EVALUATING DEMAND-RESPONSIVE TRANSPORTATION SYSTEMS

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This paper discusses some of the important elements in the evaluation of a demand-responsive transportation (DRT) system. Evaluation is and must remain primarily a local issue. Decisions on whether to provide demand-responsive service, who is to operate the service, what the quality of service is to be, and how the operation is to be financed will all be resolved at the local level. Different communities will use different mechanisms for arriving at these decisions, and clearly a set of decisions appropriate for community A may not be preferred for community B, even if the choice mechanism is the same. These mechanisms may range from public referenda on one or more proposals to a single all-powerful decision maker, though generally some pluralistic process is used.

This paper is not directly concerned with the choice mechanisms, but focuses instead on the actors affected by implementation of a service and the type and degree of impact. Because evaluation is a local issue and because statements on the degree of some impacts may not yet be possible, this paper is oriented more toward an identification of the elements involved and less toward sweeping statements about the appropriate role of these systems. Some 50 U.S. communities have made positive decisions on implementing demand-responsive services, and this number has increased exponentially during the past 4 years.

ACTORS INVOLVED

A gross aggregation of the actors who are potentially affected by decisions to implement some form of demand-responsive service is as follows:

1. Users of demand-responsive service,
2. Nonusers of demand-responsive service,
3. Operators of demand-responsive service,
4. Operators of other transportation services, and
5. Managers of other businesses and activity centers in the area.

Within each of these broad categories of potentially affected groups will generally be significantly different subgroups, each of which will be subject to a range of impacts. These issues are discussed for each of the major groups in the following sections.

Users

The users of any transportation service are the fundamental reasons for providing the service at all. If there are no users, then there are no benefits arising from use of the system. If there are users, then there are benefits derived from the system, and those benefits accrue to users and to other actors in the process. Because of this simple fact, some measure of ridership is usually a major factor in the evaluation of a service—the more people using it, the greater the benefit. This should not be the sole measure of effectiveness, but it should be an important one.

Users benefit either from the new service allowing them to take advantage of urban activities that they were not previously able to (induced demand) or from the new service being preferred to the one previously used. In both these cases the user benefit is bounded by the difference in service provided by the new service and the previously available service. If the new service is similar to a previously existing service but a little better, then induced demand may be small but the number of riders who had previously used the similar mode may be large. In this case the average benefit for each user would be small. Conversely, and this is more likely to be the case for demand-responsive services, the type of service may be significantly different from previously available services, resulting in significant levels of induced and diverted demand.

The extent of induced demand is an important factor in evaluation because for these users mobility has been increased and opportunities have been made available in the urban area that were not previously practical. These opportunities range from an unemployed person being able to take a job to previously lonely people becoming more fully involved in the community's social and economic life. People with good access to alternative modes such as automobile, bus, and taxi will be unlikely to significantly increase their trip making, but those without an automobile, without bus service, or too poor to use taxis may benefit considerably from the new service. In particular these people, currently mobility handicapped, may receive significant benefits from the new service. Diverted demand also involves a benefit to the user, and the degree of this demand indicates how well the new service competes with other services for current trips.

In either case, the estimation of the total user benefit is a function of the number of users and the difference between this service and the best of the previous services. Different users would otherwise have preferred different modes because of the range of individual utility functions; if everyone had identical utilities, they would all use the same mode for a given trip. After implementation, to determine the number of users of a new service is easy, but to estimate the average user benefit is difficult. The traditional approach is to develop a generalized cost for each service based on monetary cost and the product of an assumed value of time and the service time. The difference in generalized costs then is used as an estimate of the benefit for a user of the new service.

Evaluating existing demand-responsive services is difficult because many travel decisions are based on long-run household and individual decisions such as home location, job selection, and automobile ownership. Before the real benefit can be estimated, the system must be in operation long enough for these long-term decisions to be made. System ridership will likely increase as these longer term decisions are made.

The preceding discussion has assumed that the demand-responsive service is in addition to the previously available services; however, this may not always be the case. For example, if the service partially or completely replaces fixed-route bus service, there may be increased user costs incurred by those who previously used the fixed-route bus service and who preferred it to the new service. This may be an important factor if there is a significant fare increase involved. However, where fixed-route services are heavily subsidized, the user may have been in an untenable position from the outset; and the choice may well have been between no service at all and the new demand-responsive service.

In general, however, the number of riders is a reasonable proxy for user benefits and is one important element in evaluation. For demand-responsive transportation in particular, many users have low frequencies of use, which implies that the service is being used in unusual situations. For this reason both number of trips and number of distinct users should be considered as proxies for user benefits. The second important element in user benefits is the difference between the new service and the previous best service for each type of user. This will usually be highly correlated with level of usage.

Figure 1. User benefits from demand-responsive service.

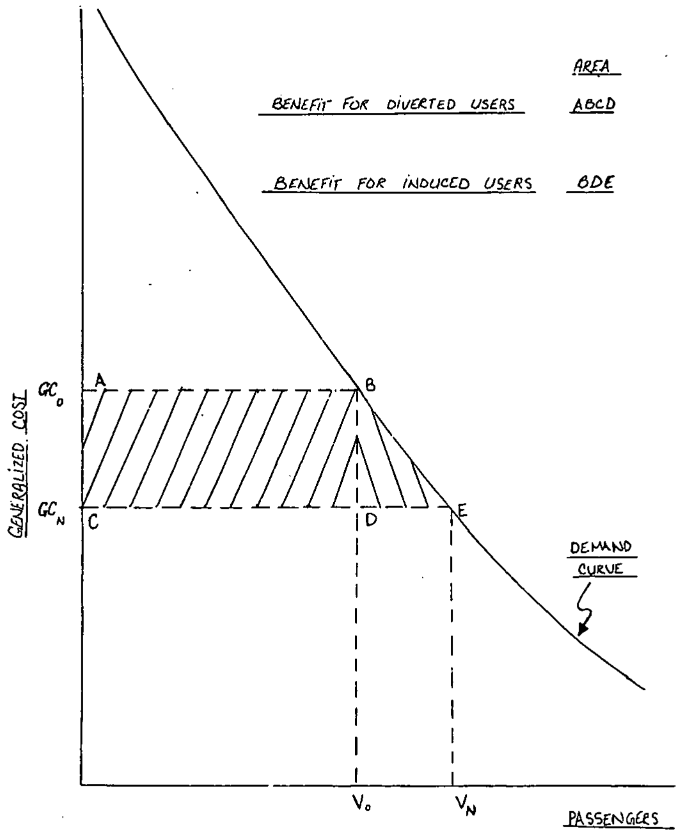

Figure 1 shows this concept of user benefits. The users of the new system are assumed to have a demand for service. The generalized cost of the new service is GC_N, that of the previous preferred mode is GC_0, and new and old number of passengers are V_N and V_0 respectively. The user benefit associated with each diverted user is then simply GC_0 - GC_N, and there are V_0 such users; the user benefit for each new user is uniformly distributed between GC_0 - GC_N and 0, and there are V_N - V_0 such users. This is a grossly simplified representation of the construct but does indicate the importance of the number of users and the improvement in quality of service in the total user benefit.

Clearly, then, one way of increasing user benefits is to reduce the fare charged or increase the quality of service—but both actions will result in a greater net cost of service. This clearly requires the evaluation of the alternatives from a multiobjective viewpoint.

Nonusers

Nonusers of the new service are potentially affected in a number of ways through externalities associated with the system. Classic transportation externalities include air pollution, congestion, and community disruption. In demand-responsive transportation, externalities tend to be much less significant than in systems involving major constructed facilities. In demand-responsive services, the major externality is generally the cost of supporting the system and that cost is not borne by the users directly. If service fares are set below cost, which will in general be to achieve some welfare objective, then nonusers will be paying the difference. The fare level and financing of the net cost will determine the extent to which certain groups of nonusers will have to pay. This decision in particular is a local responsibility and must be resolved through the political process. The key question is to what extent the social welfare objectives justify subsidization and how the subsidy is raised.

In some cases the effect of subsidization could be regressive, for example, where the service is provided only in high-income suburbs and the subsidy is based on an areawide tax. There is a real question about whether this situation can be justified or, more basically, whether nonusers should be expected to subsidize service to this user group. Subsidization in this case does not meet a social welfare objective. In the case where service is provided in low-income areas or to mobility-handicapped markets, a strong case can be made for subsidization on an areawide base.

Indications from existing demand-responsive services strongly suggest that other externalities are quite minor. Specifically it is unlikely that there will be a significant reduction in automobile use, so no improvement in air quality or reduction in congestion should be expected.

Operator of the Service

A basic decision is whether the operator of the service should be public or private, transit based or taxi based. This decision has a major impact on the economics of the system and may also dictate the fare level. Existing demand-responsive systems can be divided into profit-making taxi-based services and subsidized transit-based services. The taxi-based services typically have lower cost per vehicle hour of operation combined with higher fares resulting in the profit-making service. A necessary result is that the service is not oriented primarily to social welfare objectives and serves a smaller share of the total transportation market. The total user benefit will be smaller if this option is selected, but there will be no nonuser financial burden.

The transit-based option has higher costs largely because of higher wage rates and better benefits prevalent in the transit industry. However, one result of this is that driver turnover is much lower in the transit industry than in the taxi industry. Additional advantages of the transit option are the ease of coordination between DRT and fixed-route services and the flexibility to be achieved by shifting some drivers from fixed-route service in the peak hours to demand-responsive service in the off-peak hours.

The impact of the service on the operator is the profit (or net cost) associated with providing the service. This may be simply passed through the operator as, for instance, in the case where a subsidy is provided by the public. An additional impact is the employment directly associated with provision of the new service. In some localities it may be politically feasible to subsidize private operators of demand-responsive services to achieve the advantages of lower operating costs combined with increased user benefits associated with reduced fares.

Other Operators

There may be significant impacts on other transportation services when demand-responsive service is introduced. For example, fixed-route transit and taxi service will likely both lose ridership if demand-responsive service is introduced into an area previously providing both. These negative impacts must be recognized in the evaluation process. In particular, to compensate directly or indirectly the operators of competing services may be desirable. This is, of course, part of the local political and decision-making process.

Managers of Other Business and Activity Centers

In general, business and activity centers of all types will benefit from the new services through increased levels of activity and increased pools of potential employees. This impact will be skewed so that positive benefits will accrue to activities previously poorly served by transportation (they will become more accessible) and decreasing benefits will be associated with previously well-served activities (their relative advantage is decreased by the new service). The extent of this impact will depend on the number of users of the new service.

TOTAL EVALUATION

The total evaluation of demand-responsive services is, as previously discussed, a local process, and the factors entering the process and their relative weights will vary greatly. However, several factors now evident must be considered in the evaluation of a proposed system.

1. As previously determined in research and now confirmed by operation, there are increasing economies of scale in DRT ride operation. This in itself can be an argument for providing subsidized operation. Specifically, more productive operations can be provided at higher demand densities; however, to achieve higher demand densities requires subsidy.
2. Even in subsidized DRT services to date, demand densities have been in the range of 2 to 10 passengers/mile^2/hour. At these demand densities, to expect productivities of greater than 5 to 7 passenger trips/vehicle/hour is unreasonable.
3. If it were possible to increase demand density to the 20 to 30 passenger/mile^2/hour range, productivities in the 9 to 12 range are achievable. But the service provided must be made more attractive; subsidization alone will not suffice.

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This paper briefly reviews some of the development trends in cities and their implications for urban transportation systems. The conclusion is one we already know well: The CBD-focused, fixed-route transit systems common today are badly mismatched to the evolving needs of increasingly low-density and multinucleated cities. The principal significance of flexible-route systems such as DRT is that they have been the missing element that lets this mismatch be overcome, permitting us to think in new terms about public transit systems. Regionwide door-to-door systems such as we are beginning to see in Orange and Santa Clara Counties, in Rochester, and in Ann Arbor are the leading edge of this trend. For the first time since Henry Ford, it may not be ridiculous to think in terms of modal splits of 30 to 50 percent of all nonwalking person trips rather than 3 to 5 percent.

The second part of the paper presents some conjectures as to how these regionwide systems might evolve. The conclusion is that, although the flexible-route elements are what make these new systems possible, the major growth is likely to be in proliferation of the fixed-route structure.

The promise of these new systems is great, and success in bringing about a major shift to transit could be of substantial importance to the nation, but it is not going to be easy. We know little about these systems and the public reaction to the kinds of service we think they can offer. In my opinion, the next 5 years are the critical ones for the future of urban transportation.

REGIONWIDE, DOOR-TO-DOOR SYSTEMS

The purpose of this brief discussion, which is more fully developed in another report