driver just hooks onto a ramp. The ramp system always functions, but the movable platforms sometimes do not in cold weather.

The Transit Authority is fully paid for its service and acts as a transport agency. At the end of 1972, 9,000 permits had been issued. The budget was $3 million for 1972 and 1973.

panel discussion

PAST, PRESENT, AND FUTURE OF DEMAND-RESPONSIVE TRANSPORTATION

Daniel Roos, Massachusetts Institute of Technology, moderator

Each panelist was asked to make a brief presentation and then to respond to questions from the audience.

PANELISTS:

Thomas H. Floyd Jr., DGA International
Karl Guenther, Ann Arbor Transportation Authority
Earl W. Putnam, Amalgamated Transit Union
Anthony Simpson, Dave Systems
Roger Slevin, Cranfield Institute of Technology, Bedford, England
Jerry D. Ward, Office of the Secretary, U.S. Department of Transportation

SIMPSON: Those who are involved in demand-responsive transportation seem not to be able to develop criteria for success or criteria for accomplishing objectives. I think the difficulty arises because there are no guidelines available. Early on, criteria for success were generalized in 3 areas: (a) Would dial-a-ride work? (three years ago, nobody really could answer); (b) Would it be accepted by the public? (from various surveys, the public seemed to be in favor of it, but nobody knew whether that meant acceptance); and (c) Could it be operated at a profit?

The indication at this conference is that dial-a-ride systems do indeed work, certainly to the size and the capacity that they have been developed so far. With only rare exceptions, all of the dial-a-ride systems that have been implemented have been expanded. I do not know that we could get a better indication of public acceptance. With regard to the third criterion, all of the dial-a-ride systems that are operating, except possibly some of the Canadian ones, require significant subsidies. Nobody has yet developed a cost-benefit justification for dial-a-ride. It is a very difficult problem, and I am not sure it can be fully resolved. But it is a serious omission in the efforts that have been put into dial-a-ride—to go this far and not be able to justify it on a cost-benefit basis.

WARD: One of my surprises at this conference was how far the dial-a-ride movement has gone. There is a great deal more momentum than I had suspected from just reading the literature and talking to people in a piecemeal fashion. The second surprise was the extent of the thinking about dial-a-ride as a subsystem of a larger transportation system, i.e., tied into fixed-route systems, either bus or rail, that operate together in an integrated manner. I could not have been more impressed with the work that is going on in Rochester—with how far they have thought through what they are doing and the confidence and enthusiasm with which they approach the problem of expanding into an areawide integrated system.

There is perhaps a negative side to this momentum: It can easily lead people to rush in too quickly and result in a proliferation of systems where there is an inadequate knowledge base and an increasing number of failures. This could slow the process for a while. I am not sure what we can do about that except to encourage people to operate on the basis of as much knowledge as they can garner in a fairly new field.

The state of the art and the analytical base that we have are fairly well along. For a half dozen years, many people have been analyzing dial-a-ride systems and the variations in types of operations. But the state of the art is not nearly so far along in analyzing integrated systems of which dial-a-ride and its variants are a part. Analyses are needed to show how the pieces tie together, how cross subsidization should take place, and how the trade-offs between the productivity of the fixed-route system and the productivity of the dial-a-ride system should be made. Research in this area would be fruitful as we move into the future. We can also add other problems such as institutional and management problems.

FLOYD: When I asked why I was invited to be a panelist, I was told "You are one of the real old ones in this field—kind of representative of the senior citizens." Now I also represent another group—the handicapped. I have been on crutches and a cane recently. It came about in an interesting way.

I like to experiment with transportation systems and to personalize the experience. I started riding my bicycle to work about 2 years ago, largely on the advice of the Department of Transportation, which was promoting bicycling at that time, particularly through the Office of the Secretary. I should have learned when I was in the Urban Mass Transportation Administration never to listen to the Office of the Secretary, but once I left UMTA I became a little careless. I was careless in another way also. I managed to fall while riding the bicycle, land on my hip, and break my leg.

I did learn something interesting while being among the handicapped. There was no way to go to work except in my car with my wife driving it. There is no good way to use public transportation when you are on crutches. So, if I had not already been a convert to dial-a-bus, my being handicapped certainly made me more of one.

One of the amusing things that has happened during the movement has been the debate on terminology. What should this new service be called? Should it be called demand-responsive transportation, dial-a-bus, or dial-a-ride? There were serious and solemn discussions in the Department of Transportation and elsewhere. There were a lot of nominations for names before dial-a-bus and later dial-a-ride were selected. During this selection procedure, I fought hard for a different term. I had begun to worry about the word "dial" because, if we were going to identify ourselves with new technology, we should not refer to the dial phone, which had already begun to disappear. More and more, M.I.T., for example, had begun to talk about punching requests for service directly into the phone without going through a human dispatcher. I advocated the name touch-a-bus for touch-tone phones and when that failed I proposed push-a-bus. That also failed.

In the early days as today, funding was a major issue. Between 1961 and 1966, about $38 million was spent on research, development, and demonstration programs. No one knew how that money had been allocated, where it had gone, and what purposes it had served. One of the first things some of us did when we came to UMTA was to take a close look at the program.

The interesting finding was that about 98.9 percent of the money had gone into commuter-railroad demonstrations. Only about $500,000 in a 5-year period had gone into any kind of bus work. Within 2 years, we turned that around significantly and put several million dollars a year into the bus area. When a major problem in bus service was identified as a management problem, we began to put money into improved management methods.

Demand-responsive transportation is concerned essentially with applying better management and marketing techniques to transit. We are talking about a management tool that enables bus operators to be much more responsive than they have previously been able to be to the needs of users. This is not a big and expensive hardware development program.

PUTNAM: My organization is involved in these conferences because we believe that demand-responsive transportation can turn the industry around and create more ridership, better jobs, and more earning potential. We do not think there are labor problems involved, yet certain assumptions do apply. First, a demand-responsive system must be in some way tied into the existing public transportation systems, whether those are taxis or buses or rail. The community is a community, and mobility must be available to all citizens; to deal with a dial-a-bus system as a separate entity from all other systems is not going to solve anything and, in fact, will create organizational, institutional, funding, and labor problems. So, we believe that as an essential first step, dial-a-bus has to be planned and integrated into the overall transportation system. If that is done, we will start with existing wages, hours, and working conditions applicable to the system, and changes that are made will be collectively bargained on a local level by the people who run the system and who work for the system. My international union would expect any needed flexibilities and changes to be bargained at the the local level, and we expect that few changes would have to be made. If a dial-a-bus system is operated independently from the public transportation system, a complete reversal of the attitude of transit labor toward this system will occur. We are not enthusiastic about additional competition that will tend to undercut the transportation system and undercut wage rates. We have been concerned because the taxicab industry as compared to transit is a low-wage, high-turnover, and basically a nonunionized industry. If dial-a-bus is placed in that industry, my organization and transit labor generally would oppose that effort. There, I do not think one can simply assume that, because dial-a-bus is a labor-intensive industry, it will necessarily have labor support.

GUENTHER: The number one problem that we must solve to make dial-a-bus systems work on a universal scale is existing management organizations. I had a transit manager say to me not long ago that it is the moral obligation of citizens of the United States to walk to catch a bus. If that is so, then dial-a-bus is obviously doomed. But I think that was perhaps a reactionary statement that some transit managers have made about dial-a-bus. Reactionary management that says that the only way to do things is the way they have been done for 25 years is one of the greatest impediments to more widespread diffusion of the dial-a-bus concept.

Another problem is tied closely to existing transit management and its attitude toward change and that is the attitude of the consulting community, particularly south of the Canadian border. I have been disappointed in the reluctance of consultants to consider technical studies that were funded by UMTA and to recommend dial-a-bus to communities as one of several possible alternatives to solve transportation problems. Those of us on the dial-a-bus bandwagon have a job to do in working with consultants so that they understand what it can and cannot do, understand what it costs, and make intelligent recommendations to communities about the role of dial-a-bus in their public transit systems. In Canada there are more consultants that can provide competent design services for dial-a-bus implementation than in the United States. I think that is a sorry commentary both on our ability to communicate with consultants and on their receptiveness.

The third problem is the fear of regulatory agencies and government agencies from the local to the federal level that something might start and then fail. It is expressed to us as "Go slow." "That is too fast." "Do not move so suddenly." "Are you sure you have looked at all aspects?" We can learn so much by failures and mistakes. Sometimes we must try something to find out that it does not work.

I have been frustrated by all the bureaucratic roadblocks to getting a radio license to put in an expanded dial-a-bus system. The bureaucracy is not going to go away, and we must recognize it as a major problem and work on it.

I would like to discuss several areas that I do not consider to be problems, although others do. The first is organized labor. In Ann Arbor, organized labor has been, and I expect will continue to be, of great help in getting dial-a-bus going. Organized labor is not to be viewed as someone to fight in getting changes made. The collective bargaining process has worked successfully in Ann Arbor.

Another area is vehicles. I agree that the vehicles are not perfect. But the fact that we do not have ideal vehicles is not sufficient reason for not having dial-a-bus. The properties that claim to have the most difficult problems with small vehicles (and they are the ones that are damning them the most) are those that have a maintenance and repair organization built to service large vehicles. Small vehicles require different tools, different people, and different skills. In Bay Ridges, the vans were maintained at a local gas station and operated at a cost per mile lower than in many other operations.

The third area is research. We have developed quite a bit of capability and can proceed without a great deal of additional research.

The fourth area is money. Every successful dial-a-bus project has demonstrated that, if there is enough community support, enough community involvement, and enough optimism on the part of local leaders to make dial-a-bus work, the money tree can be shaken and sources of funding can be found. In most cases, one has to travel unconventional routes and put together weird coalitions of people to make these things happen. But no one should be dissuaded from starting a dial-a-bus project because there appears to be no money.

QUESTION: The administrator of the Urban Mass Transportation Administration has constantly emphasized the notion of benefit-cost analysis as being fundamental to UMTA funding any capital grant request. I would like the panelists to comment on the stressing of benefit-cost analysis in terms of any solving of urban transportation problems.

WARD: I think that the thrust of the Administrator's remarks is that we should do our best to know what we are getting for our money before we spend it. That is a very legitimate request to make. The problem is how far to go with analysis. There is a large gap between being able to prove in a universally accepted way what benefits are and what costs are. So one can get all wound up in an analysis that can take a great deal of time and delay actions that otherwise reasonable people would think are reasonable to take. The hope is that we can be as rational as possible about estimating what we are gaining and what we are paying for in any of the actions that we undertake.

In most cases, benefit boils down to the set of values used in the evaluation. That is a local decision and should not be dictated from the federal level. Local decision-makers must decide whether they would rather have more of A and less of B or more of B and less of A. And, in most cases, neither A nor B can be quantified in any meaningful sense.

GUENTHER: Each community does have a set of decisions to make about how it spends its money. In Ann Arbor, I think the fact that a popular vote was passed by a margin of 2 to 1 is enough of a criterion. Many people have since said, "Are you really going to reduce emissions by putting in this system? Will the air in Ann Arbor really be cleaner when you get this system going?" We have examined these questions, and it looks like there is a point in ridership at which we can make a positive statement. We are putting air-quality monitoring stations all around the city and spending $250,000 to $300,000 a year to collect and digest those data and will produce the results 5 years from now about something that has already been done. That is why we have all the delays. We are doing an extensive cost-benefit analysis right now in connection with our application for a capital grant. Questions are asked that, as far as I know, have never been asked of any applicant for a capital grant before in terms of justifying our decision to expand a demand-responsive transportation system.

SLEVIN: I would be happier in a British situation if we had a mechanism by which the populace could reflect their views. Cost-benefit analysis has been imposed on us by central government and does not give the population a chance to vote on an issue in the way the Ann Arbor population did in saying that they wanted to put in that amount of money locally to a transit system.

Cost-benefit analysis is not nearly so important as benefit analysis. It is important that we keep costs down, but the critical question is, Who is benefiting from these services? Many of us were interested in demand-responsive transportation from the beginning as a technique for meeting the unmet transportation needs of the handicapped, the poor, and the transportation dispossessed.

QUESTION: What are the most important accomplishments that we aim for during the coming year, and what mechanism might be used to achieve these?

SIMPSON: I think one of the most important tasks is to see that all aspects of dial-a-ride are integrated with the public transportation mode. For example, in cases where integration with bus transportation or commuter rail transportation has been tried, the mode of operation of the dial-a-ride system has almost always been in a one-to-many or many-to-one mode with an occasional many-to-many. The problem of using a fully responsive many-to-many system with integration is still something of a challenge in dial-a-ride. The timing problem of the many-to-many operation that has to integrate with a fixed-schedule system is surprisingly difficult to solve. We end up with a many-to-many mode, with a very good routing system and relatively efficient use of buses, but the timing of when exactly the bus will arrive and the integration with other systems is still an idea that has, in most systems, been avoided by using the one-to-many, many-to-one mode of operation. This is going to be a very important area to work in, and I am not sure that manual systems can handle the complexity of that timing problem. We may have to wait until a sufficient number of automated systems are operating.

Another has to do with experience and skills. Though attendance at these conferences on demand-responsive transportation has doubled every year, we still find that there is a very small base of people with expertise. I am concerned that people who have little skill will be putting in dial-a-ride systems and that in the next few years we will have failures because experienced people are not available. The rate of increase in dial-a-ride systems may well be limited by the skills in the work force, and training people is a slow process. To train a supervisor or a controller in a dial-a-ride system may take 6 months to a year.

GUENTHER: I have already suggested 3 areas where I think the biggest problems lie. I propose that the Transportation Research Board and the American Transit Association hold a series of workshops to educate the consulting community on how to design and implement dial-a-ride systems.

WARD: Some form of information dissemination is required on what is good and what is bad and what will work and what will not.

FLOYD: We need a national strategy that not only supports the dial-a-ride concept but provides funding and support through the various federal agencies. Two things need to be accomplished. One is to help the concept ripple out as quickly as possible. The other is a continuing vigorous research and development activity that leads to increased productivity and capability to serve. Cost is important, and the capability to do things more efficiently is important.

ROOS: In many ways, dial-a-bus transportation has been a very unusual concept in terms of how it was developed. It has largely been caused by citizens and communities. This suggests what the way of the future may be in terms not only of dial-a-bus but also of how we go about deciding on what our transportation alternatives are. With respect to some of the comments about the transit industry, dial-a-bus might be a mechanism that causes significant change within the transit industry. Some of the issues and problems that were faced and some of the solutions to those problems are going to be transferable in the future. We need new approaches in marketing and many other new approaches. In this respect dial-a-bus will play an extremely important role as a catalyst and as a mechanism for bringing about that change.

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