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Demand-responsive transportation is one of the advanced new transportation concepts that the U.S. Department of Transportation investigated as an urban transit system. In this respect, the Urban Mass Transportation Administration granted the New Jersey Department of Transportation a research, development, and demonstration grant to undertake the Haddonfield, New Jersey, DRT demonstration. Even though the DRT concept was known to transportation specialists for many years, only in recent years has adequate command and control technology been developed for demand-activated transportation systems to provide door-to-door, personalized, and shared-ride service at a reasonable price.

The Haddonfield demonstration was preceded by an experimental design that specified the following objectives for this demonstration (1):

1. Determine public attitudes toward and acceptability of the DRT concept;
2. Measure public use of the system and forecast demand for DRT, both in the Haddonfield area and in other communities in which it may be tried;
3. Determine the economic feasibility of a DRT system;
4. Test and evaluate the technical feasibility of the DRT concept; and
5. Measure and evaluate the impacts of DRT on the community.

PUBLIC ATTITUDES TOWARD DEMAND-RESPONSIVE TRANSPORTATION

Public attitudes toward DRT were assessed prior to and during the demonstration in Haddonfield through a series of surveys. These surveys also provided information on the trip-making behavior of the Haddonfield residents under different operating conditions.

In a predemonstration survey, about 75 percent of the PATCO High Speed Line users interviewed thought that they would use the service for the portion of their work trips between their homes and the PATCO station. Many of these residents were willing to use DRT for their work trips if the travel time was less than 20 minutes and the fare was less than 50 cents. On the other hand, the percentage was small for fare levels of 75 cents or more, and practically nobody was willing to use the system between home and the PATCO station if travel time was 40 minutes, regardless of fare level. This survey also indicated that the public attitude toward DRT was favorable if one considers that half of the households interviewed responded that they would make an average of 2 additional trips per week. It also showed that a high percentage of children's trips made as passengers in private automobiles might be made by riding DRT buses to the library or special school events. Those who indicated they might use the system ranked waiting time, amount of fare charged, door-to-door service, and attractiveness and comfort of the vehicle as important considerations. These public attitudes were the same for both work trips to the PATCO High Speed Line and for personal trips within the service area, such as those to the Cherry Hill Mall. The majority of those who responded negatively to the use of DRT felt that neither DRT nor the high-speed line goes near their places of work nor connects with transportation modes that do or responded that they were satisfied with driving or walking (2).

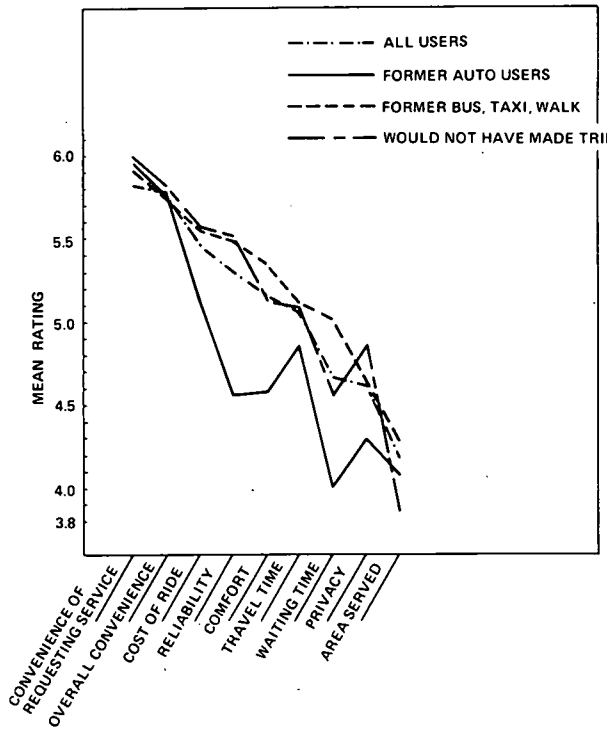
Table 3 gives the characteristics of DRT users and service area population according to surveys undertaken during the demonstration period (3). These on-board surveys also indicated that the percentage of nonwork trips made by DRT increases steadily with the age of the users and the percentage of work trips decreases steadily with the age of the users. This suggests that the system is serving 2 markets: the young people for work trips and the older people for nonwork trips (4). These users stated that convenience, cost, and reliability of DRT are the major determinants in the use of the system. The usual characteristics of wait time and travel time that are used to measure the quality of the service offered by DRT have little influence on the users.

Furthermore, a comparison was made of users' perceptions of the influence of DRT

Table 3. Characteristics of DRT users and service area population.

Characteristic	Users (percent)	Population (percent)
Age		
<15	4	29
15 to 19	14	9
20 to 24	13	5
25 to 64	54	48
>64	15	9
Income		
<$4,000	24	5
$4,000 to $10,000	33	22
$10,000 to $15,000	22	28
$15,000 to $20,000	12	15
>$20,000	9	30
Automobiles in household		
0	24	7
1	40	44
2	31	42
>2	5	7

Figure 1. Mean ratings of DRT characteristics.



characteristics and their perceptions of their former modes of transportation (5). This analysis indicated that former automobile users were not strongly influenced to use the system by the characteristics of DRT—which might explain the reason for not having a high modal shift from automobile to DRT. Former users of other modes and those who formerly did not make trips were influenced similarly to use the system by the characteristics of DRT (Fig. 1).

Surveys also indicated that the reasons DRT was not used often for work trips were the availability of automobiles and the trip destinations, which were outside the service area. Those who did not use the system because of availability of automobiles had a higher automobile ownership ratio. This fact seems to conform with the general attitude of urban travelers toward transit use and their preference for the automobile. This preference stems from the desire of these travelers to use a more convenient, comfortable, private, and flexible mode of travel, whose perceived cost of operation is low.

PUBLIC USE OF DRT

From February 1972 to September 1974, the total ridership of the Haddonfield DRT system was 657,761. On the average, about 80 percent of those trips were on weekdays, 13 percent were on Saturdays, and 7 percent were on Sundays. The monthly ridership trends of the system have been changing during the different phases of the demonstration as a result of changes in operating characteristics and seasonal effects.

Effects of Area Expansion

The initial DRT service area was 6.4 miles^2 (16.6 km^2) and had a population of 24,300. During the demonstration period, 3 area expansions occurred and resulted in different effects on system ridership.

The first expansion occurred on September 23, 1972, when 1.7 miles^2 (4.4 km^2), having a population of 3,112, was added to the original service area. The service area was increased by 26.5 percent and population increased 12.8 percent. This area expansion was not accompanied by an increase in vehicle supply, thus causing a significant increase in wait and ride times. Ridership increased from a weekly level of 3,000 to about 4,500 after the expansion as a result of both area expansion and the opening of schools and the arrival of the holiday season. The number of DRT trips increased 19.6 percent after the expansion, and the number of households increased by only 12.4 percent. This difference was due to the increased number of major trip generators available to the users (4). Because of increase in area but steady state of vehicle supply, the quality of service decreased, and this might be an important reason for the decline in ridership that occurred after the sharp increase following the area expansion.

This same situation occurred after the March 31, 1973, area expansion, which also was not accompanied by an increase in vehicle supply (Figs. 2 and 3).

The third area expansion of August 18, 1973, preceded by an addition of 6 buses to the fleet size, resulted in a sharp increase in ridership. In fact, ridership increased from about 750 to 1,000 on an average weekday and from about 525 to 950 on an average Saturday.

Effects of Changes in Mode of Operation

The most important changes in mode of operation, in terms of effects on ridership, were the introduction of the shuttle service and the reduction of fare from an average of 55 to 25 cents on October 20, 1973. Because of the introduction of these 2 changes on the same date, the advent of the holiday season, and the energy crisis, it was impossible to attribute the increase in ridership to either one of these parameters. Ridership increased by 40 percent (from 896 to 1,260 daily riders) after the fare

Figure 2. Daily DRT ridership from February 1972 to September 1974.

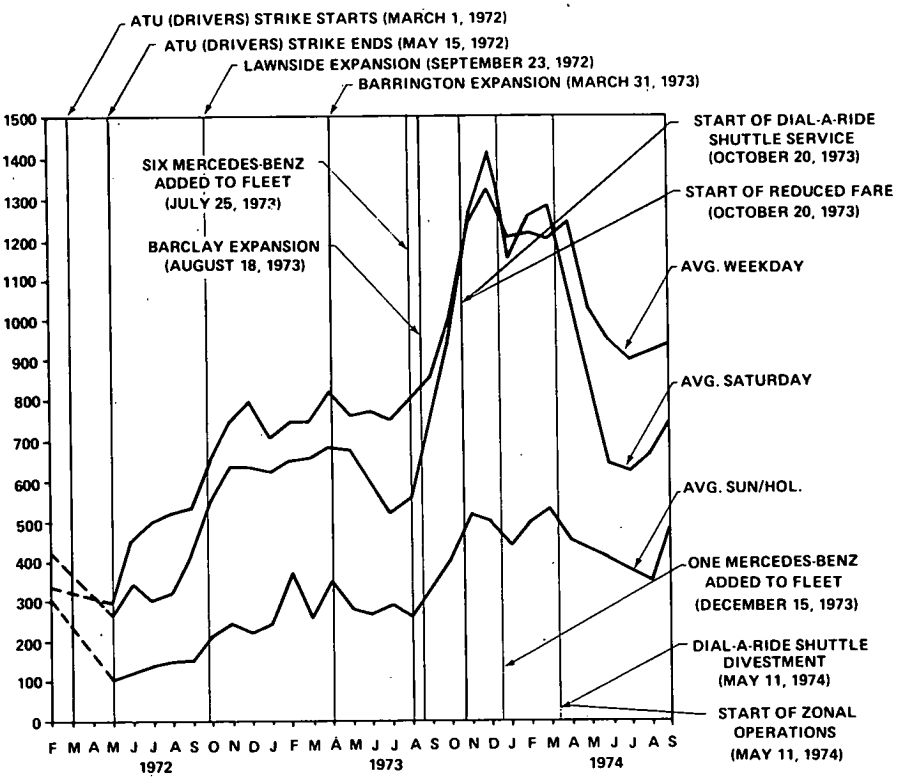
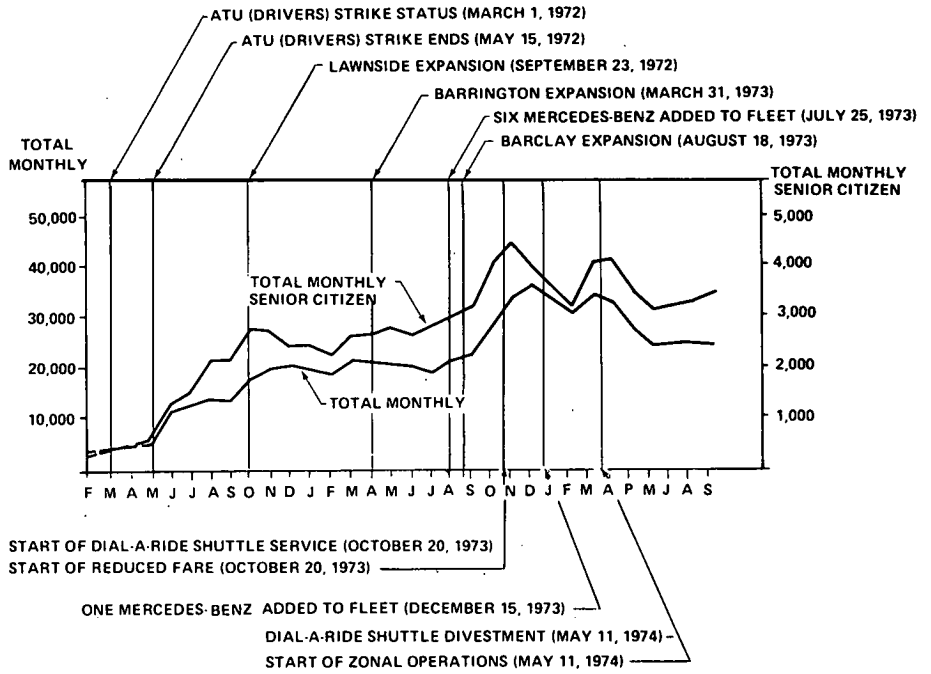


Figure 3. Monthly DRT ridership from February 1972 to September 1974.



reduction and introduction of shuttle service. However, this high ridership decreased to about 925 daily riders when Transport of New Jersey (TNJ) assumed the shuttle service (6). This decrease implies that the riders were more affected by the shuttle service than by the fare reduction. This fact seems to be in conformance with conventional transit systems, whose riders are more sensitive to service quality changes than fare changes. However, the attitudinal surveys regarding fare effects showed that the price elasticity of demand for DRT is similar to conventional transit systems at about the 60-cent fare level (6).

The introduction of zonal mode of operation and computer scheduling caused longer wait times, ride times, and pickup deviation times, which, in turn, seem to have affected ridership. An evaluation of these changes will be undertaken to determine the effects on ridership.

The ridership trend of senior citizens seems to be similar to the total ridership trends (Fig. 3). This implies that, on an aggregate basis, the senior citizens using the Haddonfield DRT system (about 12 percent of the users) seem to be equally sensitive to changes in the operating parameters of the system.

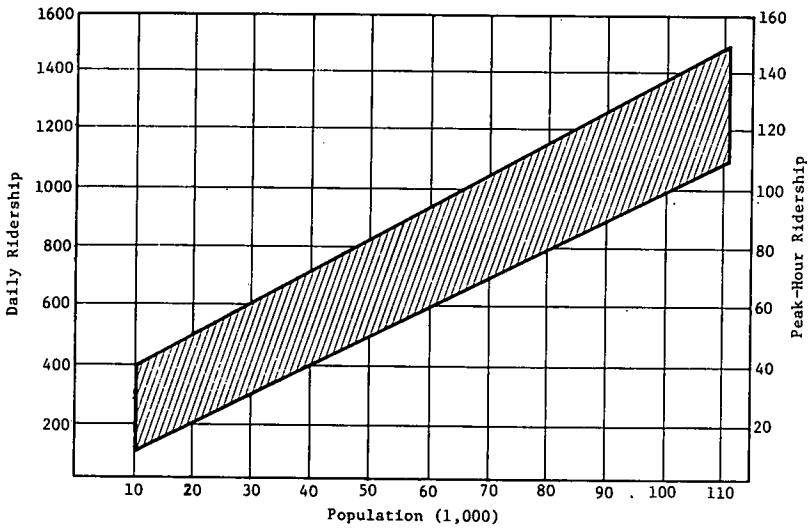
Comparison With Other Systems

In the process of evaluation of the Haddonfield DRT system, a comparison was made with other DRT systems operating in the United States and Canada (7). On an average basis, the Haddonfield DRT ridership seems to compare favorably with the range of the other DRT systems. This comparison was made after the same base line was established for the operating conditions—i.e., 16 hours of operation per day, 5 hours of peak period, and about 30 minutes wait time and 30 minutes ride time. For the period prior to the shuttle service and fare reduction, the adjusted ridership level was about 700, which is approximately in the upper range level when compared with the other systems (Fig. 4).

ECONOMICS OF DRT

The evaluation of the economic feasibility of the demand-responsive transportation concept as demonstrated in Haddonfield includes analyses of costs, revenues, and financing.

Figure 4. Daily and peak-hour ridership versus population.



The results include effects of experimentation and local conditions, and their application to other areas should be undertaken with care.

The costs of the Haddonfield DRT demonstration include the actual cost of the system, the costs of data collection and analysis, and management costs associated with the experimentation. A complete separation of the actual cost of operating the system from the experimentation is not possible; however, attempts were made to do so.

The largest percentage of the actual cost of the system is the operating cost, which is largely labor costs. In fact, labor costs consist of about 75 percent of the operating cost of the Haddonfield DRT system, and about 55 percent is for drivers. Thus, similar to conventional bus systems, DRT is a labor-intensive transit system and, therefore, its operating costs are highly related to wages. The average monthly operating cost of the Haddonfield system through June 1973 was about $33,000 for the fleet size of 12 vehicles (each having 17 seats and costing about $23,500) and 23 drivers. This monthly operating cost increased to more than $100,000 when the 6 buses (each having 10 seats and costing about $16,700) were added, the service area was expanded, and shuttle service and computer scheduling were introduced. Inflation—especially the higher cost of gasoline and wage increases—and the increases in hours of operation of each vehicle contributed to this increase in operating cost.

The average cost of operating a bus in Haddonfield was about $16.40 an hour with the manual scheduling-dispatching operation. This figure is lower than the average cost of $17.10 an hour to operate a TNJ fixed-route bus during 1973 (8). This comparison should not imply that any one method of operation is better than the other because each operates in an optimal fashion (in terms of unit costs) under different demand densities. The average cost per ride of the Haddonfield DRT service was about $3.28 from February 1973 to January 1974 and about $3.86 from February to June 1974. During the first period, the fleet size was increased and the service area was expanded; during the second period, computer scheduling was introduced.

The average revenue per trip on the Haddonfield DRT system varied between 52 and 56 cents prior to the fare reduction from 60 to 30 cents on October 20, 1973. Average revenue then dropped to about 28 cents per trip from November 1973 to May 1974, when the shuttle service was assumed by TNJ. Despite the drop in revenue per trip, the total monthly revenue remained approximately within the range of $9,000 to $12,000 because of the increase in ridership during the shuttle service. For 1973, the average revenue was 47 cents per ride, which results in approximately $2.80 in subsidy per ride. This subsidy could be reduced by increasing system productivity, imposing a more realistic fare level, attracting additional revenues from advertising, and operating efficiently with minimum experimentation.

TECHNICAL ASPECTS

The technical feasibility of the DRT concept as demonstrated in Haddonfield has been evaluated in terms of the effects of the operating parameters on the quality of service and vehicle productivity.

Vehicle Productivity

The vehicle productivity of the Haddonfield DRT system experienced variations from as low as 4 passengers per vehicle hour to as high as 11.4 passengers per vehicle hour on Saturdays during the shuttle service and reduced-fare operation. During the first 11 weeks of the demonstration, the average productivity was only about 4.09 passengers per vehicle hour because ridership was low and the fleet size was relatively high as dictated by the experimental nature of the project (9). This productivity was highest during the conventional off-peak periods of 9:00 a.m. to 4:00 p.m. and 7:00 to 11:00 p.m., which explained the relatively higher use of DRT for nonwork trip purposes.

With the service area expansion, ridership increased while the number of vehicles remained constant. This caused the average productivity to increase from 4.6 to 6

passengers per vehicle hour on weekdays and from 5.1 to 7.5 passengers per vehicle hour on Saturdays. It was hoped that ridership would increase sufficiently such that the service quality would decline to a level that causes a negative effect on ridership, passing through the point of optimal balance between vehicle productivity and ridership. This near-capacity condition did not occur because ridership did not increase enough to saturate the system operating under scatter-gather and many-to-many modes at a basic fare of 60 cents (10).

During the second year of operation, the average weekday productivity increased to a peak of about 6.6 passengers per vehicle hour and to an average of 6.3 passengers per vehicle hour. Lower productivities were experienced after the increase in fleet size because it caused a 39 percent increase in vehicle hours; monthly ridership picked up at much slower rates until the introduction of the shuttle service and fare reduction. Weekend productivities also increased from 7.7 to 11.4 passengers per vehicle hour on Saturdays and from 5.1 to 6.4 passengers per vehicle hour on Sundays. During this same period, a free-fare day was instituted on March 16, 1973, and the basic fare of 60 cents was eliminated. Productivity during that day increased to a maximum of 10 passengers per vehicle hour during the 7:00 to 9:00 a.m. morning peak and 16 passengers per vehicle hour during the 4:00 to 6:00 p.m. evening peak. On the average, productivity increased 50 percent during that day (11).

In 1974, the average monthly productivity remained at about 6 passengers per vehicle hour until the shuttle service was assumed by TNJ and the zonal mode of operation was instituted on May 11. During the first 2 months of zonal operation, monthly productivity dropped to about 4.5 passengers per vehicle hour. This decrease in productivity was due to the loss of shuttle ridership and the oversupply of buses for the zonal experimentation. In fact, normally the many-to-many mode of operation required 10 buses on weekdays and 7 buses on Saturdays during the same time that the zonal mode was in operation. On the other hand, during the weekday zonal periods (7 to 9 a.m. and 4 to 6 p.m.), 12 buses were in operation; during the Saturday zonal period (10 a.m. to 5 p.m.), 9 buses were in operation.

Quality of Service

The quality of service of the Haddonfield DRT system was measured by 3 easily computable measures: average wait time, ride time, and pickup time deviation. Wait time is defined as the time elapsing from the end of the telephone call requesting service to the time the vehicle arrives to pick up the customer. Ride time is the time the passenger rides on the vehicle from pickup to delivery. Pickup deviation is the difference between the pickup time promised to the passenger by the telephonist at the time the trip is requested and the actual pickup time. A positive deviation indicates that the vehicle arrived later than promised and a negative deviation indicates that it arrived earlier.

These measures depend on the number of vehicles available, the size of the service area, the number of requests for service in the area, and the ability of the control center to efficiently route vehicles to serve requests.

During the 11 weeks of the demonstration, these measures were 12.5 minutes mean wait time, 10.0 minutes mean ride time, and -2.1 minutes pickup deviation time. These figures were then reduced to 11.9, 9.4, and -2.5 minutes respectively because of improvements in control room procedures in estimating wait time and reducing telephone time to book a trip. After the service area expansion of September 23, 1972, these measures were 17.2, 11.7, and -0.2 minutes respectively, which implies that wait and ride times increased with the increase in ridership under constant vehicle supply. During the second year of operation, the average wait and ride times increased to about 20.8 and 12.6 minutes respectively. This increase is attributed to the substantial increase in ridership resulting from 2 service area expansions and from the introduction of shuttle service and fare reduction. Average pickup deviation changed from -0.2 to -0.3 minute during that period.

The effect of increased ridership on service quality was also significant during the

free-fare day, when wait and ride times increased to about 39 and 20 minutes respectively during the 4:00 to 10:00 p.m. period. On the other hand, with the institution of the zonal mode of operation and the decrease in ridership, the quality of service deteriorated during the first 2 months of zonal operation. This deterioration is expressed by a 30 percent increase in wait time and a 24 percent increase in ride time. The increase in wait time is caused by fixed headways of zonal cycles and the transfer time required to go from one zone to another.

IMPACTS ON OTHER MODES OF TRAVEL

Significant impacts on other transportation modes were experienced during the Haddonfield demonstration. On-board diversion surveys were conducted to estimate these impacts. The users were asked to state the mode of transportation they would have used for the trip they were making if DRT did not exist. Twenty-six percent of the users indicated that they would use the automobile as their alternative mode; about a third of them stated that they would drive, and the remainder stated that they would be passengers. Another 25 percent of the users stated that they would use taxis, which provide door-to-door service at significantly higher fares. These diversion surveys also showed that about 11 percent of the users would have used the fixed-route bus system including TNJ, 15 percent would have walked, and 22 percent would not have made the trip at all if DRT did not exist.

CONCLUSION

This brief summary of the evaluation of the Haddonfield DRT demonstration indicates that the concept was well received by the residents of the area. It indicates also that the system was not used more often for work trips because it did not reach desired destinations and because of automobile availability.

Area expansion caused ridership to increase; however, the quality of service decreased when the vehicle supply was not increased to offset this ridership increase. The introduction of the shuttle service and fare reduction caused a significant increase in ridership and system productivity without deterioration of service quality.

The effects of zonal mode of operation and computer scheduling have not been evaluated, although the information regarding the first 2 months of zonal operation indicates a deterioration of service quality and productivity.

The Haddonfield DRT evaluation also indicates that significant impacts on other modes of travel occurred—especially on the automobile and taxi, whose users shifted to DRT.

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