Abridgment

Alternative Methodologies for Measuring Transit Benefits

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In order to make correct policy decisions concerning investment and subsidization for transit services, a correct methodology must be used for measuring transit benefits. In this paper we argue that the commonly used cost-savings approach has restrictive limitations for the measurement of transit benefits. This approach assumes that the benefits from a given mode of transportation are the cost savings from other modes due to the availability of the given mode. Because of these limitations, an alternative methodology for measuring such benefits is proposed. This methodology determines transit benefits by finding areas under transit demand curves. Although this methodology has been proposed previously for measuring transportation benefits, its use has been limited due to the difficulty of determining demand curves. However, in this paper, transit benefit algorithms based on the above methodology, which only requires limited information, are derived.

THE COST-SAVINGS APPROACH FOR MEASURING TRANSIT BENEFITS

Assume that two modes are available for passenger transportation in a given urban area—the automobile and transit. Further assume that the benefits and costs from automobile travel are B_A and C_A, respectively, and the benefits and costs from transit travel are B_T and C_T, respectively. By the cost-savings approach for measuring benefits, $B_A = a_A C_T$ and $B_T = a_T C_A$, where $0 < a_A < 1$ and $0 < a_T < 1$.

If the benefits of automobile travel exceed its cost ($B_A/C_A > 1$), then $a_A C_T > C_A$ or $C_T > C_A/a_A$. Furthermore, when $0 < a_A < 1$, then $C_A/a_A > C_A$. When $C_T > C_A/a_A$ and $C_A/a_A > C_A$, it follows that $C_T > C_A$.

If the benefits of transit travel exceed its cost ($B_T/C_T > 1$), then $a_T C_A > C_T$ or $C_A > C_T/a_T$. When $0 < a_T < 1$, then $C_T/a_T > C_T$. Hence, when $C_A > C_T/a_T$ and $C_T/a_T > C_T$, then $C_A > C_T$. However, we have a contradiction.

In one situation transit travel costs exceed automobile travel costs, and in the other situation they are less than automobile travel costs. Based on the cost-savings approach, if the benefits of automobile travel exceed its costs, then the benefits of transit travel will be less than its costs. Thus, in the above situation the cost-savings approach precludes the possibility of transit benefits exceeding its costs. Because of the above limitations of the cost-savings methodology for the measurement of transit benefits, let us now consider an alternative methodology.

A DEMAND APPROACH FOR MEASURING TRANSIT BENEFITS

The demand for transit travel is represented by the demand curve D in Figure 1. The curve shows that, as fare increases, the number of transit-passenger trips demanded decreases. At fare P, Q individuals purchase transit service. Every individual who makes a transit trip pays the same fare. Furthermore, we assume that everyone willing to pay this fare values the trip by at least the amount of the fare, or he or she would not make the trip.

We can see that all individuals up to Q - 1 transit-passenger trips are actually willing to pay a fare greater than P. The rider of transit-passenger trip Q′, for example, would pay fare P′. Thus, we can divide the value of this individual's trip into two parts: the actual cash value (the fare paid of amount P) and the surplus value that the individual would pay over and above what is actually paid (amount P′ - P).

In Figure 1, if we add together all the cash values paid by riders of Q transit-passenger trips, we obtain shaded area A, which is the transit service revenue for the Q trips. If we add up all the surplus values, we obtain shaded area B, which is the surplus value of the Q trips. This area or additional benefit over and above what individuals pay for Q trips is consumer surplus. The transit revenue plus the consumer surplus is the total value of Q trips to transit riders and represents total user benefits from Q trips.

In the estimation of transit demand, two basic types of demand functions have been estimated in the literature: multiplicative and linear. A multiplicative demand function for transit-passenger trips may be expressed as:

$$T_{ij} = CF_{ij}^{-e} X_{1ij}^{b_1} X_{2ij}^{b_2} \ldots X_{nij}^{b_n} \quad (1)$$

where

T_{ij} = the number of transit-passenger trips from zone i to zone j,
F_{ij} = the transit-fare price from zone i to zone j,
X_{kij} = the kth variable that influences the demand for transit-passenger trips from zone i to zone j (k = 1, 2, . . . , n), and
C = a constant.

By substituting the values of the X_{kij} variables for a given ij zonal pair in Equation 1, we obtain the following demand-curve equation for transit-passenger trips:

$$T_{ij} = a_{ij} F_{ij}^{-e} \quad (2)$$

where $a_{ij} = CX_{1ij}^{b_1} X_{2ij}^{b_2} \ldots X_{nij}^{b_n}$. Demand curves for transit-passenger trips for given ij zonal pairs based on Equation 2 will have the same fare elasticity (-e) but different slopes, since the slope of a given demand curve will be $dT_{ij}/dF_{ij} = -ea_{ij}F_{ij}^{-e-1}$ and since a_{ij} would be expected to vary from one ij zonal pair to another.

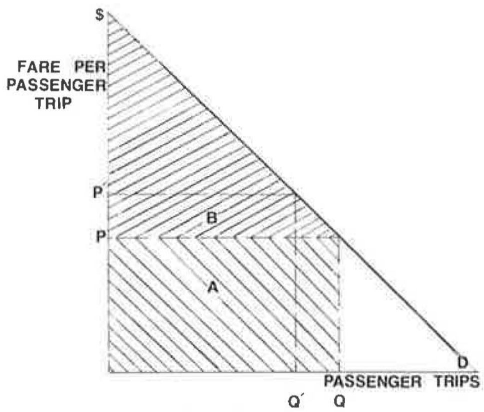
In order to derive a benefit algorithm for measuring user benefits for a given ij zonal pair based on demand Equation 2, let us solve Equation 2 for F_{ij} in terms of T_{ij} to obtain:

$$F_{ij} = (a_{ij}/T_{ij})^{1/e} \quad (3)$$

In order to obtain the user benefits from $\bar{T}_{ij}$ trips, we integrate Equation 3 from one (an improper integral will result from using zero) to $\bar{T}_{ij}$ and obtain the following:

$$CS_{ij} + FR_{ij} = [a_{ij}^{1/e}/(1 - 1/e)]\,[(1 - \bar{T}_{ij}^{1/e-1})/\bar{T}_{ij}^{1/e-1}] \quad (4)$$

Figure 1. Transit benefits.



where CS_{ij} = the consumer surplus from $\bar{T}_{ij}$ trips and FR_{ij} = the fare revenue from $\bar{T}_{ij}$ trips. If we let $FR_{ij} = F_{ij}\bar{T}_{ij} = a_{ij}^{1/e}\bar{T}_{ij}^{(-1/e+1)}$ and subtract it from Equation 4, we obtain the following algorithm for estimating consumer surplus:

$$CS_{ij} \doteq FR_{ij}\{[\bar{T}_{ij}^{1/e-1} - (1/e)]/[(1/e) - 1]\} \qquad (5)$$

Let us now assume that the demand function for transit-passenger trips from the ith to the jth zone is linear and may be expressed in terms of F_{ij} as:

$$F_{ij} = a_{ij} - b\,T_{ij} \qquad (6)$$

where $a_{ij} = C_0 + C_1X_{1ij} + C_2X_{2ij} + \ldots + C_nX_{nij}$, and F_{ij} and T_{ij} are the same as defined previously. The consumer surplus and fare revenue for $\bar{T}_{ij}$ trips may be expressed as:

$$CS_{ij} + FR_{ij} = a_{ij}\bar{T}_{ij} - (b/2)\,\bar{T}_{ij}^2 \qquad (7)$$

By multiplying Equation 6 by T_{ij}, we can obtain the fare revenue for $\bar{T}_{ij}$ trips or:

$$FR_{ij} = a_{ij}\bar{T}_{ij} - b\bar{T}_{ij}^2 \qquad (8)$$

By subtracting Equation 8 from Equation 7, consumer surplus may be expressed as:

$$CS_{ij} = (b/2)\bar{T}_{ij}^2 \qquad (9)$$

With the fare elasticity expressed as $-e_{ij} = (-F_{ij}/\bar{T}_{ij})/b$ and $FR_{ij} = F_{ij}\bar{T}_{ij}$, solution of this relationship for b and substitution of this into Equation 9 will obtain the following consumer surplus algorithm:

$$CS_{ij} = FR_{ij}/2e_{ij} \qquad (10)$$

Note that a_{ij} does not appear in either Equation 5 or 10. Thus, only the number of trips ($\bar{T}_{ij}$), the fare revenue, and the fare elasticity are required to determine consumer surplus.

AN APPLICATION OF THE CONSUMER-SURPLUS ALGORITHMS

In this section of the paper, the consumer-surplus algorithms (Equations 5 and 10) will be used to estimate consumer surplus from transit trips for the Tidewater Transportation District Commission.

On a typical day in 1976, 41 829 bus-passenger trips were made, of which 59 percent were work trips and 41 percent were nonwork trips. Previous researchers have found a difference in the fare elasticity between work and nonwork trips; therefore, separate consumer-surplus estimates were found for these two types of trips. From demand modeling done by the Tidewater Transportation District Commission (1), we found that

1. The elasticity for work trips is -0.267,
2. The median number of work trips between all zones is 7,
3. The number of zonal pairs involving work trips is 3525, and
4. The average fare is $0.33.

Assuming a multiplicative demand function, we obtain the following estimate of the consumer surplus for work trips by using Equation 5:

$$\overline{CS}_{ij}^{w} \doteq (0.33)(7)(7^{2.74} - 3.74/2.74) \doteq \$170 \qquad (11)$$

By multiplying this amount by the number of zonal pairs involving work trips (3525), we obtain $599 250 as our estimate of the consumer surplus from all work trips for the typical day.

In a study by Kraft and Domencich (2), the fare elasticity for nonwork transit trips was found to be approximately twice that of the fare elasticity for work trips. Thus, we assume that the fare elasticity for nonwork trips is -0.534. By using seven and $0.33 as the average number of nonwork trips and fare, respectively, we obtain the following estimate of the consumer surplus for nonwork trips:

$$\overline{CS}_{ij}^{nw} \doteq (0.33)(7)(7^{0.87} - 1.87/0.87) \doteq \$10 \qquad (12)$$

By multiplying this amount by the number of zonal pairs that involve nonwork trips (2450), we obtain $24 500 as our estimate of the consumer surplus from all nonwork trips for the typical day.

By summing the consumer-surplus estimates for work and nonwork trips and multiplying by the annual factor of 300 days, the estimated consumer surplus for the 1976 fiscal year is $187 125 000. By adding the fare revenue of $4 997 160 for the 1976 fiscal year to our consumer-surplus estimate, we obtain $192 122 160 as our estimate of user benefits from the Tidewater Transportation District Commission for the 1976 fiscal year.

By using the linear consumer-surplus function represented by Equation 10, the consumer surplus for work trips is $15 263/day and $5296/day for nonwork trips. Hence, the total annual benefits, including consumer surplus and revenue for the year, was found to be $11 163 660. The total operating and capital cost in 1976 was $10 286 820.

SUMMARY AND CONCLUSION

In this paper alternative methodologies for measuring transit benefits were analyzed. It is argued that the cost-savings approach that is commonly employed has restrictive limitations, which may be too restrictive for this approach to be practical. The rarely used method of estimating benefits directly from the demand functions was also pursued. Although measuring transit benefits by finding areas under transit demand curves does not have the limitations of the cost-savings approach, demand curves, themselves, are difficult to estimate. However, this paper has developed algorithms for measuring such areas that require minimal and easily obtained data. The required data are fare, fare elasticity, number of trips, and revenue.

REFERENCES

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Abridgment

Development of Transit District Boundaries for an Areawide Small Bus Program

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The development of a feasible transportation program within a metropolitan area requires the consideration of community needs, demand potential, and the system's impact on the community life-style and environment.

The population of a metropolitan area is not homogeneous; therefore, it is difficult to justify a fixed-time, fixed-schedule, line-haul system throughout an entire metropolitan area. The requirements for secondary trips, such as shopping, social, and recreational trips, are even more difficult to determine because of the peculiar nature of these trips. Yet, although such trips are secondary in nature, they are extremely important in order to maintain a proper level of service in an area as well as for the economic growth of a community. The needs of a community, therefore, require careful investigation.

The Southeastern Michigan Transportation Authority (SEMTA) is responsible for the coordination and operation of public transit in the Detroit metropolitan area. The total public transportation system in this area is primarily divided between SEMTA, which serves the entire area, and the Detroit Department of Transportation, which provides service within the limits of the city of Detroit. The current bus service program consists primarily of fixed-route, fixed-schedule buses that operate along major corridors in and out of the Detroit central business district (CBD) as well as cross-town line-haul systems. In addition, several small bus programs operate as dial-a-ride systems or feeder systems to the line-haul system in some suburban communities.

In 1976 we were involved in a study to determine the transportation service needs for the secondary trips in a three-county study area (Wayne, Oakland, and Macomb Counties) within the SEMTA region. The objective was development of a comprehensive small bus program based on this information. Determination of the service needs necessitated addressing questions related to (a) the logical boundary for the service area, (b) public transportation needs within each community, and (c) the relative priority of various service areas within the region.

A review and analysis of all the existing small programs in Michigan provided the rationale for transit district boundaries. The three-county study area consisted of an approximately 4823-km^2 (1862-mile^2) area with a population of 2.7 million; it encompassed 73 cities and 58 townships and villages.

DEVELOPMENT OF TRANSIT DISTRICTS

The criteria for transit district boundaries include service area, population of the service area, natural boundaries, continuity between adjacent areas, other geographical considerations, similarities between the socioeconomic characteristics, demographic considerations, and land use considerations. The study was conducted in a three-stage process:

1. Transit districts were developed by using the service area, with primary emphasis on the consideration of optimal service area and population density.
2. The primary candidate districts established in the first stage were tested for sufficient travel demand; nonwork trips as a percentage of total daily person trips were used as the measure of travel demand potential.
3. The different geographical units were analyzed to establish transit districts.

The nonhomogeneity of the socioeconomic, demographic, and land use characteristics were considered in this stage to arrive at the final transit district boundaries.

Data Base

The study used the available data on small bus programs for the entire state of Michigan, regional travel and socioeconomic data available from Southeast Michigan Council of Governments (SEMCOG), and census information.

The travel data used were approximately 10 years old. However, in the absence of more recent or updated data, they were sufficient for making some preliminary judgments in terms of determining the transit districts and potential for transit demand.

Development of Service-Area Criteria

In order to develop service areas that can be used to