Issues on the Application of an Advanced Public Transit System to Dial-a-Ride Service

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Abstract

The Federal Transit Administration's Advanced Public Transportation System (APTS) program consists of demonstration projects that illustrate the use of new technologies in public transit. In view of the fact that similar systems are beginning to use new technology to locate and dispatch vehicles, this article reports on a study that examined issues that must be considered in implementing new systems. Specifically, the study focused on initial parameters for the computer program, defining and accessing these parameters in relation to quality of service, and measuring rider responses to guarantee performance.

The implications of these issues for service quality were examined for the APTS demonstration project in Winston-Salem, North Carolina. The study analyzed consumer response to the Mobility Manager, a Geographic Information System (GIS) applied to the site's demand-responsive minibus service for the elderly and people with disabilities. Survey data from two questionnaires issued before and after the implementation of the Mobility Manager were utilized to examine travel behavior and perceived service quality. In addition, data from driver manifests issued after implementation of the Mobility Manager are used to clarify results.

Introduction

This article examines three key issues that affect service provided by an APTS:

1. Selection of the appropriate software (see, for example, Stone et al. 1993).
2. Establishment of the initial parameters in terms of quality of service provided each day and level of service desired.
3. Assessment of daily service quality as perceived by users of the service.

In particular, the article reports on a study of the Mobility Manager APTS demonstration project in Winston-Salem, North Carolina. The study first looked at the key initial parameters used during implementation of the Mobility Manager. Next, it investigated changes in the quality of service performance, as indicated by consumer responses before and after implementation and confirmed results with driver manifest data. The study focused on service characteristics derived from the Code of Federal Regulations, Title 49, Part 37, including travel time, on-time performance, and acceptance of travel requests. Trip rates were used as a surrogate for acceptance of travel requests.

The APTS program of the Federal Transit Administration involves projects that demonstrate application of advanced technologies in transit systems (Casey et al. 1991). This article focuses on the site's TransAID operations, a minibuses dial-a-ride service for special populations in Winston-Salem. TransAID utilizes new transit technologies including automated computer dispatch, automatic vehicle location, and smart cards. Taken together, these technologies make up the Mobility Manager—a GIS combined with a management information system that assists the transit agency in scheduling, routing, billing, and administration.

TransAID services are provided in eight 15-passenger minibuses (vans) equipped for nondisabled passengers and 11 vans equipped for wheelchairs. The system operates in Forsyth County, which includes Winston-Salem, from 5:30 A.M. to 6:30 P.M. during weekdays. Limited service is provided for dialysis patients on Saturdays. No fare is charged for the TransAID service. The study analyzed TransAID services in 1994, the year the Mobility Manager

was implemented, and 1996. The dial-a-ride system operated 12 vehicles in maximum service during these two years. In the study years, annual passenger miles decreased from 955,328 to 435,959 and trips per vehicle-revenue mile decreased from 0.46 to 0.30 (Federal Transit Administration 1994, 1996).

The Mobility Manager provides each driver with a computer-generated daily detailed schedule. As part of the study, the schedule was manually reviewed for missed appointments and operating efficiency. Two key parameters for the analysis were the maximum travel time of 2 hours and the pickup time window of 20 minutes. Manifests were reviewed for scheduling errors with the possibility of a manual override when necessary.

The Mobility Manager was intended to improve service quality. In particular, it was designed to enhance the system's telephone response service. Confirmation of reservations was expected to be immediate, travel time would be reduced, and pickup and dropoff times would be more accurate.

Study Design

This section presents findings from before and after studies of consumer responses along with their comparison to vehicle scheduling information acquired in October 1997. An initial analysis of service evaluations presented in Benjamin et al. (1997) was inconclusive. Spring et al. (1997) investigated the performance of system components for the Mobility Manager and the results also showed no service improvements.

The Mobility Manager's effectiveness depends on the efficiency of the automated routing and scheduling system. The capabilities of automated dispatching systems for dial-a-ride services have been studied for more than two decades. Lerman and Wilson (1974) and Lerman et al. (1977) discuss initial attempts at computer-automated dispatching. Based on comparisons to a computer simulation, these studies reported a 10 to 20 percent reduction in average travel time from automated routing and scheduling procedures. These studies also noted that the first automated system application provided travel times comparable to manual schedules but with more reliability for on-time pickup and delivery.

Three Data Sets

Three different data sets were used in the current study. These include:

- survey data (the before study) of rider travel before implementation of the Mobility Manager was completed in the summer of 1994,
- survey data (the after study) that replicated the before study with the same subjects two years later (1996), and
- driver manifest records from a week in the fall of 1997 that were selected at random by the transit authority.

User questionnaires consisted of three parts:

1. Respondents were asked how they traveled during the last week (number and purpose of all trips using the dial-a-ride service). The time frame of a week was chosen because of the low daily trip rate for these subjects.
2. Respondents were asked to provide details about the last time they traveled including travel time, on-time pickup and arrival, and about reserving the trip.
3. Respondents were asked about their background (gender, age, income, and mobility-related disabilities).

Driver manifests were used to compare planned and actual travel times to reported times from the survey data to confirm reported results and to determine operation details. Planned times were provided as computer output and actual times were entered by the drivers. Driver manifests were used because the survey recorded riders' perceptions. The manifests were considered to be more accurate and allowed an evaluation of what travel times were planned by the system and not due to traffic or other factors. Cross-sectional comparisons were possible because all samples were random.

In addition, the time to complete the direct trip (base time) was used to evaluate the planned schedule. Although it was anticipated that travel time was longer for shared-ride service, the base time provided an idea of how much extra time was required and whether the extra time was related to the direct distance of the trip.

The second survey was performed two years after implementation of the Mobility Manger. This lag gave both riders and operators time to adjust to the system and to measure more accurately its full impact.

Survey Respondent Descriptions

The before-study survey was completed by 272 TransAID riders, of which 176 were still service users at the time of the after study, and were contacted by mail to participate in the after study. Of the 176 people, 162 responded to the after study, and 101 surveys were completed (Table 1).

General Socioeconomic Statistics

The initial data analysis was presented by Benjamin et al. (1997). A summary of sociodemographic descriptions of respondents is presented in Table 2. Note that disabilities are not mutually exclusive and some riders have more than one disability.

The lack of significance of all of these χ^2 statistics indicates that in a comparison of the characteristics between the before and after studies there is no

Table 1 Respondents' Survey			
<i>Measure</i>	<i>Level</i>	<i>Frequency</i>	<i>Percent</i>
Surveys	Complete	100	62
	Incomplete	62	38
	Total	162	100
<i>Measure</i>	<i>Level</i>	<i>Frequency</i>	<i>Percent</i>
Incomplete	Doesn't use service	14	23
	Phone disconnected	13	21
	No contact	12	19
	Doesn't live at this phone	9	15
	Deceased	8	13
	Nonpublished phone	2	3
	Not interested	2	3
	No recollection	2	3
	Total	62	100

Table 2
Respondent Sociodemographics

<i>Measure</i>	<i>Levels</i>	<i>Before Study</i>		<i>After Study</i>	
		<i>Frequency</i>	<i>Percent</i>	<i>Frequency</i>	<i>Percent</i>
Age	18–39	19	8.09	1	1.02
	40–64	54	22.98	26	26.53
	More than 64	162	68.94	71	72.45
	Total	235	100.00	98	100.00
	$\chi^2 = 0.41$	$p = 0.52$			
Education	Elementary	76	35.68	29	31.18
	High School	110	51.64	49	52.69
	College	27	12.68	15	16.13
	Total	213	100.00	93	100.00
	$\chi^2 = 0.96$	$p = 0.62$			
Employment	Employed	5	2.26	2	2.02
	Unemployed	216	97.74	97	97.98
	Total	221	100.00	99	100.00
	$\chi^2 = .02$	$p = .89$			
Disability	Seeing	95	42.99	12	12.12
	Hearing	101	45.70	4	4.04
	Grasping	81	33.65	16	16.16
	Walking	139	62.90	65	65.65
	Wheelchair	83	37.56	26	26.26
	Total	221	100.00	99	100.00
	$\chi^2 = 42.4$	$p = .00$			

statistically significant difference for age, education, and employment. Further, there are few people who were employed in both studies.

Service Usage and Quality

Responses before and after implementation of the Mobility Manager were analyzed to determine service utilization and quality. For this group, 45 percent of riders rode TransAID the week before the first survey but only 30 percent used the service the week before the second survey. The trips reported were unequally distributed between days of the week. The largest number traveled

on Monday (47%), with other trips distributed over the remaining portion of the week. Only 2 percent of the sample rode on Saturday, and no service was provided on Sunday. Similar results were reported in the second survey.

Table 3 shows trips made by disability and trip purpose. Of these trips, 76 percent of the before-study (74.4% of the after-study) group traveled for medical reasons. The majority rode for medical reasons in each disability group in the before and after studies and the disability group with the largest percentage of medical trips was for those people who had difficulty walking. Virtually all of the trips were round-trips, and most people traveled by TransAID only once during the week. The average number of trips by all modes reported during the survey week was 2.8 in the before study and 3.8 in the after study. Only one-third of the respondents made a second round-trip, and about one-fourth made more trips. Thirty-seven users made five round-trips, and only one rider reported making a sixth trip (for a medical purpose) before and, at most, five round-trips after. The χ^2 test for independence of the distributions of trips in the before and after studies was significant, which may be related to differences in reported disabilities.

Table 3
Percent of Weekly Trips by Disability and Trip Purpose

<i>Trip Purpose</i>	<i>Before Study</i>					<i>After Study</i>				
	<i>I</i>	<i>II</i>	<i>III</i>	<i>IV</i>	<i>V</i>	<i>I</i>	<i>II</i>	<i>III</i>	<i>IV</i>	<i>V</i>
Medical	70.3	100.0	61.2	83.6	70.5	63.2	100.0	63.0	83.8	54.4
Other	29.7	0.0	39.8	16.4	29.5	36.8	0.0	37.0	16.2	45.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Observations	23.0	8.0	34.0	131.0	87.0	8.0	1.0	20.0	59.0	13.0
Trips	74.0	20.0	93.0	341.0	146.0	19.0	1.0	27.0	74.0	22.0
I	Difficulty seeing									
II	Difficulty hearing									
III	Difficulty reaching and grasping									
IV	Difficulty walking									
V	Uses a wheelchair									
	$\chi^2 = 50.0, p = .0$									

Change in Service Usage Patterns after the Mobility Manager

Table 4 summarizes travel by trip purpose and age group. Only adults between the ages of 18 and 65 have a significant amount (about 20%) of educational trips.

Service was requested at a minimum of 24 hours in advance during the before study with a no same-day requests after despite the addition of that option during the after study.

Table 4 Trip Purpose by Age Group (among all one-way trips)				
Trip Purpose	Age			
	Before Study		After Study	
	18-65	Over 65	20-67	Over 67
Medical	78.3	72.0	71.2	60.0
Other	21.7	28.0	28.8	40.0
Total	100.0	100.0	100.0	100.0
Observations	77.0	154.0	35.0	63.0
Tours	111.0	202.0	59.0	90.0
	$\chi^2 = 4.34$ $p = .23$			

For respondents more than 65 years old in the before study, 72 percent of the trips were made for medical purposes. For the above 65-year-old group, other trip purposes included shopping and nutrition, with each representing about 10 percent of the trips, demonstrating that TransAID was helping with their daily activities. The χ^2 test for dependence of the distribution of trip purposes from the before and after studies was not significant, indicating stable travel patterns.

Comparison of Service Characteristics before and after Implementation of the Mobility Manager

Three sets of data were used to examine improvements in service characteristics: travel time, on-time service, and trip rates as a surrogate for accessibility. Three data sets were available for the first two measures: the complete original data set, panel data (with attrition), and observations from driver man-

ifests. Cross-sectional analyses were completed with the original data set and the after-panel data because of the difference in respondents due to attrition. Panel data were tested because of advantages in providing more precise results and cross-sectional analyses were conducted with observations from driver manifests to clarify the after results. Only statistics for adults 18 years and older in the before study, age 20 and older in the after study, and the driver manifests are reported.

Analysis of Changes in Travel Time

Travel time statistics for the initial total sample, for the responses of subjects who continued with the panel before and after the project, and observations from driver manifests are presented in Table 5. There was an increase in average travel time for comparisons between cross-sectional before data and recent driver manifest data (22.8 to 36.2 minutes with $t = 5.51$), between cross-sectional before data and the after-panel subsample (22.8 to 27.3 minutes with $t = 2.06$), and between responses given by panelists before and after project initiation (a difference increase of 7.5 minutes with $t = 3.1$). All of the differences were significant at the 5 percent level. The observed maximum planned time is almost three hours (173 minutes)—almost one hour more than the maximum reported before time and the initial heuristic parameters. These time increases

Table 5
Reported and Observed Travel Time Changes

<i>Parameter</i>	<i>Survey Data</i>				<i>Manifest Data</i>		
	<i>Total Sample</i>	<i>Panel</i>					
	<i>Before Study</i>	<i>Before Study</i>	<i>After Study</i>	<i>Difference</i>	<i>Planned</i>	<i>Actual</i>	<i>Base</i>
Mean	22.8	20.4	27.3	7.5	38.6	36.2	10.2
Maximum	240.0	120.0	90.0	55.0	173.0	105.0	6.0
Minimum	0.0	0.0	5.0	-100.0	1.0	0.0	32.0
Standard deviation	23.0	15.8	15.6	19.9	23.5	29.7	0.0
Number of cases	194.0	85.0	77.0	68.0	428.0	491.0	10.0

are meaningful and are evidence that intended service improvement for riders was not achieved.

Detailed Analysis of Passenger Travel Time after Implementation of the Mobility Manager

Table 5 also presents summary measures of planned travel time by the Mobility Manager that were taken from recent manifests and base travel time, which is the travel time for a direct trip based on the MAPQUEST GIS shortest route (GeoSystems, 1998). On average, a passenger requested service for a trip of 4.1 miles, which takes 10.2 minutes (base travel time). The passenger was initially scheduled to be on a vehicle for 38.6 minutes on average, while actually he or she was on a vehicle for 36.2 minutes on average.

There are substantial variations among base travel time with a median base time of 10 minutes, indicating that most service requests are for relatively short trips within the city limits. The longest trip request takes 32 minutes, while the shortest request takes less than 1 minute (0.1 mile).

Actual travel time is much longer than the base travel time: 36.2 minutes on average, with a maximum of 105 minutes, a minimum of 0 minute, and a median of 30 minutes. In the trip with the longest actual travel time, a passenger requested a 5.5-mile trip, which takes 11 minutes base travel time, but actually took 105 minutes. A detailed inspection of the manifest revealed that the passenger was among seven passengers picked up at the same origin. The vehicle picked up four more passengers at the next stop. Finally, the passenger was dropped off ninth, after all other six passengers picked up at the first origin with her had already been dropped off and two other passengers picked up at the second stop had been dropped off. As a result, she traveled 42 miles and was on the vehicle for 105 minutes.

The actual travel time is clearly the result of the planning process using the Mobility Manager. Study data reveal that the average planned travel time is 38.6 minutes, which is slightly longer than the average actual travel time, with a maximum of 173 minutes (nearly 3 hours). Again, the researchers looked closely at the case of the longest planned travel time. The passenger requested a 5.0-mile trip, which takes 13 minutes base travel time, but he was

scheduled to take a 173-minute trip. He was among 12 passengers scheduled to be picked up at the same origin, and scheduled to be dropped off last. Thanks to five cancellations, he was actually on the vehicle for 80 minutes. Furthermore, of 11 passengers with him, 3 requested longer trips (base travel time) than his.

The overall effect of the Mobility Manager is illustrated in Table 6. The table presents travel time for multiple shared-ride trips and for single passengers. In this table, the average actual travel time for riders who travel without other passengers is significantly less than for riders who travel with multiple passengers (26.7 compared to 40.1 minutes with $t = -3.16$).

Table 6						
Travel Time for Multiple Passengers versus Single Passengers						
	<i>Multiple Passengers</i>			<i>Single Passengers</i>		
	<i>Base Time</i>	<i>Actual Time</i>	<i>Planned Time</i>	<i>Base Time</i>	<i>Actual Time</i>	<i>Planned Time</i>
Average	9.3	40.1	43.8	13.1	26.7	23.9
Standard deviation	5.3	24.8	31.5	6.1	16.6	16.9
Maximum	2.3	105.0	173.0	32.0	100.0	101.0
Minimum	0.0	0.0	1.0	0.0	5.0	4.0
Median	9.0	35.0	37.0	12.0	23.0	20.0
Sample size	330.0	303.0	362.0	107.0	125.0	129.0

Difference among Travel Times

To further emphasize the role of the dispatching procedure using the Mobility Manager, the difference between actual travel time and base travel time (actual extra travel time) was examined for each trip. The difference indicates how many extra minutes each passenger must be on a vehicle if the passenger chooses to use TransAID service rather than an alternative transportation mode.

Table 7 shows that, on average, the difference between actual travel time and base travel time is 26.4 minutes, with a maximum of 96 minutes. The dif-

ference may depend on the number of passengers picked up at the same origin or dropped off at the same destination (or number of passengers on a vehicle at the same time).

Table 7			
Passenger Travel Time after Implementation of Mobility Manager			
	<i>Planned Travel Time Minus Base Travel Time</i>	<i>Actual Travel Time Minus Base Travel Time</i>	<i>Actual Travel Time Minus Planned Travel Time</i>
Average	28.4	26.4	-2.1
Standard deviation	28.3	23.5	26.1
Maximum	160.0	96.0	92.0
Minimum	-9.0	-11.0	-99.0
Median	20.0	19.0	0.0

The difference between planned travel time and base travel time is 28.4 minutes on average, with 160 minutes maximum. These figures are both longer than the difference between actual travel time and base travel time, indicating that a long actual trip is not accidental, but actually scheduled to last long.

Because of unexpected cancellation of scheduled trips and unexpected request of unscheduled trips, the actual travel time could differ from the planned travel time, where the former factor reduces the actual travel time and the latter factor increases the actual travel time. On average, the difference is only -2.1 minutes. A negative average indicates that TransAID operation tends to schedule each trip slightly longer than it actually takes, though it is not statistically significantly different from 0. However, the individual’s actual travel time could be 99 minutes shorter or 92 minutes longer than initially scheduled.

Analysis of Changes in Timely Arrivals

Transit authority policy of a 20-minute window applies specifically to pickup time at the origin. However, the ability to arrive at the destination in a timely manner is also important. The percent of people who reported arrival at the origin greater than the allowable 20 minutes before or after the scheduled

time was 15.9 percent for the entire before sample; 12.0 percent, panel before sample; 14.3 percent, panel after study; and 34.6 percent, driver manifests. The z statistics for the reported comparisons of the complete before sample and the after panel and the panel data are 0.7 and -0.7, which are not significant at the 5 percent level. The manifest data, however, when compared to the after-reported data had a z statistic of 4.9, which is significant at the 5 percent level. In other words, the reported times were significantly smaller than the observed manifest data.

Delay time is defined as the difference between planned and actual arrival time at either the origin or destination. Delay time statistics are presented in Table 8. Delay time was analyzed for both pickup and arrival at the destination. For pickup, there was no significant difference in delay time. Despite the low average pickup delay, there were maximum delays of up to two hours that continued after implementation of the Mobility Manager that exceed the desired limits.

Further, an increase in average delay time at the destination was observed for the total before sample with the after-panel subsample (-4.2 to -20.0 minutes with $t = 3.10$), for the before- and after-panel subsample (-4.8 to -20.0 minutes with $t = 6.3$), and the total before sample with the manifest (-4.2 to -7.6 minutes

Table 8
Reported and Observed Delay Time

Parameter	Reported						Observed	
	Total Sample		Panel					
	Before Study		Before Study		After Study			
	Origin	Destination	Origin	Destination	Origin	Destination	Origin	Destination
Mean	-3.7	-4.2	-4.5	-4.8	-4.6	-20.0	-3.7	-7.6
Maximum	90.0	60.0	90.0	60.0	45.0	45.0	60.0	60.0
Minimum	-120.0	-120.0	-120.0	-180.0	-120.0	-120.0	-123.0	-123.0
Standard deviation	22.2	19.2	24.3	20.4	23.6	13.7	25.2	25.2
Number of cases	271.0	271.0	100.0	88.0	101.0	26.0	461.0	442.0

with $t = 3.27$). All of these t statistics are significant at the 5 percent level. Delays as much as two hours were observed for both reported times and times after implementation of the Mobility Manager.

Analysis of Changes in Trip Rates

Trip rate is the number of trips taken in a week. Trip rate responses were taken only from reported data and are summarized in Table 9. The trip rate increase for the panel was significant at the 5 percent level ($t = 5.2$) but the cross-sectional comparison was not significant. This indicates that the trip rates were stable for these subjects.

Table 9				
Reported Number of Weekly Trips by TransAID Riders				
<i>Parameter</i>	<i>Total Sample</i>	<i>Panel</i>		
		<i>Before Study</i>	<i>After Study</i>	<i>Difference</i>
Mean	1.8	1.4	1.9	1.4
Maximum	6.0	6.0	5.0	7.0
Minimum	0.0	0.0	1.0	-3.0
Standard deviation	1.5	1.2	1.2	2.0
Number of cases	251.0	93.0	56.0	56.0

Given a large overall attrition rate (63%), an insignificant increase in the trip rates per user resulted in less overall usage of the TransAID services during the study period, as indicated in decreases in annual passenger miles and trips per vehicle-revenue mile during the study period.

Conclusions

During the study period, there was little change in the environment. There was no change to the street network, passenger eligibility qualifications, fares, or management personnel. Little change occurred in the number and type of vehicles. There were no significant differences between age, education, and employment of the total before and after panel sample. However, since this is not a controlled experiment and detailed information on dispatching before the Mobility Manager is unavailable, the researchers must qualify their conclusions.

Several key findings emerged from this study. First, there is substantial attrition in the panel. While attrition in panel studies may be 10 percent, the

total attrition here is 63 percent. This is large even if the small number of Head Start riders is considered. Of these subjects, there were only two refusals (less than 1%). Attrition may be due to changes in travel behavior over time, substitution of other modes, or the transient nature of the service population. The remaining users included a large number who moved or changed phone numbers. This suggests that future research on new transit technologies, such as the Mobility Manager, should oversample the relevant population.

Second, the results of the comparison of surveys suggest that implementation of the Mobility Manager in Winston-Salem did not clearly achieve the intended improvements, despite the potential for travel time reductions reported in earlier studies.

Third, for the three key variables identified by federal regulations (travel time, pickup delay time, and trip rates as a surrogate for accessibility), it was found that travel time increased, there was no change in pickup delay time (but a significant increase in dropoff delay time), and the trip rates remained stable for these subjects. The researchers believe there is a trade-off between travel time and efficiency. While individual performance measures decreased, overall system efficiency did not improve.

These performance results highlight the importance of the three issues mentioned earlier: input parameters that were used for the dispatching heuristic, regular monitoring of the service operation through driver manifests, and periodic review of consumer surveys.

Two parameters in the heuristic were critical. Maximum travel time was set at 2 hours and the pickup time window was 20 minutes. Setting parameters is one way to establish policy for an APTS. Careful review should be given to the setting of these parameters including input from riders.

These results suggest that service performance should be monitored daily. When computer manifests are available, their schedules may be reviewed daily and possible problems addressed by careful monitoring by trained personnel who can correct and manually improve scheduling errors. Manifest reviewers should be assisted by computer output that includes calculation of statistics to recognize problems (e.g., the travel and delay times that exceed predetermined

limits) and flags to help find scheduling errors. Long travel times occurred when there were many additional stops during a shared ride. Daily summary statistics would serve to alert reviewers of persistent problems and assist in the review.

Also, users' views should be measured regularly to ensure that their perceptions on service quality are improving.

With automated dispatching becoming more widespread, this study suggests that the true potential of technologies, such as Mobility Manager, from the consumers' perspective is their ability to improve the perceived quality of service. Future implementation of technological improvements must consider the direct impacts on consumers.

Finally, several extensions and refinements are recommended for future studies. First, even though the researchers carefully controlled the before and after surveys, there always exist factors that change between the two periods and affect the survey results. Second, because the second survey was done two years after the first, changes due to aging of riders that may affect their health and comfort level should be taken into account. By measuring any health problems directly, their covariance can be controlled.

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