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Improving Paratransit Planning in the Twin Cities Metropolitan Area

JOHN F. HOFFMEISTER AND H. ROBERT MENHARD

A case study of the application of a demand-forecasting technique for demand-responsive transportation systems is presented. The paper shows how one such tool, the FORCAST model (which is based on calibration data from Rochester, New York, and Haddonfield, New Jersey), was successfully validated on two demand-responsive systems and applied in the Minneapolis-St. Paul area. The paper further shows how the demand-forecasting technique has been accepted by the Metropolitan Council (the regional metropolitan planning organization), the Minnesota Transit Commission (the regional transit operator), and the Minnesota Department of Transportation to (a) determine the feasibility of proposed new demand-responsive services, (b) determine the expansion potential of existing community-centered transit services, (c) aid in service design changes in existing services, (d) determine whether existing services have reached their long-run equilibrium ridership, and (e) explore the possible integration between fixed-route and paratransit services in selected service areas or subregions. The paper highlights the application lessons learned from using the model and indicates on-going and future applications of paratransit models in Minnesota in paratransit and subregional planning. This experience should be of use to other communities or regions that plan to use demand-responsive transportation services.

When new paratransit systems were proposed in the Minneapolis-St. Paul (Twin Cities) area in the past, no analytical tools were available to predict the demand for, and cost of, the proposed services. Estimates of demand were based on judgment and comparison with other transit or paratransit systems in operation. Specifically, demand estimates were often based on productivities assumed or derived from fixed-route operations and neglected some unique features of paratransit operations such as doorstep pickup and drop-off, circuitous routings, and the equilibrium between supply and demand.

As a result of these ineffective planning techniques, paratransit services have often failed to meet expectations. Overprediction of demand has led to the demise of some systems, as deficits per passenger have exceeded policy maxima or when local officials viewed a system as a failure because it had not attracted the expected number of passengers. Furthermore, underprediction of demand can also have significant consequences, particularly if there are more passengers than the system can handle. Such problems, which were encountered in the Twin Cities area, were due to the lack of effective analytical tools for paratransit planning and, in particular, the inability to accurately forecast demand.

This paper presents a case study of the acquisition, validation, and acceptance of one such tool that has significantly improved the ability of planners in the Twin Cities area to design and implement paratransit options.

PARATRANSIT PLANNING AND IMPLEMENTATION IN MINNESOTA

In 1976, the Metropolitan Council of the Twin Cities Area initiated a study to consider the legal, regulatory, and institutional aspects of paratransit in the Twin Cities area. This study, which was performed with the assistance of Multisystems, Inc., led directly to the establishment of the Minnesota statewide paratransit demonstration program in 1977, which has since evolved into an on-going state transit and paratransit grant program administered by the Minnesota Department of Transportation (MnDOT).

One of the objectives of the first paratransit study initiated by the Metropolitan Council was to explore the use of general planning guidelines for paratransit services. At the end of this study, and in light of the new state paratransit demonstration program and the on-going implementation of paratransit projects by the Metropolitan Transit Commission (MTC), the Council recognized the need for paratransit planning tools that could analyze the feasibility of proposed paratransit services. Thus, in 1978 the Metropolitan Council decided to acquire state-of-the-art paratransit planning models to fill the needs of all of the major organizations charged with paratransit planning and implementation in the area. These organizations included the Metropolitan Council, MnDOT, MTC, and the local community governments.

The Metropolitan Council has three institutional roles in the paratransit planning process. Under Minnesota state law, the Council must review and approve the funding of any paratransit project that is operated either by MTC or private operators. In this role, the Council is interested in the cost-efficient and cost-effective expenditure of local, state, and federal funds. The Metropolitan Council is also responsible for producing a regional transportation policy plan that is implemented by operating agencies such as MTC. In particular, this policy plan calls for the provision of subregional transportation services in which demand-responsive and other paratransit services can play a significant role. Finally, the Metropolitan Council is responsible for producing regional travel-demand forecasts and thus maintains the zonal socioeconomic and travel data necessary to apply paratransit feasibility and service design models.

MnDOT, as administrator of the statewide transit and paratransit program, is interested in the financial and technical feasibility of proposed and on-going paratransit projects in Minnesota.

MTC has been an initiator and implementor of selective community-based demand-responsive transportation (DRT) projects in the Twin Cities area. In this role, MTC explores paratransit service design changes and the technical and financial feasibility of new services.

The local community governments are, of course, most interested in the specific design of the system and its ability to serve the needs of the residents and the business community. In many cases, this requires the ability to determine the impacts of a service on individual segments of the community. In addition, local governments are interested in the costs and revenues of the system because they affect the local subsidy required.

Five principal purposes were identified by these organizations. They included the following capabilities:

1. To determine ridership and feasibility of proposed new paratransit services,
2. To determine the growth potential for existing DRT services through determining the equilibrium (long-term) ridership potential of the service,
3. To aid in service design changes for existing paratransit services (e.g., changes in the number of vehicles used, fares, etc.),
4. To determine the expansion potential (if any) for existing paratransit services (e.g., expansion

of the service areas of the projects), and

5. To explore the possible integration between fixed-route and paratransit services in selected service areas or subregions.

It was deemed important that these models incorporate level-of-service variables such as walk times, ride times, and fares as well as geographic and demographic descriptions of the service area in order to be useful in service design and feasibility studies.

FORCAST MODEL

One of the paratransit planning tools that was acquired as a result of this process was FORCAST (1). FORCAST is a predictive package that estimates the demand for paratransit service and the quality of the service for a given user-specified service area (2). The primary purpose of the model is to predict ridership for the many-to-many dynamically dispatched paratransit services, which are commonly referred to as dial-a-ride, but it is not limited to such applications. The package has also been expanded to allow for the investigation of shared-ride taxi, exclusive-ride taxi, checkpoint many-to-many, and "cycled many-to-one" demand-responsive feeder services (3). In addition, FORCAST is capable of investigating the impact of integrating paratransit with line-haul bus or other paratransit service areas. An external transportation system, which consists of express bus, local bus, and/or commuter rail, is described in terms of the level of service provided between transfer points and zones outside of the service area.

The outputs provided by FORCAST include a description of the modal split of trips made by workers living or employed in the service area, number and modal split of trips made by the nonworking population older than 16 living in the service area, and the quality of service provided on each available mode. A report on modal ridership is produced for every period analyzed and includes a complete breakdown of trips according to market segment. Market segmentation separates out all combinations of trip purpose (work, home-originating nonwork, and non-home-originating nonwork), age category (16-64, 65 and older), and automobile ownership level (0, 1, or 2 or more automobiles per household). The level-of-service characteristics presented at each period include in-vehicle travel time, out-of-vehicle travel time, user cost, and trip distance.

Details of FORCAST

This section contains additional information on the structure and operation of FORCAST.

The FORCAST package consists of five distinct modules that predict the following:

1. Service quality of a paratransit mode based on the area served, number of vehicles used, and patronage;
2. The modal split of work trips based on the service quality characteristics of paratransit, automobile, and conventional transit modes available to the user;
3. The frequency of travel for nonwork purposes by the nonworking population;
4. Modal choice and destination of nonwork trips that originate at home; and
5. Modal choice and destination of nonwork trips that originate at nonhome locations.

These five modules are connected via an equilibration routine that iteratively searches for the point at which predicted ridership and service quality are consistent (2). This balancing of supply and demand is performed for each user-specified time period.

FORCAST contains five distinct supply models, one for each mode presented above. Each generates estimates of the average systemwide wait times and the origin-to-destination ride times experienced by patrons. The supply models for doorstep and checkpoint many-to-many dial-a-ride and shared-ride taxi are descriptive equations calibrated by using simulated service characteristics. Each of the resultant equations was able to predict, on average, the simulated wait time and ride time to within 10 percent (2). The exclusive-ride taxi supply model is similar to that of shared-ride taxi service, except that it includes a term to correct for the requirement that only one demand can be served by a taxi at a given time and recognizes that ride time is equal to that of the automobile. The taxi model was calibrated on a set of simulations performed by Gerard (4) and predicted within 3 percent all of the simulated runs reported. The supply model used to analyze many-to-one feeder services is based on work performed by Daganzo and others (5) and modified by Menhard and others (6).

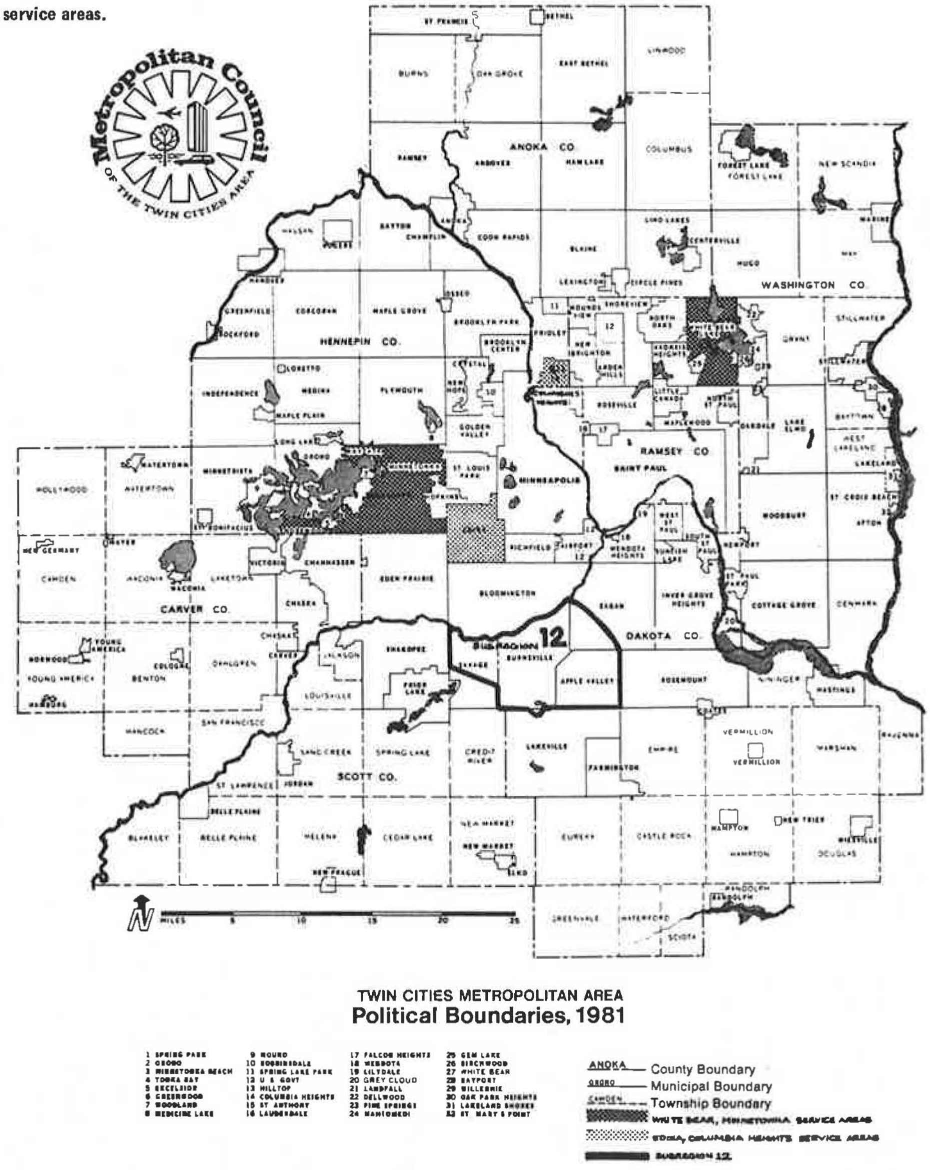
The demand estimation methodology used in FORCAST consists of four components. One is used to predict the modal split of work trips specified by an origin-destination daily work-trip matrix. The remaining three components are used to determine the characteristics of nonwork trips made in the community. Among the nonwork characteristics estimated by these portions of the model system are frequency of travel, modal split, and destination choice. All of these models were calibrated on data from Rochester, New York, and Haddonfield, New Jersey (2).

The principal methodology employed for the estimation of modal split of both work and nonwork trips and destination choice for nonwork trips is based on disaggregate choice theory (7). The disaggregate choice models employed to estimate modal split and destination in each of the demand methodology components are of the multinomial logit form (8). Travel alternatives available to one person are not necessarily those available to others. For instance, the choice of driving an automobile is not an option for an individual who cannot drive or does not have an automobile available. The set of alternatives available in the demand models includes a single paratransit mode (competing paratransit modes are not handled) plus the following conventional modes: automobile, drive alone; automobile, shared-ride; and conventional transit. The work model bases modal-split calculations on automobile ownership of the household, sex and age of the worker, and the distance, travel time, wait time, and cost of each available mode.

The nonwork forecasting methodology includes a procedure that determines the length of time a member of the nonwork population spends at his or her present location. The dwell time distributions are functions of the age of the individual, the location of the individual, whether the individual has already made a trip that day, and the automobile ownership of the household.

The nonwork choice model also estimates the probability that an individual will choose a specific mode on which to take a trip and predicts the destination zone. The set of alternatives consists of all combinations of mode and destination zone that are available to an individual. The inputs to the nonwork choice models include automobile ownership; age of the individual; the wait time, ride time, out-of-pocket travel costs, and distance of the trip by each mode available; and the area popu-

Figure 1. Paratransit service areas.



lation and employment of each potential destination.

Initial FORCAST Validations

Prior to its use by the Metropolitan Council, FORCAST was validated against paratransit and taxi services in Ann Arbor, Michigan; La Habra, California; and Davenport, Iowa. The table below presents the results of the validations:

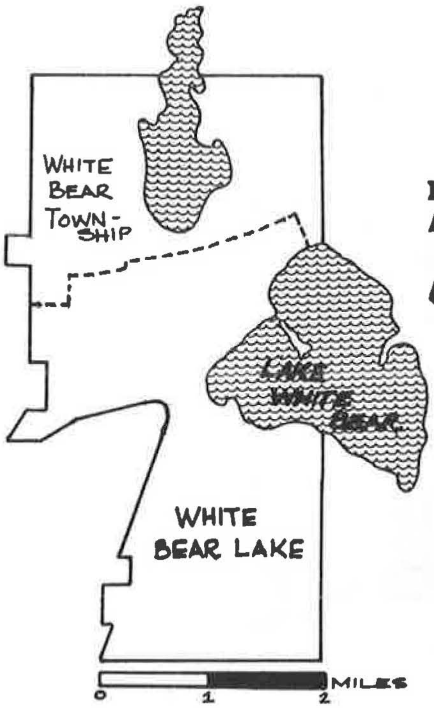
Study	Daily Ridership Predicted	Daily Ridership Observed	Difference (%)
La Habra, 1974 (2)	266	400	-32
La Habra, 1977 (3)	280	360	-22
Davenport (2)	730	580	+29
Ann Arbor Teltrans (3)	2310	2250	+3
Ann Arbor taxi (3)	1866	1500-2000	+8

These comparisons indicate that the model should be accurate to within ±30 percent of the average daily system ridership. In addition, the breakdown of ridership into its market segments is reasonably accurate although, as expected, the confidence interval on these estimates is significantly greater than for total ridership.

WHITE BEAR LAKE VALIDATION

When FORCAST was initially acquired by the Metropolitan Council, considerable skepticism existed regarding its possible transferability to the Twin Cities planning and paratransit environment. Because the model had been calibrated on data from dial-a-ride systems that operated in Rochester, New York, and Haddonfield, New Jersey, it remained an open, empirical question as to whether the model could replicate ridership and level-of-service values experienced in the Twin Cities area. To answer this question, two local validation sites were chosen. The first validation was performed on the Community Centered Transit Service (CCTS) demonstration project, a demand-responsive system operating in White Bear Lake that used three 12-passenger vans (9). White Bear Lake is a low-density suburban residential community located to the northeast of St. Paul (see Figure 1). The population of the 19-mile^2 service area was 55 500 (population density of 2870/mile^2) when the demand-responsive system was implemented. The total employment in the service area was 3388 (employment density of 175/mile^2). The service was operated from 7:00 a.m. to 6:00 p.m., Monday through Friday, and had a

Figure 2. White Bear Lake service area.



general fare of $0.50. Senior citizens (65 and older), children aged 7 to 18, and handicapped persons paid half fare and children younger than 7 paid no fare. (Figure 2 illustrates the shape of the service area.)

To model this relatively straightforward dial-a-ride operation by using FORCAST, the White Bear Lake service area was divided into 12 zones. The socioeconomic data inputs for each zone and for the service area as a whole were derived from 1970 census values. (Household size distributions and population age distributions have not changed substantially in this community from 1970 to 1978.) Three separate time periods of operation were considered in modeling the system; they included 7:00-9:00 a.m., 9:00 a.m.-4:00 p.m., and 4:00-6:00 p.m.

Once the FORCAST outputs were obtained for this system, the average daily ridership and breakdown of ridership by user classification were compared. (This level of examination is most relevant for decisionmakers, such as MTC, since it relates directly to revenues, costs, and subsidy levels. In addition, MTC did not collect any ridership data by time period.) Average daily ridership was obtained from average monthly ridership data collected by MTC by assuming 22 weekdays/month.

The table below presents average daily ridership comparisons between FORCAST and the actual MTC ridership:

Riders	FORCAST Model	MTC Ridership	Variation (%)
Adults (17-65)	140-144	138	+3
Senior citizens (65 and older)	30-32	21	+48
Total	170-176	159	+9

The predicted range of 170-176 average daily riders predicted by FORCAST compares favorably with an actual average daily adult ridership of 159 (an error of +9 percent). In addition, CCTS carried an average of 34 children/day who were younger than 17. Because FORCAST cannot be used to predict ridership for children younger than 16 (the model was validated entirely on adult travel behavior), these riders were left out of the comparison of actual and predicted ridership. This restriction on FORCAST's use could significantly limit its application for planning systems in which a substantial number of young people are expected to use the system. This error may in part be attributed to the exclusion of young riders from the model's calculation of service quality. Had these students been included, the quality of service (wait and ride times) for adult riders would have been reduced and fewer would be expected to use the system. Another possible source of error may be that FORCAST assumes all residents recognize their transportation alternatives whereas, in reality, some did not know about CCTS. The total predicted daily adult ridership was high by 3 percent while senior citizen ridership was high by 48 percent (although only a small number of senior citizens rode the service).

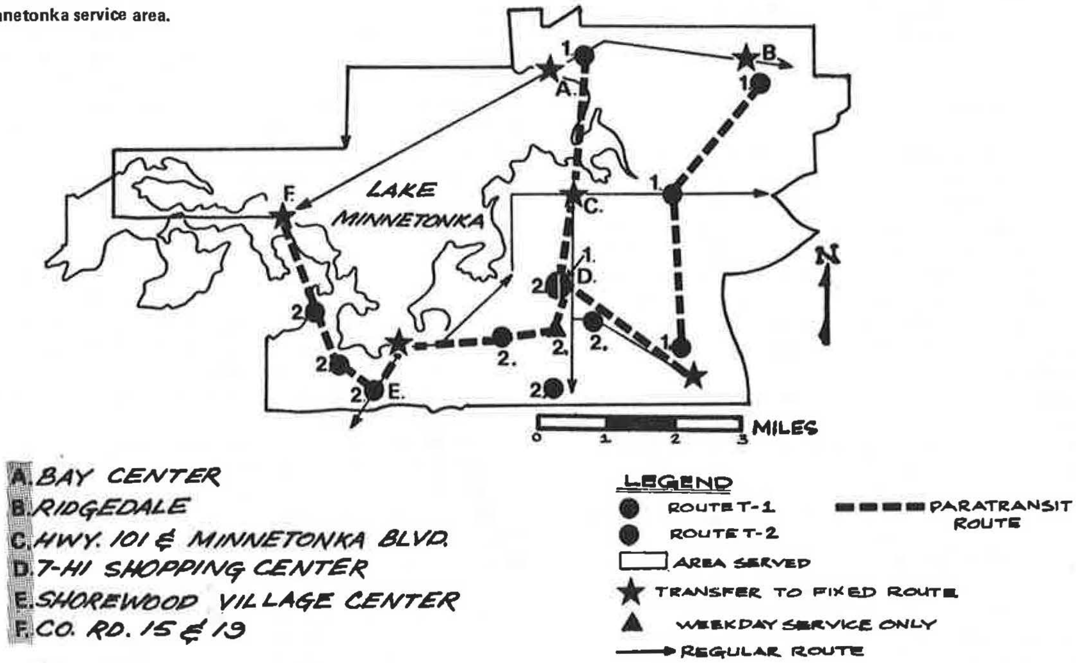
Another aspect of the validation of FORCAST was an examination of the level of service for the White Bear DRT system. (Although the ability to accurately predict level of service was not the major objective in the development of the model system, it is an implicit objective, since in the equilibrium structure of the models, errors in service predictions will produce errors in demand forecasts.) Unfortunately, MTC did not keep records of the wait and ride times experienced by the users of the system; thus, only a comparison of the actual and predicted ride distance could be made. The average trip length experienced by users of the White Bear system, as reported in MTC's evaluation of the White Bear paratransit system, was 3.0 miles. The FORCAST model predicted average trip lengths of 3.27 miles, 2.84 miles, and 3.29 miles during the 7:00-9:00 a.m., 9:00 a.m.-4:00 p.m., and 4:00-6:00 p.m. time periods, respectively. Weighted by the predicted ridership in each time period, the average daily trip length is 3.02 miles. This obviously compares very favorably with the actual average trip length.

The ability of FORCAST to replicate actual ridership and level of service to within 10 percent provided a positive demonstration that the model could be used in the Twin Cities area. Also, in comparison with the accuracy of methods previously used to estimate paratransit demand in the region, FORCAST performed well. Before CCTS service was implemented, patronage was projected at 134 000 passengers/year (508 passengers/day) as compared with 183/day that actually materialized. This initial estimate was high by 178 percent, whereas FORCAST results were only 9 percent higher than actual ridership. This overestimate of ridership translated directly into an underestimate of the subsidy per passenger that was used to establish the financial feasibility of the service. If the FORCAST planning tool had been available when the project was begun, the resulting subsidy of about $3.00/ride could have been predicted and a more informed decision could have been made regarding implementation of the project.

LAKE MINNETONKA VALIDATION

After the successful validation of FORCAST on the White Bear Lake service, the Metropolitan Council performed a similar validation on another local site. This site was at Lake Minnetonka in the western Hennipin County area of the metropolitan area (see Figure 1). Minnetonka is a low-density suburban residential community. The population of the 40-mile^2 service area was 62 140 (population

Figure 3. Minnetonka service area.



density of 1556 persons/mile^2), and total employment was 22 553 (employment density of 565/mile^2).

The Lake Minnetonka paratransit project (10), commonly known as Tonkamobile, was initiated on April 14, 1980, as a one-year demonstration project wholly funded by MnDOT through the state paratransit grant program. Two types of Tonkamobile service were offered: (a) a point-deviation paratransit system and (b) an employee subscription service. The employee subscription service accommodates commuter trips to five employment areas from the communities of Wayzata, Greenwood, Deephaven, Minnetonka, Excelsior, and Woodland. Point-deviation service, in which vehicles are scheduled to stop at a given point at a designated time, is provided during off-peak hours to communities in the Lake Minnetonka area (see Figure 3). Between points the vehicles may deviate to accommodate passenger trip requests. Several time points are coordinated with MTC regular-route service and transfers granted by the system are honored by regular-route transit and vice versa.

A patron used the off-peak service by boarding a vehicle at a designated time point or calling the radio dispatch center in advance of the trip for door-to-door service. The days, hours of operation, and fares of the point-deviation service are given below:

Item	Description
Days	Monday through Saturday
Hours	9:00 a.m.-3:00 p.m., Monday-Friday
	9:00 a.m.-6:00 p.m., Saturday
Fares ($)	
Adults	0.60
Senior citizens (65 or older)	0.30
Youth (6-17)	0.30
Children (under 6)	0
Transfer	0
Deviation	
Adults	0.20
Senior citizens and youth	0.10
Children	0

The point-deviation service used four 12-passenger vans.

Modeling this application was much more complex than that in White Bear Lake because it was necessary to replicate interactions between Tonkamobile and MTC's fixed-route operation and the designation of locations provided with essentially scheduled service. The Minnetonka service area was divided into 18 zones for the purpose of analyzing the off-peak point-deviation service. In addition, one external zone was used to represent downtown Minneapolis, which riders of the point-deviation system could reach by transferring to an MTC fixed-route bus. There was also one MTC fixed-route bus that operated within the service area in competition with the demand-responsive operation. This route was included in the analysis. No attempt was made to replicate the subscription service because it is beyond the capabilities of FORCAST.

The nonpeak period (9:00 a.m.-3:00 p.m.) was analyzed by assuming that the system operated in a many-to-many demand-responsive mode. To accommodate deviations from the designated time points, a distance circuity factor of 1.3 was used in the model. The four 12-passenger vehicles were modeled as operating with manual dispatching and an assumed vehicle speed of 18 mph. The boarding and alighting time for passengers was estimated to be 30 s. An average fare of $0.68 was used. These assumptions approximated actual operations. Socioeconomic inputs were derived from the Metropolitan Council's 1980 zone-level file. Socioeconomic inputs that were not available from the zonal files were obtained by applying the 1970 census trends to the 1980 zone base. The automobile operating cost was 6.7¢/mile in 1974 dollars.

The above analysis, which was done by using FORCAST, predicted that between 72 and 76 trips could be expected during the 9:00 a.m.-3:00 p.m. period. This gives a predicted vehicle productivity of 3.08 passengers/vehicle-h and compares with a vehicle productivity range of 2.25-2.75, which represents a daily ridership in the range of 54-66. The FORCAST patronage predictions were only 20 percent higher than actual ridership, which further supported the transferability of the model. These results led to the acceptance of FORCAST for planning applications by the Metropolitan Council, MTC, and MnDOT.

APPLICATIONS OF FORCAST MODEL

Once FORCAST was validated in Minnetonka, it was then used to analyze possible ridership increases if the service hours were extended from 6:00 a.m. to 7:00 p.m. The model was then also used to explore the effect on expected ridership of increasing fares in both the peak and off-peak periods. (The results of these sensitivity analyses are available to the interested reader from the authors and show how the model can aid in making service design changes in existing services.)

The FORCAST model is also being used for two purposes regarding existing shared-ride taxi services in the Twin Cities metropolitan area to determine the expansion potential of these shared-ride taxi services in Hopkins and Columbia Heights (i.e., Has ridership reached its equilibrium level in these municipalities?) and to explore the possible integration between fixed-route and these shared-ride taxi services via transfers. Results from these applications are not currently available.

Another application of FORCAST is for subregional planning. In 1976 the Metropolitan Council adopted a revised transportation chapter of its comprehensive Metropolitan Development Guide (11,12). The central focus of the transportation development guide and policy plan is to enhance more efficient use of existing and committed transportation investments in the region. Among other things, it suggests that future highway and transit improvements should be scaled to serve off-peak rather than peak-period demand levels, that investments in new capacity should be concentrated within the urban service area delineated by the Metropolitan Development Guide, that transit services should focus on providing for travel within subregions and to the metro centers rather than providing service between subregions, and that a wide variety of means should be considered for encouraging people to travel as passengers (whether in transit vehicles, taxis, or private automobiles) rather than as drivers.

In line with these policies, several studies are being performed to define what constitutes cost-efficient and cost-effective subregional transit services (both fixed-route and paratransit) in two separate subregions. Subregion 3 constitutes old suburbs that have high population density and fairly extensive fixed-route services. Another, subregion 12 (shown in Figure 1), is an area of much lower population density and has no public or private locally oriented transit or paratransit services. The fixed-route transit service that does exist serves primarily passengers who travel to destinations outside the subregion, especially to the Minneapolis central business district (CBD).

In subregion 3, FORCAST has been employed in its current demand-responsive mode to investigate the ridership potential and financial feasibility of community or subregionally based paratransit services that could complement the existing fixed-route transit services. In particular, demand-responsive service options were explored for the off-peak period (9:00 a.m.-3:00 p.m.) in the communities of Edina and Bloomington (see Figure 1).

In the Edina application, a nine-vehicle paratransit service was estimated to be capable of generating 550 trips daily in the off-peak period, with an average person ride time of 6.7 min and an average wait time of 31 min. This ridership was considerably higher than that experienced in White Bear Lake or Minnetonka, so a check was made to determine if these patronage results seemed reasonable in comparison with the Minnetonka results, where a successful validation was made against actual ridership figures. A run of FORCAST was made by using the same input values as those for the Minnetonka runs (i.e., with four service vehicles rather than nine). The average total DRT ridership predicted for Edina was 230 passengers in the 9:00 a.m.-3:00 p.m. period. For Minnetonka, FORCAST predicted 74 daily off-peak trips, while the actual ridership in this period was 60-65 trips.

Approximately three times the ridership would be expected to be generated in Edina as in Minnetonka. However, since the population density in Edina is 2.45 times as great as in Minnetonka and the employment density is 4.95 times as great, this result from FORCAST appears reasonable with respect to validated results.

Assuming an operating cost of service provision of $21.00/vehicle-h, fares of $1.00 for adults and $0.50 for the elderly, and an increment of youth ridership of 10 percent of total ridership (since FORCAST does not predict ridership for riders younger than 17 years of age), one can derive an operating subsidy of $1.40/trip. The ability to derive such a figure is of importance to MTC, which has a policy maximum that serves as a cutoff point for the funding of services. Thus, the ability to accurately forecast DRT ridership becomes an important input into service funding decisions.

Agency planning staffs were also interested in ridership estimates for possible evening operations (7:00-11:00 p.m.) and FORCAST was run on the Edina service area for these hours. Because none of the systems on which the model was calibrated (Rochester, New York, and Haddonfield, New Jersey) or validated has operated later than 7:00 p.m., ridership estimates for these hours could not be accepted.

The Metropolitan Council, acting for the communities in subregion 12 (primarily Eagan, Apple Valley, Burnsville, and Savage), has received a Section 6 planning grant (Urban Mass Transportation Act of 1964, as amended) to explore the feasibility of checkpoint dial-a-ride services in this area. A checkpoint dial-a-ride service would pick up passengers at selected stops (or checkpoints) in the service area rather than at their doorstep. However, the system would still be demand responsive, since persons would have to call in to request service. Some degree of doorstep paratransit responsiveness is retained, ideally enough to ensure a reasonably strong ridership; at the same time, though, some degree of doorstep paratransit's responsiveness is eliminated, ideally enough to assume the potential for high productivity.

The FORCAST model is currently being revised in order to make ridership estimates for a possible checkpoint paratransit system in this area. In its current configuration, FORCAST only predicts ridership for doorstep demand-responsive services. Accurate demand estimates will be crucial to determine the technical and financial feasibility of a checkpoint dial-a-ride system in subregion 12, since this area, in general, has a low population density.

COST OF APPLYING FORCAST

The fixed cost of data input preparation and computer setup needed to run FORCAST on a selected service area ranges from $500 to $750, depending on the size and complexity of the service area. Once this setup cost is incurred, the marginal cost of making an additional computer run to check the sensitivity of parameters is only around $10. Thus, once the initial setup is made, only a very small marginal cost is incurred to explore a variety of service design modifications.

CONCLUSIONS

The experience described in this paper shows the importance of successful validation of a demand model on conditions and systems that operate in the area where the model is to be used. This can establish the geographical and temporal transferability of the model and dissipate the initial skepticism regarding the validity of an imported model. Thus far, FORCAST has been successfully validated on a pure dial-a-ride system, a demand-responsive point-deviation service, and a shared-ride taxi operation. FORCAST ridership projections were validated to within 10 percent in White Bear Lake and 20 percent in Minnetonka. The previous method of forecasting ridership for demand-responsive paratransit systems in the Twin Cities area was based on extrapolation of fixed-route experience and exhibited errors of up to 300 percent.

After the successful validation of FORCAST, it has been accepted and made an integral part of the paratransit and subregional planning process in the Twin Cities area. It has been and is being used jointly by the Metropolitan Council, MTC, and MnDOT for a range of applications.

In summary, FORCAST is viewed as a demand-estimation technique that has been successfully transfered to the Twin Cities area and has been, and is being, used in the service design process. It is believed to provide an objective reference point for demand estimates and thus avoids any special pleading by prospective sponsors or operators of a system. It is also useful to regional and state agencies, such as the Metropolitan Council and MnDOT, that must review, approve, and fund local projects.

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Decision Procedures for Paratransit Management

MARY JO KUNKEL AND MICHAEL J. DEMETSKY

Because many transit managers oversee fairly extensive paratransit systems, specialized evaluation procedures are needed as decisionmaking aids for improving existing services and for instituting new services. A framework that describes the transit evaluation process is presented, which incorporates procedures for intramodal evaluation of existing services and intermodal comparison of alternative services. These procedures consist of a set of indicators, measures, and standards for each mode used in the transit system. The measures and standards are used in periodic evaluations that screen failing services for additional analysis with a set of diagnostic indicators. An intermodal alternatives comparison is used in the service design when an existing service is mismatched with a user group or when a mode is to be chosen for a proposed service. An application of the process and procedures to a case-study transit agency, the Tidewater Transportation District Commission (TTDC) in Norfolk, Virginia, illustrates the modification needed in applying the decision aid. Both management perspective and system data were provided by TTDC. The results of the application indicate that the evaluation process and procedures can serve as a decisionmaking tool for paratransit management.

Paratransit services are an integral part of many transportation systems in the United States. Services such as dial-a-ride, carpool matching, subscription buses, jitneys, and rental cars provide transit to commuters, shoppers, and elderly and handicapped riders who otherwise might not be served by public transportation. Paratransit is capable of meeting these diverse travel needs because of its greater responsiveness and adaptability in comparison with conventional services (1).

As with fixed-route bus transit services, it is desirable to evaluate paratransit services from operator and user perspectives. The evaluation process provides the information necessary to monitor and improve the operation and service level of existing services and to make good decisions in replacing failing services or instituting new services.

The majority of transit evaluation procedures developed to date addresses issues that relate to fixed-route services (2-7). Many transit managers, however, deal with fairly extensive paratransit systems, so a specialized evaluation is needed. By using this need for a paratransit-specific management aid as the focus, this paper describes a decision framework for evaluating paratransit services and presents a set of procedures for implementing the framework. The applicability of the procedures is demonstrated with a case study from the Tidewater Transportation District Commission (TTDC) in Norfolk, Virginia.

EVALUATION FRAMEWORK

Figure 1 illustrates a typical transit service evaluation process. This flowchart consists of two major components: the intramodal and intermodal evaluation processes. Each component lists several steps, which include data input, analysis, implementation, test, and feedback for reevaluation.

The intramodal evaluation is used to compare the performance of individual services with the performance of other services of the same type. For example, a shared-ride taxi service that operates in one neighborhood would be compared with all shared-ride taxis in the system. If such a service performs poorly and cannot be adequately improved, an intermodal evaluation assists in the comparison of several alternative modes by helping the manager identify the service that best suits the user, the operator, and the community. The comparison of alternatives is also carried out when a mode must be chosen for a proposed service.

Performance Evaluation

For each mode in the system, a separate set of performance criteria is used to evaluate services. The choice of the indicators, measures, and standards that describe the performance of a mode is important in developing an evaluation procedure that is meaningful and useful (8). Management must first express the explicit and implicit goals and objectives for the transit system. These include the operator's efficiency objectives, the user's effectiveness objectives, and society's fiscal and environmental constraints. Next, indicators are chosen that directly relate transit characteristics to the underlying objectives. For example, a cost-efficiency objective translates into an expense per produced output indicator for many transit services. These indicators are quantified with measures that relate operating characteristics to the indicators and objectives. The final step is to choose a method for judging performance as described by the measures. Here the actual performance of a service is compared with values for that measure that are acceptable. In this paper, the standards are either

1. A desirable standard set (D) at the system average for a service type $\bar{X}$, or
2. A permissible standard set (P) at one standard deviation away from the average.

A service passes the evaluation for one indicator (i.e., for one criterion) if it is better than average. The permissible standard relaxes the desirable level by one standard deviation. These standards are based on recent systemwide performance evaluations. In this manner, standards are generated for a system at a point in time that reflects the current status of the system rather than imposing externally generated, and perhaps unrealistic, standards.

A service will be ranked into one of three possible ranges. The first is passing (P), which occurs when the actual value of the measure for a service is greater than the desirable standard $\bar{X}$. A service that ranks between the desirable standard and the permissible standard ($\bar{X} \pm s$) is assigned an investigation-warranted rating (I). The service that achieves a performance value worse than the permissible standard is rated as failing (F).

Both intramodal performance evaluation and intermodal performance comparisons use this technique of comparing performance values, as described by the measures, with standards that have been set on overall system performance. The differences in these two processes of evaluation are in the decision procedure and in the follow-up course of action. Each process is described here, and it is then followed by a specific application.

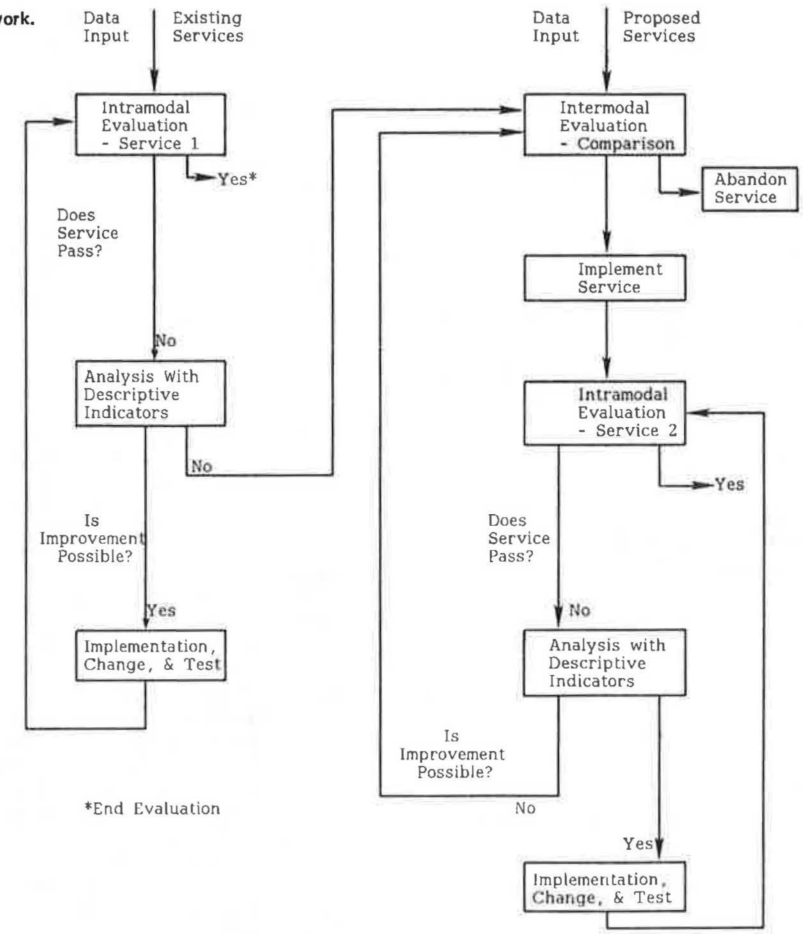
Intramodal Evaluation

A two-step evaluation is recommended for the comparison of individual services with the systemwide performance: (a) general evaluation and (b) diagnostic analysis.

General Evaluation

When using the general evaluation, each service area

Figure 1. Transit evaluation framework.



is screened to detect those areas that are performing poorly. Only a limited number of indicators is required. For example, in Tables 1 and 2, one indicator and one measure are chosen from a larger set developed for each objective and for each mode type (demand-responsive transit and ridesharing). This general measure is listed at the top of each group of indicators in Tables 1 and 2.

Diagnostic Analysis

When the periodic, general evaluation detects a failing service, diagnostic indicators can be applied to the performance data to detect the deficiency. Several indicators per objective are now needed. Tables 1 and 2 list some suggested indicators and measures for each of the objectives and paratransit types.

Intermodal Evaluation

When a set of transit alternatives is considered for an area, the benefits and weaknesses of each possible mode can be determined from measures shown for the indicator categories given in Table 3. Two scoring schemes are combined for the alternatives comparison. The first scheme applies for those indicators that are based on modal factors, specifically the cost-efficiency, effectiveness, and conservation of public funds categories, as shown in Table 3. For the measures in these categories, a point system based on comparison of the service value with the standard is used. Again, both a desirable standard (which reflects the targets set for the system) and a permissible standard (which sets the lowest allowable level of performance) are established. The same scoring allocation is used here as in the intramodal evaluation.

A second scoring scheme is used for the intermodal factors of comparison. Because standards for a transit mode relative to fuel efficiency and air pollutant objectives are unrealistic on a small scale, an intermodal comparison is recommended. Based on manufacturers' estimates and expected ridership levels, an optimum mode can be chosen for each of these two indicators (9). One point is given to this optimum mode; all others receive 0.0 for that indicator.

The final step in this comparison, after calculating the indicator scores, is to determine the weights for each indicator category. This system gives the transit evaluator the flexibility to accurately reflect the goals for the system.

The perfect score for this evaluation is 1.0 and is attained when all evaluation objectives have been fully met. This condition rarely occurs, so the mode that receives the best score is typically chosen. A minimum allowable score is assigned to a no-transit-service alternative so that only viable alternatives will be chosen for implementation in this analysis.

APPLICATION OF EVALUATION PROCESSES

The intramodal and intermodal evaluation procedures are illustrated through a case study of certain services of TTDC in Norfolk, Virginia. The TTDC Maxi-Taxi and vanpool-leasing services illustrate the use of the demand-responsive and pooling intramodal evaluations. In total, two intramodal evaluations

Table 1. Demand-responsive transit evaluation.

Objective	Indicator	Measure
Cost efficiency	Expense per produced output	Cost per passenger mile
	Labor productivity	Vehicle hours per employee
	Vehicle use	Vehicle hours per vehicle
	Administrative efficiency	Office personnel per vehicle
	Pricing	Revenue per cost
	Ridesharing ratio	Passenger occupancy
Service effectiveness and use	Consumed output	Avg number of passengers per hour of operation
	Travel time	Transit trip time per automobile trip time
	User cost	Fare
	Directness of service	No. of passengers transferring per total passenger trips
	Safety	No. of accidents per 100 000 miles
	Vehicle comfort and cleanliness	Inspection results
	Driver courtesy and skill	No. of complaints
	Vehicle access	Wheelchair accessibility
	Public awareness	Percentage of market group answering positively in survey

Table 2. Ridesharing evaluation.

Objective	Indicator	Measure
Cost efficiency	Expense per produced output	Cost per passenger mile
	Trip length	One-way trip mileage
	Seat use	Riders per vehicle occupancy
Service effectiveness and use	Success rate	Percentage of pools surviving a 12-month trial period
	Travel time	Transit trip time per automobile trip time
	User cost	Fare
	Reliability	Wait time (lateness)
	Vehicle comfort and cleanliness	Percentage of users satisfied with vehicle condition
	Safety	Percentage of users satisfied with safety
	Public awareness	Percentage of market group answering positively in survey

and two intermodal evaluations are described. The intermodal evaluations reflect modal changes within a service area in the Tidewater region, which are then compared with the no-transit-service alternative. Maxi-Taxi is compared with local bus service, and the vanpool option is compared with express bus service.

Indicator and Measure Modification for TTDC Case Study

In applying the general evaluations, changes are made in the basic indicator and measures sets (Tables 1 and 2) to adapt the procedures to the specifics of the TTDC case study. These variations represent user group restrictions and data limitations.

The major change in the demand-responsive service evaluation is the substitution of cost per passenger for cost per passenger mile (see Table 1). Although federal reporting requirements include a passenger-mile value, transit authorities only report a system average that is based on sample data. The passenger-trips value is an adequate output measure for the Tidewater Maxi-Taxi service because the service areas are relatively small and homogeneous. The trip-length component of the passenger-mile measure, then, is not considered a factor in cost efficiency for this service.

Table 3. Intermodal evaluation scoring description.

Indicator Category	Measure	Maximum Possible Score
Cost efficiency	Cost per passenger mile	1.0
Effectiveness		
Travel time	Transit trip time per automobile trip time	1.0[a]
User cost	Fare	1.0[a]
Reliability	Wait time	1.0[a]
Conservation of public funds	Revenue per cost	1.0
Fuel efficiency	Passenger miles per gallon	1.0
Pollutant minimization	Grams per passenger mile	1.0

[a] 3.0 ÷ 3 = 1.0.

Other changes in the Maxi-Taxi evaluation are in the measures for the descriptive indicators. For labor productivity, cost per hour is used, since labor costs are represented by an hourly figure. Cost per mile for vehicle use and cost per vehicle for administrative efficiency are used for similar reasons.

The indicator for vehicle accessibility is eliminated in the Maxi-Taxi evaluation. Tidewater provides a special transportation service (STS) for transportation disadvantaged citizens in the region, and wheelchair-accessible vans are available through STS. Transportation for the elderly and the handicapped is not provided by Maxi-Taxi.

No substitutions are made for the vanpooling evaluation. Although few of the measures are currently available, the transit authority is capable of obtaining all suggested measures in an increased data-collection effort.

Tables 4 and 5 summarize the intramodal evaluations and define the objectives, indicators, measures, and standards for both Maxi-Taxi and vanpooling. For the intermodal evaluations, the major substitution is for the effectiveness indicators. Rather than computing the travel-time ratio, fare, and wait-time values for each alternative, the same effectiveness indicators from the intramodal evaluations are used. Maxi-Taxi is assessed on passengers per hour, and vanpooling is rated on the success rate for the effectiveness objective. This method is simpler for existing service evaluation, although the three-component effectiveness measure may be a better choice when dealing with predicted service attributes.

Intramodal Evaluation

Standards

As the next step in fitting the evaluation procedures to a transit region, standards must be chosen that reflect the community's objectives and goals. For TTDC, policy is not in a form that can be translated into evaluation standards, which prevents the use of policy as a basis. For this study, then, the standards are derived from system and industry averages.

For the general evaluation of the intramodal procedure, ranges about the system averages for each measure are used as standards. The desirable standard (D) is set at the average, which encourages long-run improvement, since the standard adjusts as the overall level of service improves. The permissible standard (P) is set at the average plus or minus the standard deviation, which allows for a more liberal level of performance. The standard, then, is based on both the current performance of the overall system and the sensitivity of the measure to variance in the average. This type of stan-

Table 4. Intermodal evaluation for TTDC Maxi-Taxi.

Objective	Indicator	Measure	Standard[a]
Cost efficiency	Expense per output	Cost per passenger mile	1
	Labor productivity	Cost per hour	1
	Vehicle use	Cost per mile	1
	Administrative efficiency	Cost per vehicle	1
	Ridesharing level	Riders per vehicle occupancy	1
	Pricing	Revenue per cost	1
Service effectiveness and use	Consumed output	Passengers per hour	1
	Travel time	Trip time ratio	2
	User cost	Fare comparison with drive-alone automobile	1[b]
	Directness of service	No. of passengers transferring per total trips	2
	Reliability	Wait time	2
	Vehicle comfort and cleanliness	Inspection results	2
	Safety	No of accidents per 100 000 miles	2
	Driver courtesy and skill	No. of complaints	2
	Public awareness	Percentage of market group answering positively in survey	2

[a] 1 means $P = \bar{X} \pm s$, and $D = \bar{X}$; 2 means industry average as used in conventional services.
[b] P = 80 percent and D = 100 percent.

Table 5. Intermodal evaluation for TTDC vanpool service.

Objective	Indicator	Measure	Standard[a]
Cost efficiency	Expense per output	Cost per passenger mile	1
	Modal efficiency	Trip length	1
Service effectiveness and use	Success rate	Percentage of pools surviving a 12-month trial period	1
	Travel time	Trip time ratio	2
	User cost	Fare	1[b]
	Vehicle comfort and cleanliness	Percentage of users satisfied	2
	Safety	Percentage of users satisfied with driver's skill	2
	Public awareness	Percentage of market group answering positively in survey	2

[a] 1 means $P = \bar{X} \pm s$, and $D = \bar{X}$; 2 means industry average as used in conventional services.
[b] D = 80 percent (drive-alone automobile cost) and P = 100 percent (drive-alone automobile cost).

dard works well in a transit system that has a wide range in levels of performance, as is the case with the Tidewater region.

The standards for the Maxi-Taxi general indicators are shown in the table below (note that $\bar{X}$ = average and s = standard deviation):

Measure	$\bar{X}$	s	$\bar{X} \pm s$	$\bar{X}$
Cost per passenger ($)	4.59	1.16	5.75	4.59
Passengers per hour	2.8	0.8	2.0	2.8

The statistics are calculated from the TTDC data files. The standards for vanpool general indicators are compiled in the table below:

Measure	$\bar{X}$	s	$\bar{X} \pm s$	$\bar{X}$
Cost per passenger mile (¢)	3.79	0.7	4.5	3.8
Percentage of pools surviving	89	7	82	89

The cost per passenger mile statistics are calculated from a sample of operating characteristics for TTDC vanpools that were available at the TTDC office. The percent-failure values, however, are assumed as representative because data of this type have not been collected. The assumed failure rates are verified as reasonable and representative by the service development manager at TTDC. These data are one of the additional data needs for the transit authority.

For the descriptive indicators in both intramodal evaluations, TTDC has little or no data currently available for the paratransit modes. Many of the same measures are used for conventional bus services and are considered reasonable as paratransit measures. But, because of the data availability problem, standards cannot be set and services cannot be tested here at the descriptive indicator level.

Tables 4 and 5 contain the suggested form for the recommended standards for the descriptive measures. Many indicators are easily quantified, and a range about the average can be used to set the permissible and desirable standards. Other indicators are quantified in user surveys and by measures that are commonly used in the transit industry. For these indicators, standards may be set at TTDC bus evaluation levels and, where needed, standards for the paratransit evaluation are based on comparative values of competing alternatives.

Maxi-Taxi Service

TTDC currently operates the Maxi-Taxi service in seven communities in the Tidewater area. These service areas have received varying levels of service, so both good and poor services are evaluated with the prescribed procedures.

The evaluation for demand-responsive services focuses on three service areas--Deep Creek, Great Bridge/Greenbrier, and Churchland. The general evaluation is performed to determine whether the service is meeting the standards for the operating criteria of transit management and the needs of the users. The results are summarized in Table 6.

The Deep Creek service evaluation shows that both of the service performance statistics achieve the desirable standard limit; therefore it passes both categories. No further evaluation is required for this service.

The Churchland service passes the evaluation for the effectiveness category but rates an I on the efficiency category. The service is sufficient because it surpasses the permissible standard limit, yet an investigation of the service is warranted because changes in the service may improve its efficiency. Descriptive indicators (such as vehicle productivity, labor productivity, ridesharing level, administrative efficiency, and pricing) should be checked to determine the high cost factor and followed by efforts to improve this aspect.

The Great Bridge/Greenbrier evaluation shows a service that fails in both efficiency and effectiveness. In this case, changes in the existing service should be sought, followed by an intermodal comparison if sufficient improvement cannot be achieved within the service mode. The transit manager, in this particular example, reduced the hours of service by cutting the service fleet from two vans to one van and the performance indicators both adjusted to within the acceptable ranges. The cost per passenger dropped to $5.33 and the number of passengers per hour increased to 3.0.

Vanpool Leasing Service

TTDC transit policy encourages all forms of ridesharing, from conventional bus service to carpooling. As a program under this policy, TTDC promotes the vanpooling option through contact with employers. In this evaluation, then, the market groups are organized by employer. The three groups studied were the General Electric (GE) plant in Portsmouth, the Norfolk Naval Shipyard (NNSY), and the Newport News Ship Building and Dry Dock (NNSB&DD). Two perspectives were considered in this modal evaluation--that of TTDC, the leaser-organizer, whose objective is to provide the most cost-efficient service possible, and that of the user (including both rider and operator). The general indicators are cost per passenger mile and percentage of pools surviving the 12-month trial period.

As with the Maxi-Taxi evaluation, the general evaluation is performed to assess the adequacy of the service by comparing the operating characteristics with the standards. The results are given in Table 7 for the three employers mentioned.

The performance ratings show that this service is satisfactory for NNSY vanpoolers. The high failure rate of this last group indicates that the service is not meeting the needs of the users. The descriptive indicators would identify the problem attributes of vanpooling in this market area for both the effectiveness and efficiency indicators. Because the data needed for the application of the descriptive indicator set were not available, this part of the evaluation is omitted here.

Intermodal Evaluation

Standards

For the intermodal evaluation, the standards from each intramodal evaluation are used. This allows for inherent varying levels of service between modes. For example, bus passengers per hour should not be compared with Maxi-Taxi passengers per hour levels. Maxi-Taxi, then, has the same standards for the cost per passenger and passengers per hour measures. Vanpooling evaluation at the intermodal level uses the same standards for the cost per passenger mile and percent-success measures.

Fixed-route conventional bus service standards that are needed for the intermodal evaluation are calculated from performance data of all routes in the Tidewater region and are presented in the table below:

Measure	$\bar{X}$	s	$\bar{X} \pm s$	$\bar{X}$
Cost per passenger ($)	1.43	1.24	2.67	1.43
Passengers per hour	26.9	13.9	13.0	26.9

Table 6. Maxi-Taxi evaluation results.

Measure	Value	Standard	Performance[a]
Deep Creek[b]			
Cost per passenger ($)	3.49	P 5.75 D 4.59	P
Passengers per hour	4.1	P 2.0 D 2.8	P
Churchland[b]			
Cost per passenger ($)	5.03	P 5.75 D 4.59	I
Passengers per hour	2.8	P 2.0 D 2.8	P
Great Bridge/Greenbrier[c]			
Cost per passenger ($)	9.63	P 5.75 D 4.59	F
Passengers per hour	1.5	P 2.0 D 2.8	F

[a]P = pass, I = investigation warranted, and F = fail.
[b]January-March 1981.
[c]December 1980-February 1981.

Table 7. Vanpool evaluation results.

Measure	Value	Standard	Performance[a]
GE			
Cost per passenger mile (cents)	4.0	P 4.5 D 3.8	I
Percentage of pools surviving	86	P 82 D 89	I
NNSY			
Cost per passenger mile (cents)	3.96	P 4.5 D 3.8	I
Percentage of pools surviving	80	P 82 D 89	F
NNSB&DD			
Cost per passenger mile (cents)	3.35	P 4.5 D 3.8	P
Percentage of pools surviving	97	P 82 D 89	P

[a]P = pass, I = investigation warranted, and F = fail.

Revenue per cost is a measure of the conservation of public funds. The actual ratios (with an upper limit of 1.0 for a service that at least equals the cost with the revenues) are used as both the measure and the point allotment in the evaluation. A direct comparison is used because a low operating ratio is not an acceptable condition and, for this objective, the highest ratio is always optimal.

The fuel-efficiency and air pollution indicators are also not compared with standards. The optimum mode is chosen for each measure, and the total score is allotted to that mode.

The no-transit-service alternative should be chosen whenever the sum of the weighted indicator scores is below some minimum acceptable level. To reasonably ensure that any newly implemented service will be successful, in this study a minimum of 0.20 is chosen. The transit service that meets two or more criteria to a partial degree could be chosen. Any service ranking below this minimum, even if it is the optimum, has a doubtful chance for success and would at best have a marginal operation. Any deficit funding, as well as administrative effort, would be better spent on another service.

Maxi-Taxi and Local Bus

The weights for the indicator categories in Tables 9 and 11 (given later) represent TTDC policy. Equal emphasis is placed on efficiency, effectiveness, and public-fund conservation, with slight weights for fuel-efficiency and air pollution minimization.

In November 1980, a Maxi-Taxi service was instituted in the Ocean View/Bayview area of Norfolk, which replaced bus route number 14. The statistics for each of these services, along with the intramodal standards and scoring, are summarized in Table 8. Also noted are the comparative indicators and the distributed scores. Table 9 organizes the scores, weights, and ratings for each alternative and the no-transit-service alternative. Maxi-Taxi is clearly the superior alternative, and the no-service alternative is the second choice. Based on this evaluation, conventional bus should not be implemented in this service area with the stated level of service, for it does not meet the objectives of the transit operator, user, or community.

Vanpooling and Express Bus

NNSY is served by two express bus routes (numbers 45 and 47) as well as 22 TTDC-owned vanpools. The intermodal evaluation is applied to this case study to test the pooling modes. The statistics are compiled in Table 10 for both modes and then incorporated into Table 11.

The results of the evaluation show that, in this case, express bus is the superior mode for the market group. Vanpooling, however, has a fair rating, so this alternative can also be offered for those commuters who are adverse to bus transit.

Table 8. Intermodal evaluation indicator ratings—Ocean View/Bayview.

Service Type	Cost Efficiency	Effectiveness	Conservation of Public Funds	Fuel Efficiency	Pollutant Minimization
Fixed-route bus					
Measure	Cost per passenger ($)	Passengers per hour	Revenue per cost	Passenger miles per gallon	Grams per passenger mile
Value	5.32	5.6	0.06		
Standard					
D	1.43	26.9			
P	2.67	13.0			
Score	0	0	0.06	1.0	0.0
Maxi-Taxi					
Measure	Cost per passenger ($)	Passengers per hour	Revenue per cost	Passenger miles per gallon	Grams per passenger mile
Value	3.81	4.0	0.10		
Standard					
D	4.59	2.0			
P	5.75	2.8			
Score	1.0	1.0	1.0	0.0	1.0

Table 9. Intermodal evaluation results—Ocean View/Bayview.

Service Type	Cost Efficiency	Service Effectiveness[a]	Conservation of Public Funds[a]	Fuel Efficiency[b]	Pollution Level[b]	Rating
Maxi-Taxi	1.0	1.0	0.10	0.0	1.0	0.68
Conventional transit	0.0	0.0	0.06	1.0	0.0	0.068
Status quo (no service)						0.20

[a]Weight = 0.3. [b]Weight = 0.05.

Table 10. Intermodal evaluation indicator ratings—NNSY.

Service Type	Cost Efficiency	Effectiveness	Conservation of Public Funds	Fuel Efficiency	Pollutant Minimization
Express bus					
Measure	Cost per passenger ($)	Passengers per hour	Revenue per cost	Passenger miles per gallon	Grams per passenger mile
Value	0.60	37.8	0.46		
Standard					
D	2.67	26.9			
P	1.43	13.0			
Score	1.0	1.0	0.46	0.0	0.0
Vanpooling					
Measure	Cost per passenger mile (cents)	Percentage surviving	Revenue per cost	Passenger miles per gallon	Grams per passenger mile
Value	3.96	80			
Standard			1.07		
D	3.8	89			
P	4.5	82			
Score	0.5	0.0	1.0	0.0	1.0

Table 11. Intermodal evaluation results—NNSY.

Service Type	Cost Efficiency[a]	Service Effectiveness[a]	Conservation of Public Funds[a]	Fuel Efficiency[b]	Pollution Level[b]	Rating
Vanpool	0.5	0.0	1.0	1.0	0.0	0.50
Express bus	1.0	1.0	0.46	0.0	1.0	0.74
No transit service						0.20

[a]Weight = 0.3. [b]Weight = 0.05.

CONCLUSIONS

The procedures demonstrated in this paper present a framework for the development of a common paratransit evaluation strategy for application at the system and individual service levels. Transit operators can use the structure to evaluate their current operations as an aid in decisionmaking about service changes. The results show the feasibility and practicality of formalized indices in paratransit performance evaluation. The logical development of the performance evaluation is highly appropriate for explaining transit management options to citizen groups.

ACKNOWLEDGMENT

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Computer-Assisted Management Information System for Regional Advance-Reservation Bus Service

JOHN COLLURA, ANTHONY D. ROGERS, AND ROBERT P. WARREN

A historical and technical review of the computerized management information system (MIS) implemented by the Cape Cod Regional Transit Authority (CCRTA) in 1980 is presented. The paper attempts to evaluate its success and recommends further research into options for the use of computers by paratransit providers. CCRTA's MIS meets the present operational and administrative information needs associated with the 25-vehicle b-Bus regional demand-responsive bus service, including innovative procedures for allocating costs to towns and collecting revenue from riders. The MIS generates monthly invoices for mailing to riders, who are charged according to trips taken and kilometers traveled. A similar charging scheme is used to allocate costs to member towns for service provided to their residents. The many reports generated by the MIS have proved valuable to managers, administrators, and policymakers, and the scheduling component of the MIS has resulted in faster, more efficient, and more reliable service for riders. The MIS uses a Data General Nova minicomputer, two hard-disk drives, three cathode-ray tube terminals, and a dot-matrix printer. The MIS costs about $50 000 (including hardware and software and excluding finance costs).

Demand-responsive bus service has inherently complex information needs and, as a result, a significant portion of the costs involved in providing such services can usually be identified as information management costs. Demand-responsive services frequently employ one office worker for every three or four drivers. Each individual trip involves answering a telephone; obtaining the name, address, destination, date and time desired, billing information, etc.; finding a bus that will be in the right areas at the right times; and scheduling the bus to make the pickups and drop offs. Human service agency invoices must be prepared, user fees must be collected, and statistical reports must be generated.

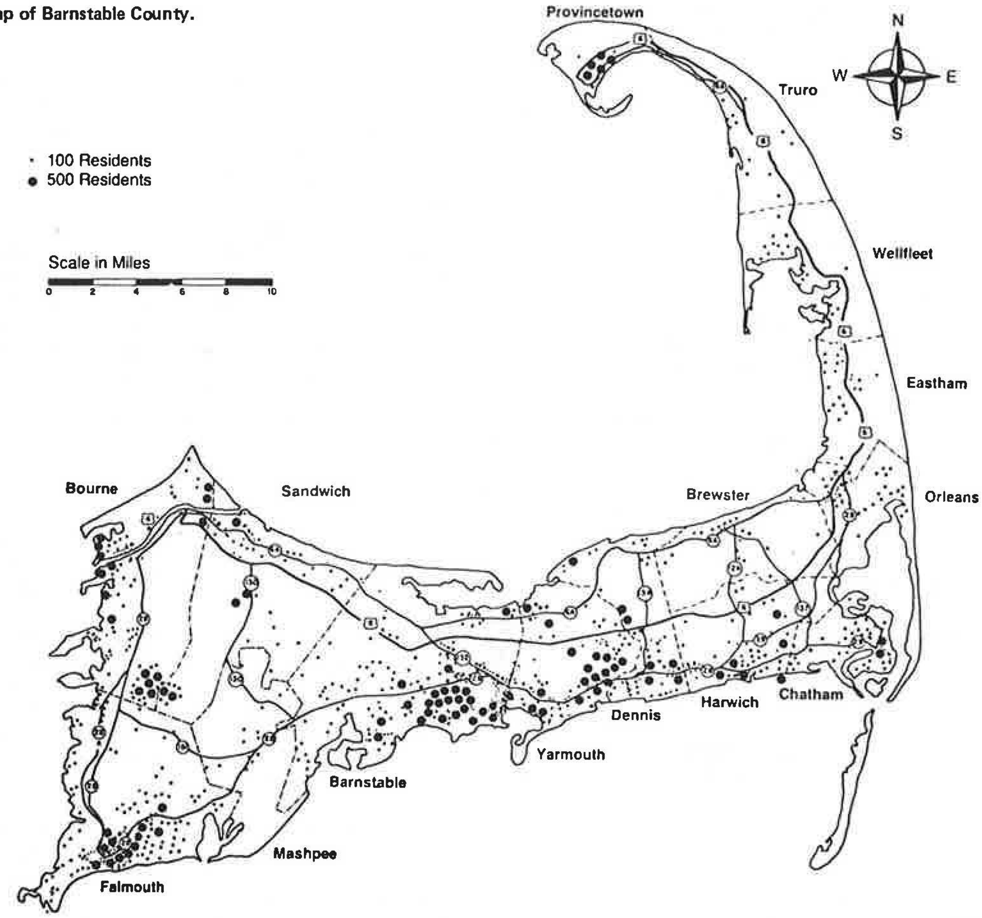
The significance of information management has been amplified by the wave of fiscal austerity now sweeping the nation. In many areas sponsors of such services are being forced to consider cutting service levels, increasing fares, and/or finding ways to reduce costs. Information management is relevant for two reasons: (a) policymakers need good information in order to make such decisions intelligently and (b) information management is one area where cost savings might be realized.

In addition, lower subsidy levels generally lead to higher costs for both users and local sponsors. Increases in user costs show the importance of equity in the generation of revenues, and increases in the local shares paid by municipalities magnify the importance of equity in the allocation of costs between municipalities.

Demand-responsive services that serve many towns have particularly complex information needs. Costs and revenues must be allocated among member towns. Each town needs to know what service they are receiving; thus, all statistics must be kept separately for each town. The variety in trip lengths is greater, so it becomes important to develop trip-length and passenger-kilometer information.

This paper describes the particular information needs of the b-Bus, a regional advance-reservation demand-responsive service provided by the Cape Cod

Figure 1. Map of Barnstable County.



Regional Transit Authority (CCRTA), and the computer-assisted management information system (MIS) that CCRTA now uses to meet these needs.

The CCRTA MIS generates more useful information than the previously used manual procedures, and it costs less. It has also facilitated implementation of highly equitable fare-collection and cost-allocation policies that would not have been practical otherwise.

BACKGROUND

Cape Cod

Barnstable County (Cape Cod), Massachusetts, has a year-round population of 140 000 and a summer population, due to an annual influx of tourists, of 450 000. The 15 communities that make up Barnstable County cover 1008 km^2 (389 $miles^2$) and have a population density of 139 persons/km^2 (54 persons/$mile^2$) (see Figure 1). More than one-third of the Cape's population can be described as either elderly or handicapped.

The b-Bus Program

The b-Bus is a 25-vehicle regional advance-reservation demand-responsive service. Annual ridership exceeds 150 000, and some 2500 clients are served. The FY 1982 gross costs are expected to exceed $900 000.

The b-Bus program was initially administered by Barnstable County but was turned over to the newly created CCRTA in 1979. Coordination of Cape Cod's transportation services was achieved later that year when the b-Bus was consolidated with a similar operation that catered exclusively to human service agency clients (1).

Previous Information Management Procedures

Before implementation of the MIS, the primary information processing task associated with the b-Bus program--the scheduling of 13 000 individual one-way trips each month--was a "paperwork nightmare".

More than 20 clipboards hung on a wall in the operations center, each one holding 20 or 30 drivers' schedules. When a call came in, a "Request for Service" form was completed that contained all relevant information: pass number, name, address, town, funding eligibility, if elderly, if handicapped, and the requested trip, i.e., origin, departure time, destination, requested return trip, trip purpose, etc. All information was taken over the phone from the client or from an index card file. The client was put on hold while the form was passed to the dispatcher, who then consulted the appropriate drivers' schedules on the appropriate clipboards. The dispatcher checked the appropriate box on the request form: 1, request can be scheduled; 2, alternate time suggested; or 3, request cannot be scheduled. Box 2 was the most common result. The form was then passed back to the receptionist, who reconnected with the client and informed him or her of the determination. If the trip could be scheduled, the information was later entered on the appropriate driver's schedule.

In practice this procedure was less burdensome than it might appear. Very often the receptionist would know the client and be able to fill out the form from memory. Often the receptionist would just speak to the dispatcher to get confirmation of a request and, because many of the clients were making the same requests each week, the receptionist and dispatcher could complete the process almost immediately without use of the form and then fill out the form after the client hung up.

With consolidation had come direct responsibility for the preparation, verification, and documentation of monthly invoices required to secure human service agency funding for client transportation. The appropriate information was manually copied from drivers' schedules to large index cards and then to monthly summary sheets maintained for each funding source. The process required the time equivalent of 1.5 clerical workers and often took more than one month to complete.

Fare-collection procedures also involved considerable clerical work. All riders were given serially numbered identification cards. Possession of the pass qualified elderly and handicapped clients to free health care transportation. Other clients and elderly and handicapped persons who wanted other services paid a quarterly fee. Payment of this fee entitled a rider to unlimited service for a fixed three-month period. The pass numbers were used to track revenues and identify paid clients. When clients telephoned to schedule trips, the receptionist would check the index card file to determine if the individual was eligible for the service requested.

Another information need that was difficult to meet was the determination of trip lengths. The b-Bus covers a large area, and trip lengths vary from 128 km (80 miles) to "next door". Information about trip lengths is therefore essential to all monitoring and evaluation efforts. In addition, this information was necessary for the allocation of costs to member towns. The sharing of the vehicles by the towns made use of vehicle hours or kilometers for cost allocation impractical, and the widely varying trip lengths made allocation according to trips taken immensely inequitable to towns whose residents usually made short trips. CCRTA settled on a multivariable cost-allocation formula that takes into account trips taken and kilometers traveled by the residents of each town (2).

This information need had been met previously with off-site computer assistance. Drivers entered pickup and drop-off vehicle odometer readings on their drivers' logs, which were periodically shipped to the University of Massachusetts at Amherst. There the information was keypunched and analyzed with assistance from the University Computing Center. This process was time-consuming for drivers and administrative staff and also expensive, but the information yielded was essential to CCRTA's monitoring and evaluation program and to the implementation of the multivariable cost-allocation formula.

The information management procedures used prior to implementation of the MIS worked; i.e., the information that was clearly needed was produced. But the time equivalent of six full-time positions was consumed in scheduling, billing, fare processing, and other clerical functions. Despite this large commitment of human resources, the process was slow and inaccurate, and only essential information was generated.

Concept

It became clear to the administrative staff of CCRTA that such information management functions were ideally suited for automation. Each task could be reduced to a series of well-defined steps that are repeated many times. The manual procedures were time-consuming not because of any inherent procedural complexities but rather because of the immense volumes of information involved.

Interest in computerization of the system was present in 1976, before the service had even been initiated; however, the origin of the current MIS can be traced to an internal CCRTA memorandum written in 1978 by A.D. Rogers entitled, Proposal for a Study to Evaluate the Feasibility of Development of a Data Processing System for the Barnstable County b-Bus Program. The concept grew more popular over the months, and when staff resources were made available by completion of the consolidation project in 1979, a committee was formed to evaluate the feasibility of MIS implementation. Within months the committee unanimously agreed that computerization of the information processing functions associated with the b-Bus service would produce benefits that would outweigh the costs involved.

Implementation

The CCRTA Advisory Board later endorsed the project and in January 1980 authorized publication of a nonspecific request for proposals (RFP); non-specific meant that it did not require that computer technology be used to meet the information needs specified. In fact, one of the RFP responses constituted an offer to meet the minimum requirements (only) without computer assistance. As expected, this "man-with-calculator" response showed the largest price tag of all responses received, which included the following:

1. Two proposals to provide custom-designed microbased distributed processing systems (lowest cost).
2. A proposal to provide a sophisticated scheduling and dispatching computer system developed for large taxi operations. This system used full color video graphics to show scheduled vehicle locations and included optimizing software that would directly assist in the scheduling process (highest cost).
3. One proposal to provide a prepackaged comprehensive system designed specifically for paratransit operations.
4. One proposal to provide a custom-designed minicomputer system (median-level cost).

An RFP review committee composed of professional people from the community that had direct experience with computer applications rated the proposals and unanimously recommended an award to Crosbro, Inc., of Brockton, Massachusetts, which submitted the last proposal listed above.

Crosbro's proposal directly addressed all information needs identified in the RFP (both required and desirable), identified how needs would be met, delineated hardware component specifications, outlined software organization, and demonstrated that sufficient capacity would be available to triple the size of the operation without modification of hardware or software.

In April 1980 CCRTA awarded a contract to Crosbro for development of such a system. Over the following seven months, CCRTA staff and the operations staff worked closely with the firm in creating, adjusting, and refining the system. The MIS went on-line in December 1980 and is currently meeting all the information needs identified in the RFP.

MIS

The MIS installed at CCRTA provides on-line scheduling and provides various operational, managerial, and statistical reports. In addition, the data that are gathered and maintained by the system enabled CCRTA to add a billing and payment system of the type necessary to support a new and innovative fare-collection system.

The MIS is operated on a Data General Nova 4/S computer with 64 kilobytes of core memory. The hardware includes 20 megabytes of disk storage, a 180 characters/s dot-matrix printer, and 3 cathode-ray tube (CRT) terminals. The hardware is expandable and can be altered to support new applications as well as greater volumes. The programs were written in Data General Business BASIC and the data files are indexed sequentially.

Scheduling and Dispatching

File maintenance and inquiry routines are available that allow operations personnel to interactively add, delete, and modify master file records; make inquiries against particular records; or produce hard copy listings of entire files.

The on-line inquiry routines are used each time a request is called in by a client. The receptionist retrieves information about a client by entering their pass number or name and then checks the appropriate schedules by entering the requested date and appropriate schedule numbers. If the trip can be scheduled, the receptionist instructs the system to transfer the trip information to the trip file. There are routines that can be used to schedule trips, one for adding trips to the trip file that were not prescheduled, and one to schedule trips that are made regularly, such as medical therapy trips. All routines require a minimum of data entry, since names, addresses, and frequently made trips are already known by the MIS.

Each evening the next day's schedules are assigned to individual drivers and vehicles and hard copies are produced. Drivers are also given log sheets on which they record vehicle odometer readings, fuel and oil consumption, maintenance data, etc. The MIS has the ability to estimate the length of any trip when given the origin and the destination; thus, it is unnecessary for drivers to record pickup and drop-off odometer readings. If any changes are made to the schedule during the day (e.g., a client does not take a trip for which he or she is scheduled), a note is made on the schedule and the change is entered into the MIS the next day along with the log sheet information.

Integration

The CCRTA MIS does not provide automated scheduling. The system does assist in the scheduling process by providing the receptionist with all necessary information and by automatically transferring relevant information to the trip file, but the receptionist still makes all the decisions.

This assistance is important; however, it also produces most of the data needed by the other MIS routines described below. If scheduling was not part of the MIS, all schedule information would still have to be entered. Integration of scheduling and administrative functions eliminates the need for batch data entry, thereby saving time and money.

Demand-responsive operations that consider implementation of single function systems should consider this integration factor carefully. It may be cost effective to obtain computer assistance for one function only (e.g., for preparation of human service agency invoices), but implementation of a comprehensive MIS would almost certainly be even more cost effective.

Maintenance

The drivers' log information described above is accumulated in a vehicle maintenance file along with information from the maintenance shop regarding tune-ups, oil changes, repair work, costs, etc. Maintenance routines produce reports that indicate the performance of each vehicle, maintenance work needed, year-to-date maintenance cost, etc.

Human Service Agency Billing

At the end of each month a routine is run that produces detailed invoice documentation for special purpose trips made by clients of human service agencies that have contracts with CCRTA for client transportation.

Client Billing

CCRTA has taken full advantage of the MIS by implementing an innovative client billing system. Previously, revenue was collected through a quarterly fee mechanism. Payment of a small fee made clients eligible for three months of unlimited service. This mechanism was inequitable in that the amounts paid bore no relation to the service used, but the fees were so low that the inequities had minimal impacts on individual clients.

In 1980 the CCRTA Advisory Board decided that revenues from the b-Bus system had to be increased significantly. Because large increases in the quarterly fees would have made the small inequities into significant problems, CCRTA developed and implemented an entirely new mechanism.

The quarterly fee mechanism has been modified and is now optional. Elderly and handicapped persons can pay a quarterly fee of $20, take medical and local trips for free, and pay $0.06/km ($0.04/mile) for nonmedical, nonlocal trips. If they choose not to pay the quarterly fee, they are charged $0.75 for each trip and an additional $0.06/km for nonmedical trips.

Other persons can pay a $30 quarterly fee and $0.10/km ($0.06/mile) for nonlocal trips. If they choose not to pay the fee, they are charged $1/trip plus $0.10 for each kilometer traveled.

All revenues are collected through an invoice mechanism similar to that used by telephone companies. When a client requests a trip, the system automatically determines if the trip is billable based on the type of client and the trip purpose. If the trip is billable (e.g., a shopping trip), the MIS calculates the distance and the fare and displays the information on the receptionist's CRT. This gives the client an opportunity to cancel prohibitively expensive trips. The date of the oldest unpaid invoice is also displayed, which gives the operator an opportunity to inquire about payment of overdue invoices.

Invoices are produced monthly and give a line-by-line breakdown of all charges incurred by the client during the past month along with all past due charges. The invoices also show nonbillable trips and discounts that may have been granted.

A cash-receipts routine allows the operator to enter payments and post them to unpaid invoices. For each entry, a payment record is created and stored in the invoice file. At the same time the payment is added to the appropriate revenue accumulator in a town file. A cash-receipts journal is printed daily that shows all payments received.

An adjustment routine allows the operator to enter credit and debit memos to adjust for over and under charging. For each such entry, a memo record is created and posted in the invoice file. The

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Analysis of Taxicab Industry in Chicago Metropolitan Area

CHRISTINE M. JOHNSON, CLAIRE McKNIGHT, ANTHONY M. PAGANO, AND LEONARD ROBINS

The Chicago Area Transportation Study initiated a comprehensive investigation of the taxicab industry in the Chicago metropolitan area in fall 1979. The study resulted in the collection of financial and trip information from a cross section of taxi companies that ranged from rural "ma-and-pa" type operations to one of the oldest and largest urban taxi fleets in the United States. Five conclusions were drawn in the analysis that have implications for public funding policy, for efforts being made to deregulate or re-regulate the taxi industry, and for the taxi industry at large. Those five findings include the following: (a) The taxi industry is chronically weakening, (b) leasing has significantly changed short-term market risk liability and incentives for productivity on the part of operators, (c) there are both economies and diseconomies of scale in taxi operations, (d) taxi service areas have become subregional as opposed to being strictly local, and (e) taxis can supply exclusive demand-responsive service for about the same per passenger cost as publicly subsidized demand-responsive services. The paper concludes with recommendations for updating taxi regulations to recognize new operating realities and a review of public funding policy as it relates to use of, or competition with, the taxicab industry.

In September 1979, the Chicago Area Transportation Study (CATS) initiated a comprehensive investigation of the taxicab industry in the Chicago six-county area, an area that includes the City of Chicago and 263 suburban and satellite municipalities. The study resulted in the collection of both financial and trip information from a cross section of taxi companies that ranged from rural "ma-and-pa" operations to one of the largest and oldest urban taxi fleets in the United States. Five of the conclusions of this two-year study have important implications for both state and federal transportation funding policies and for the taxi industry at large. The purpose of this paper is to present those five findings.

BACKGROUND

Region

The Chicago metropolitan area, which encompasses the counties of Cook, Lake, McHenry, Kane, Will, and DuPage, offers unusually fertile ground for studying the taxi industry. Within this 3719-mile² area are small rural communities with populations of less than 10 000 where, until the recent introduction of Regional Transportation Authority (RTA) bus service, the local owner-operator taxi was the only "public" transportation available. There are new, rapidly sprawling suburbs and other areas that are older, more densely populated, and have well-established transit and taxi systems. Finally, there is the City of Chicago, which has densities of 13 000 people/mile² and a central business district (CBD) served by seven rapid transit lines, seven commuter lines, and one of the oldest and largest taxi conglomerates in the United States.

Taxi Industry

Within this six-county area there are 5741 taxis, or 0.81 taxis/1000 population. Eighty percent (4600) are in the City of Chicago. Of the remaining 1141 vehicles located in the suburbs, 75 percent are located in the older suburbs of Cook County.

Most of the cab companies are old. Checker and Yellow Taxicab Companies in Chicago date back to World War I. The suburban firms, many of which grew up as feeders to commuter rail stations, have an equally long history. We found the median age to be 25 years, with several more than 50 years old.

Few of the suburban companies operate with an exclusive franchise; nearly all experience some form of competition within their service area. The suburban companies are also relatively small; the average fleet size is 21 vehicles. The range, however, is extensive; there are numerous legal and illegal owner-operators in rural areas and a few large (100 or more vehicle) associations in the rapidly growing north and northwest suburbs. By contrast, two very large and interlocking companies (Checker with 1500 vehicles and Yellow with 2500 vehicles) control 80 percent of the taxis in the City of Chicago.

Operations and organizational structure also vary within the region. Where two-thirds to three-fourths of the Chicago taxi business is street hail, 90 percent of the suburban business is dispatched and nearly one-third of that is nontraditional taxi business (either package delivery or contract work). In Chicago, more than 90 percent of the taxicabs are leased for a flat, 24-h rate, much like a rental automobile. The driver is considered an independent operator and keeps all earnings after lease and gasoline costs have been paid. One-third of the suburban taxi firms operates on a commission structure where operators and drivers split the day's gross earnings on a 60/40 basis. The remaining cab companies are either associations of owner-operators or operate under a variable-lease system. Typically, a variable lease sets the lease rate at 50-60 percent of the driver's daily gross and is thus indistinguishable from the commission structure, except that the driver is considered by the company to be an independent contractor, not an employee.

In 1970 the taxi fleet as a whole carried a significant number of the region's trips: slightly less than 1 percent; however, that modal share has slipped to less than 0.5 percent of all daily passenger trips. In fact, one of the reasons for initiating our investigation was the suspicion that the taxi industry may be seriously weakening.

SCOPE AND RATIONALE OF STUDY

CATS initiated the two-year study of the taxi industry for three reasons:

1. To assess the financial stability of the industry. There have been numerous indications at the national level that the taxi industry may be seriously weakening (1; and correspondence of the Inter-

national Taxicab Association collected from Al LaGasse, March 6, 1981).

As with all other forms of transportation, the cost of operating a taxicab has increased dramatically during the 1970s. A barometer of this change is the increased cost of driving an automobile, which the American Automobile Association reported increasing by 53 percent between 1976 and 1980. The response of most taxi companies has been to increase fares. In the past, such an increase had little effect on ridership because a large portion of the taxi market (the business traveler and the poor) either had no alternative or were insensitive to price increases. There is now evidence that taxi demand has become, or is becoming, elastic (2).

The primary reason for this new price sensitivity is that former captives now have alternatives. The rental automobile business, which has been growing at an annual rate of 12 percent for the past several years, offers an increasingly attractive alternative to the business traveler. A recent study of taxi riders in Dallas found that half of the out-of-town users who would be unwilling to pay increased taxi fares would turn to a rental automobile as an alternative (3). The low-income taxi user, who constituted close to 33 percent of the taxi market, has benefited from the general increase in public transportation funding and service as well as the numerous new specialized transportation programs. The result is that many now have alternatives when faced with increases in taxi fares.

2. To respond to numerous complaints from and about the taxi industry. There are more than 150 different and often conflicting sets of taxicab regulations in the Chicago area. Taxi operators have frequently complained about the deadheading caused by nonreciprocal regulations and the time-consuming and redundant safety inspections required in each municipality they serve. Further, with the emergence of RTA in the past six years, many have complained that new feeder buses and dial-a-ride (DAR) services are encroaching on their market. Consumers have complained about fare gouging, lack of neighborhood service, and escalating prices.

3. To explore ways that this existing resource could be more efficiently used and more effectively incorporated into the existing transportation system. Several authors (4-6) have suggested that taxicabs can provide some forms of public transportation cost efficiently. Options include use of taxis as a substitute for owl or fixed-route service, for service to the elderly and the handicapped, and for low-density circulation systems.

DATA SOURCES

Several data sets were assembled to carry out the multifaceted scope of the investigation. In the paragraphs below, we briefly describe the five data sets used in reaching the conclusions presented here.

Financial Survey of Taxi Operators

In-depth interviews were conducted with taxi company owners and managers to obtain detailed financial information. Although this approach was extremely time-consuming, it avoided the problem of one operator including utility and radio repair bills in administration while another operator included these costs in maintenance, thereby rendering the data noncomparable.

Of the 100 or more taxi companies in the area, 36 agreed to participate in the 6-h interview; 31 provided reasonably complete information. Of these, 28 were suburban firms that collectively own 58 percent of all suburban taxis and 3 were Chicago firms operating 37 percent of the Chicago taxi fleet.

The survey elicited the following categories of information:

1. The organizational structure and management history of the company;
2. Fleet information: number, age, maintenance, and replacement practices;
3. Driver information: number and compensation procedure;
4. Full documentation of 1979 operating expenses based on 19 preestablished expense items;
5. Revenue estimates for 1979 and information on the source of revenue; and
6. Vehicle use; each operator was asked to keep daily odometer readings on at least 10 of his or her vehicles for seven days.

Wherever possible, cost data were obtained from actual records--either income tax returns, accountants' statements, or ledgers kept by the company. Property owned by the taxi company and used for operating the business was assigned an annual rent of 10 percent of the appraised value. Annual depreciation for nonvehicle capital equipment was assigned as follows: $N(P - S)/L$, where N is number of items in stock, P is purchase price, S is salvage value, L is life span, and unsalaried labor (usually owners whose wages were company profits) was assigned an annual salary of $15 000 per full-time equivalent employee.

Origin and Destination Data

During the week of May 14, 1980, the drivers of each of the taxi companies that participated in the financial survey were asked to keep trip records (in the form of trip sheets) of all trips on a selected day of that week. The records contained information on origin, destination, fare, number of passengers per trip, as well as vehicle odometer readings.

Origin and destination information was collected for 6058 suburban trips from 31 percent of all suburban taxis, and 5700 City of Chicago taxi trips were also collected, which represents about 10 percent of all Chicago taxi vehicles. Greater detail on survey methodology is presented elsewhere (7).

Vehicle Registration Records

The Illinois Secretary of State's office provided 1979 and 1980 taxi and livery vehicle registration records. These records contain information on the taxi vehicle and its owner. From these records we derived information on the total supply of taxis, their geographic distribution, and vehicle age. Similar summary information for 1973 and 1975 was available elsewhere (6).

Time Series Data on Checker Taxicab Operations

Checker Taxicab Company, which operates 1500 taxis in the City of Chicago, provided CATS with four years (1976-1980) of historical information on operating costs and vehicle use for both their commissioned and lease fleet. In addition, they provided information on the productivity and revenue of their commissioned fleet, which at that time consisted of about 200 vehicles.

Financial and Operating Data on Publicly Subsidized Social Service Transportation Services

A concurrent study carried out by the University of Illinois, Chicago Circle (UICC), under the auspices of a grant from the Program of University Research, If the taxi industry is to extricate itself from its current financial situation, two forms of public action will be required. First, taxi ordinances must be updated to reflect current operating realities. Included in that update would be provisions that allow taxis to offer a broader range of services to a larger market segment and quicker recovery of costs and greater flexibility in the pricing of services. If prices must be regulated, then those regulations should distribute the risk of the fixed price equally between the company or operator and drivers.

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Taxi-Based Public Transportation for the Elderly and the Handicapped

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The system organization, performance, and taxi firm impacts of California's taxi-based elderly and handicapped (E&H) systems are analyzed, and the results are compared with taxi-based general-public demand-responsive transportation (DRT) systems. The data were gathered from 48 California taxi-based E&H systems. Sponsors have restricted ridership to the elderly and the handicapped due to budgetary constraints and, when such constraints are severe, they have also rationed service among this group. The low demand services that often result are ideally suited to provision by taxi firms, as they can be integrated with other taxi services. In many cases demand is so restricted that sponsors simply subsidize regular taxi service, as shared riding is difficult or infeasible. Due to the prevalence of such subsidized exclusive-ride taxi (ERT) services, E&H systems are considerably less cost effective than taxi-based general-public DRT. E&H services have been organized in essentially three ways: as traditional dial-a-ride operations, as subsidized ERT service, or as user-side subsidy shared-ride taxi (SRT) service. SRT has proved to be the key to superior performance. In general, shared-ride operations result in high levels of performance, provide the most favorable taxi firm financial impacts, and initiate the company into the paratransit diversification process. In situations where the sponsor faces a severe total cost constraint, however, organizing a subsidized ERT system is probably the only feasible strategy. Subsidized ERT systems are about 40 percent more expensive than user-side subsidy SRT systems, have less impact on company revenues, and do little to enhance taxi firm evolution.

Two trends have dominated the recent diffusion of demand-responsive transportation (DRT) services. The first is the growing reliance on private contractors, particularly taxi firms, as DRT providers, albeit within the framework of a publicly subsidized and sponsored transit service. The second trend is the increasing tendency of government sponsors of DRT systems to restrict use of the service to certain population subgroups or individuals, most notably the elderly and the handicapped. In a number of communities around the country, these two developments have coincided, which results in the establishment of a generation of taxi-based restricted-ridership DRT systems, typically targeted at elderly and handicapped individuals. California alone contains nearly 50 such public transportation systems.

Taxi-based DRT systems for the elderly and the handicapped are not simply a smaller-scale version of general-public DRT systems but instead represent distinctive forms of community-level transit. The joint decision to restrict ridership and to use a local taxi firm as the provider has a significant effect on system organization and performance. Restricting use to the elderly and the handicapped reduces demand well below the levels achieved by general-public DRT systems, in which the elderly and the handicapped typically comprise about 25-50 percent of the passengers. In addition, many sponsors impose restrictions within this category, thereby further decreasing potential demand. The resulting low demand density limits the ability of the provider to practice shared riding and often renders it infeasible. In fact, the use of a local taxi firm gives the sponsor the option of simply subsidizing traditional exclusive-ride taxi (ERT) service. In contrast to taxi-based general-public DRT systems, which are normally subsidized shared-ride taxi (SRT) services that often use vehicles dedicated solely to the DRT system, many taxi-based elderly and handicapped (E&H) systems closely resemble ERT operations in their organization, fare structure, productivity achievements, and cost-effectiveness. Moreover, the impacts on participating taxi firms--both financially and in terms of organizational development--tend to differ significantly between E&H and general-public systems.

Taxi-based DRT thus consists of two distinctive forms of paratransit services, of which only one--subsidized SRT for the general public--has previously been subjected to comprehensive analysis (1,2). The purpose of this paper is to provide a similar analysis of the issues, both institutional and performance, associated with taxi-based E&H services, which are quite possibly the most rapidly growing component of taxi-based paratransit.

This analysis is based on the results of a study of 48 taxi-based E&H systems in California, which comprise essentially all such systems currently operating in the state. Data were collected on the operating and financial performance of these systems for the 1979-1980 and/or 1980-1981 fiscal years. Information was also obtained via personal interviews with sponsors and providers on the process leading to the establishment of these systems, the impacts on the involved taxi firms from participation in public transportation, and the nature and evolution of the relation between the public and private sectors. These California systems not only represent the largest single data base available for analysis of taxi-based E&H services, but they also offer the advantages of geographic and organizational diversity as well as relative longevity.

In analyzing California's experiences with taxi-based E&H services, our focus has been on three major issue areas: (a) system organization, (b) impacts on taxi firms, and (c) system performance and its determinants. Throughout the analysis the differences between taxi involvement in general-public and E&H services will be emphasized, thus illustrating the distinctive organization, impacts, and performance of these two forms of taxi-based paratransit.

SYSTEM ORGANIZATION

The organization of a taxi-based E&H system encompasses six factors:

1. Decision to restrict ridership and the severity of the restriction,
2. Decision to use a taxi firm as provider,
3. Determination of whether to use dedicated vehicles or an integrated fleet system,
4. Selection of a subsidization option,
5. Adoption of a provider compensation mechanism, and
6. Choice of a user payment system.

In practice, these factors are highly interrelated. A sponsor's decision to restrict ridership and its determination of what the role of the system will be--ranging from basic community public transit to a strictly supplemental and highly restricted service--have a major bearing on the feasibility and attractiveness of the other specific system organization parameters. Instead of an infinite variety of systems, the reality is a small number of distinct types that are organized in ways that are internally consistent as well as compatible with sponsor objectives, the market situation, and the operating capabilities of the taxi provider.

Restricting Use to the Elderly and the Handicapped

Over the past several years, sponsors of DRT systems have increasingly opted to restrict eligibility of use, almost invariably as a strategy for containing costs. The sponsors of California's taxi-based E&H systems have been similarly motivated. All but 2 of the 48 systems faced either absolute funding limitations or serious competition for the funds that were used to subsidize the service.

The most frequently used source of subsidy for taxi-based E&H service is a special funding category of California's state transit subsidy program. Article 4.5 of the Transportation Development Act (TDA) provides for up to 5 percent of TDA funds to be used for community transit services in the largest urban counties. These counties, however, are precisely the areas in which fixed-route transit is dominant; thus, merely obtaining the 5 percent funding for local DRT services has been quite difficult politically. Moreover, even when the full 5 percent is available for community transit (as in the San Francisco Bay area), it represents a relatively small sum to a city and by itself is typically inadequate to finance a general-public DRT system. Therefore, in the 26 systems that depend entirely on Article 4.5 funds for subsidies, there is strong pressure to restrict use to the elderly and the handicapped.

Although none of the remaining 22 systems faced such stringent absolute limits on available subsidies, all were funded by sources that could be allocated to competing purposes, i.e., streets and roads in the case of regular TDA subsidies, other municipal programs in the case of increasingly scarce municipal general funds, and other transit services in the case of transit agency funds. Although regular TDA funds can be used for streets and roads in nonmetropolitan areas only if no unmet transit needs exist, it has been the common practice in such areas to spend as little as possible on transit and the remainder on highways. Restricting DRT use to the elderly and the handicapped thus preserves most of the TDA funds for the community's highest transportation priority--highway maintenance and construction--while alleviating the plight of those seemingly in greatest need of a transit alternative.

In deciding to restrict DRT ridership, then, public officials were predominantly concerned with the total cost of the system and not its potential performance or cost-effectiveness. The relative weight given in subsequent system design to the factors of total cost and cost-effectiveness depended on the stringency of the fiscal constraint, but in every case the former was deemed more important when initial decisions about the system were made. As a result, a political and planning climate has been created (at least in California) in which the elderly and the handicapped have policy priority for scarce DRT resources.

Choice of Taxi Firm as Provider

Most of the restricted-ridership DRT systems established in California have been designed specifically as taxi-based E&H systems. About 80 percent of all restricted-ridership DRT systems in the state use a taxi firm as provider, whereas only about half of all general-public DRT systems are operated by a taxi company. Of the 48 E&H systems that were the focus of this study, only 2 had a provider other than a taxi company bid on the system. That is, in 46 of the 48 systems, the only feasible provider was a taxi firm. The two exceptions, moreover, are systems that used dedicated vans and are targeted primarily at the transportation handicapped. In a majority of cases there was no competitive bidding. A contract for service was generally negotiated with either the sole local taxi company or all the taxi firms that serve the area.

There are several reasons why California's E&H

systems have been targeted at and operated by taxi firms. In common with taxi provision of general-public DRT, the use of a taxi firm in an E&H system offers the sponsor the advantages of low production costs, in-place capability, and rapid implementation. Moreover, few sponsors of either general-public or E&H service wish to incur the difficulty or expense of being in the transportation business. Using a local firm also provides political advantages; it avoids potential government competition with private firms and it may ensure that taxi service is available to the community by keeping the local taxi firm (or firms) afloat financially. The latter objective has become increasingly important in many small cities where conventional taxi service alone often will no longer sustain a company. Finally, the taxi industry in California has been relatively aggressive in pursuing local public transportation opportunities.

Equally significant, many of the E&H systems in California are not suited to cost-effective operation by any provider other than a local taxi company due to their low demand densities. In such situations the traditional dial-a-ride form of service organization (dedicated vehicles, provider-side subsidy) leads to high subsidy costs per passenger for the sponsor, whereas if demand is very low a user-side subsidy scheme makes financial sense for the provider only if the E&H operation can be integrated with another transportation service that produces significant revenues. Due to their operation of regular ERT services in the same area as the E&H service, taxi firms have a large advantage over other providers with respect to the latter consideration.

Subsidization, Compensation, and Mode of Operation

California's taxi-based E&H systems are predominantly organized along user-side subsidy principles whereby a provider receives payment only for consumed service (e.g., passenger trips). As indicated in Table 1, 85 percent of all systems are subsidized in this fashion. Overall, only 25 percent of the E&H systems use dedicated vehicles. Fully 75 percent of the systems are based on the combination of an integrated fleet operation and payment for consumed service, a combination shown to be associated with a high level of cost-effectiveness when taxi vehicles are deployed in a shared-ride mode of operation (3). However, three-fourths of the taxi-based E&H systems in California that use this combination of organizational arrangements do not practice shared riding but instead are ERT operations. In fact, only 22 of the 48 systems included in this study are organized on shared-ride principles; the remainder are simply subsidized ERT systems, most of which use ERT meter fares as the basis for provider compensation. This stands in marked contrast to California's 25 taxi-based general-public DRT systems, all of which are shared-ride operations and most of which use dedicated vehicles.

These distinctive organizational features of taxi-based E&H systems stem primarily from three factors. The first is that the rationale for restricting DRT use to the elderly and the handicapped derives directly from budgetary limitations, and low ridership is the inevitable consequence when such limitations are at all severe. In most such cases, service is not only restricted to the elderly and the handicapped, but it is also rationed by strict eligibility standards and limitations on the number of trips that may be taken. Low ridership means very low demand densities compared with general-public DRT systems, and it severely constrains the feasible options for organizing the service.

For example, the demand density for general-public DRT systems in California ranges from 5 to 50 passengers/mile^2/day; taxi-based systems average about 16 passengers/mile^2/day. In contrast, overall demand density for E&H systems is about 6 passengers/mile^2/day and much less for many systems that ration service. For example, consider two roughly comparable communities, Hayward and Fullerton, the former having an E&H system for which service is rationed and the latter a general-public DRT system. Demand density in Fullerton was nearly eight times greater than that in Hayward. Even so, the Fullerton system achieved a vehicle productivity of about 5.5 passengers/vehicle service hour, which is reasonable but not outstanding for DRT. Given the much lower demand density in Hayward, it is apparent that shared riding is virtually infeasible. Not surprisingly, this system is simply a subsidized ERT service.

The second major factor that affects the choice of system organization parameters is the sponsor's objective for the E&H service. These objectives are heavily influenced by the level of funding available. When funds are restricted, sponsors typically view DRT as a supplemental service to fixed-route transit for those elderly and handicapped people who have difficulty using or accessing the bus system. In contrast, when there is no stringent limitation on subsidy availability, sponsors are prone to view the DRT service as basic public transit for the elderly and the handicapped members of the community. The latter group of sponsors was three times more likely to organize the E&H system along SRT lines than those sponsors that had to contend with severe financial constraints and thus designed a supplemental service. Although both groups of sponsors were concerned with the total cost of the E&H system, those who opted for a basic public transit system did not deem demand restrictions necessary in order to keep within an absolute budget ceiling and were thus able to give higher priority to cost-effectiveness considerations in designing the system. Most of these sponsors thoroughly investigated their options and realized that shared riding was an essential component of any cost-effective system. The other group of sponsors largely opted for subsidized ERT service and viewed cost-effectiveness as a secondary objective for their supplemental E&H systems if it meant additional funds or administrative effort had to be committed to the service to make shared riding feasible.

The diffusion of information about other DRT systems in California is the third factor that influences system organization choices by sponsors. Typically lacking any detailed knowledge of paratransit operations and often unable to afford a consultant to plan the system, most sponsors sought to simplify the task of designing the service by seeking out service models that had achieved good results elsewhere.

Several sponsors that desired a system that could provide basic public transit used the highly successful El Cajon SRT system as their model, thereby organizing their system on the basis of an integrated fleet, shared riding, and compensation for consumed service. Many of the sponsors who organized subsidized ERT systems admitted that they were simply following the lead of a neighboring city or adopting the general practice for an E&H system in their region. The search for the best system organization scheme for a particular local situation thus tended to be limited except in cases where the sponsor was either unusually knowledgeable or required a cost-effective basic transit system.

Table 1. Compensation arrangements and mode of operation by different subsidy and vehicle use combinations.

System Organization Arrangement	No. of Systems[a]
User-side subsidy, integrated fleet systems	
ERT operations, ERT meter-fare compensation	25[b]
ERT operations, fixed-fee compensation	4
SRT operations, fixed-fee, zonal-fare, or mileage compensation	5
SRT operations, ERT meter-fare compensation	5[c]
User-side subsidy, dedicated vehicle systems	
SRT operations, fixed-fee compensation	5
Provider-side subsidy, dedicated vehicle systems	
SRT operations, vehicle-hour compensation	6
SRT operations, cost plus compensation	1

[a]Total sums to more than 48 because 3 systems use multiple arrangements.
[b]In several systems meter fares are discounted by 10 percent.
[c]In three systems shared riding practiced on only one leg of user round trip and meter fares are discounted by $0.25.

User Payment System

Many sponsors of California's taxi-based E&H systems devoted at least as much attention to devising a user payment mechanism as they did to such factors as provider compensation and mode of operation. In part, this preoccupation with revenue management is attributable to a state requirement that at least 10 percent of the total cost of an E&H system must be recovered from the farebox. More importantly, the use of a taxi provider, particularly in the context of user-side subsidies, creates additional options for user fare payment compared with conventional transit. As indicated in the table below, sponsors have used four different methods for recovering revenues from users of the system (note that for scrip with discount that it is a cash discount of 50-90 percent of scrip face value):

Mechanism	No. of Systems SRT	ERT	Total
Scrip with discount	0	15	15
Tickets or coupons	9	6	15
Tickets with meter limits	1	7	8
Cash fare	10	0	10

There is a strong relation between system mode of operation (SRT or ERT) and user payment mechanism. Shared-ride systems rely either on tickets, which users typically purchase from the sponsor for $0.50 or $0.75, or on cash fares, which are also generally in the $0.50-$0.75 range. The SRT systems that use tickets are predominantly those based on integrated fleet, user-side subsidy arrangements, while the cash fares are used primarily in dedicated vehicle, provider-side subsidy systems. In general, the more complicated ticket mechanism is used instead of cash fares only when it is an integral part of the provider-compensation scheme; that is, when the provider is reimbursed a fixed fee per ticket collected. In such cases, the ticket mechanism enables the sponsor to target subsidy at eligible users, to easily adjust the level of subsidy and provider payment, and to ensure provider honesty in reimbursement claims. When provider-side subsidy is used, however, these benefits are substantially reduced and sponsors are more sensitive to the administrative costs and inconveniences of ticket schemes.

ERT systems, on the other hand, have made extensive use of scrip payment schemes while completely shunning cash fares. The scrip system is well suited to subsidized ERT. It works well with meter fares, is readily converted to cash, and therefore meets little resistance from drivers or owners. Perhaps the main advantage of the scrip system is that it enables sponsors to recover a guaranteed, and usually higher, percentage of service costs from the user compared with other payment mechanisms. Scrip discounts to the user average 75 percent and range between 50 and 90 percent. Scrip, like tickets, can be rationed when the E&H system operates under a tight budget. Moreover, another attraction to budget-conscious sponsors is that scrip systems contain an inherent disincentive to long and costly ERT trips, since the user is paying a fixed percentage of the actual meter fare. A simple ticket system, in contrast, does not discourage such trips. About half of all sponsors of subsidized ERT systems that use tickets have been forced to adopt a limit on the meter fare for which the ticket is sufficient user payment; additional mileage is paid for solely by the user. The scrip system and the ticket scheme with a meter fare limit are employed predominantly by the most fiscally constrained sponsors, and they have proved to be effective mechanisms for keeping subsidy requirements within stringent budget limitations.

TAXI FIRM IMPACTS

Financial Impacts

Becoming a public transportation provider is a significant development for any taxi firm, but impacts on E&H service providers are typically much less significant than those that occur to taxi firms that become general-public DRT (or other public transit) contractors. Two readily available impact measures are the number of transit systems (both E&H and general-public) for which the taxi company is a provider and the revenues the firm receives from its transit contracts.

Taxi firms that are primarily E&H service providers generally have a lower level of involvement in public transportation operations than general-public DRT taxi providers. Only 4 of the 41 California taxi firms that are E&H-only service contractors have obtained multiple exclusive contracts for public transportation services. Sixty percent of the E&H-only service providers participate in but a single public transportation operation, whereas 73 percent of the taxi firms that have general-public DRT contracts are providers for more than one system.

Because the size of DRT contracts can vary widely, the amount of revenues the firm receives from contract operations is probably a better measure of impacts than the number of systems in which it participates. As indicated in Tables 2 and 3, 29 percent of all E&H service providers obtain at least $100 000 from contract operations and about 15 percent make $250 000 or more. However, among providers who participate only in E&H systems, only 22 percent derive $100 000 or more from contracts and a mere 5 percent make as much as $250 000. In contrast, 55 percent of all taxi firms with general-public DRT contracts make at least $250 000 from these operations.

Those E&H service providers who also operate general-public transit systems (DRT or fixed-route) gross approximately $510 000 annually from their public transportation contracts. For all California taxi firms that are general-public DRT providers, average annual contract revenues are about $390 000. In contrast, firms that operate only E&H systems receive an average of $76 000 annually from these contracts. Thus, E&H-only service providers make an average of only 15 to 20 percent as much from public transit contracts as do their more widely diversified counterparts.

Financial impacts on providers are also significantly affected by system organization factors, particularly whether or not the taxi firm is the opachieve high productivities. However, subsidized ERT systems are almost always high-cost services. Even though the provider is paid only for consumed service, the low productivity of conventional taxicab operations creates a need for ERT fares to be relatively high. Only when trip lengths are short (1.5 miles or less) can subsidized ERT compete with the cost-effectiveness of user-side subsidy SRT systems. The high costs of ERT-type services also include a significant administrative cost component, nearly $1.25/passenger, or more than 20 percent of total system costs for the majority of systems. Although only a handful of the subsidized ERT systems spend large absolute dollar amounts on administration, virtually all must allocate a significant proportion of total program funds to this activity due to the requirements of certifying and checking user eligibility, selling scrip or tickets, and ensuring that a limited budget is not exceeded--all of which are integral aspects of this type of E&H system.

In general, the most cost-effective way of organizing an E&H system is to establish a shared-ride service and compensate the provider on the basis of consumed service units. The cost-effectiveness superiority of such systems--about 40 percent--is an expected result. It is consistent with previous findings for taxi-based general-public DRT systems, which have demonstrated that an integrated fleet SRT system with consumed service payment was considerably more cost effective than the dial-a-ride form of system organization (1). The very purpose of shared riding is to achieve the highest possible productivity, and the use of consumed-service compensation gives the operator a compelling incentive to be as productive as possible. It bears emphasis that the absence of restrictions on elderly and handicapped use of these systems is an important reason that they were able to achieve levels of productivity that kept costs per passenger low. With utilization rates 3 to 6 times those of the other types of service, demand density was at a level where shared riding was easily accomplished. In addition, the combination of relatively high ridership and lack of stringent use restrictions reduces administrative burden, both relatively and absolutely.

CONCLUSIONS

During the past several years, taxi firms have emerged as the principle providers of DRT service for the elderly and the handicapped in California. The proliferation of taxi-based E&H systems has occurred not only because taxi firms have a cost advantage over other potential providers but also because they are uniquely well suited to the requirements of a restricted-ridership DRT system. The low demand prevailing in many such systems makes the traditional dial-a-ride form of DRT organization either infeasible or overly expensive. Integrating the E&H service with the local taxi firm's other services by using either shared riding or exclusive riding is usually a simpler and relatively less-expensive way of providing the desired service.

Almost 50 taxi firms are currently involved in restricted-ridership DRT systems in California, but the number that experiences substantial favorable impacts is much less. Although a handful of companies have benefitted significantly from a single subsidized ERT contract, the largest benefits have typically accrued to firms that are involved in shared-ride E&H service operations, provide service for a general-public DRT system, and possess multiple public transportation contracts.

Significant impacts from public transportation involvement are particularly a function of the provision of shared-ride services. Not only do SRT providers receive more revenue than those firms that provide only subsidized ERT service, but many are also engaged in a diversification process that has improved their overall capabilities and established them as competent paratransit contractors. In contrast, companies whose only contracts are for subsidized ERT services typically remain as conventional taxi operators, noninnovative and heavily dependent on a single type of service that has steadily experienced a market shrinkage. Although subsidized ERT has short-run benefits for these firms, it may not be a long-run solution to the problem of ERT decline.

Shared-ride operations are also the key to cost-effective organization of an E&H system. The most cost-effective method of organizing many E&H services is through the El Cajon model--a single provider, shared riding, user-side subsidies, and an integrated fleet. Subsidized ERT is a significantly more expensive service, but it is probably the only feasible strategy in situations of very low demand where the sponsor faces a severe total cost constraint. Overall, taxi-based E&H services are about 30 percent more expensive than taxi-based general-public DRT.

We are thus left with the central dilemma of taxi-based E&H services. Shared-ride operation is the key to good system performance, the most favorable financial impacts, and the initiation of the taxi provider's evolution toward a paratransit contractor; it therefore should be employed whenever possible. However, restricting use of the service to the elderly and the handicapped in response to financial constraints results in low service demand, which is an impediment to shared riding. On the other hand, low demand is the factor that makes the local taxi firm such an appropriate choice of provider for many E&H service programs. If California's experiences are representative, taxi-based forms of service are the wave of the future in transportation for the elderly and the handicapped. The issues now are how to improve the cost-effectiveness of these services and how to organize and use them to foster long-lasting beneficial impacts for participating taxi firms.

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