1977-78. Computer tapes. FHWA, U.S. Department of Transportation, 1977-1978.
2. MVMA Motor Vehicle Facts and Figures. Motor Vehicle Manufacturers Association, Detroit, 1982.
3. P. Fulton. Public Transportation: Solving the Commuting Problem? Presented at 62nd Annual Meeting of the Transportation Research Board, Washington, D.C., Jan. 1983.
4. F.M. Scherer. Industrial Market Structure and Economic Performance, 2nd ed. Rand McNally, Chicago, 1980.
5. P. Gelb. Effects of Taxi Regulatory Revisions in San Diego, California. Final Report. UMTA, U.S. Department of Transportation, Dec. 1982.
6. P. Gelb. Effects of Taxi Regulatory Revisions in Seattle, Washington. Final Report. UMTA, U.S. Department of Transportation, Feb. 1983.

This paper is based on research conducted for UMTA under the University Research and Training Grant CA-06-0183. The views expressed herein are those of the authors and not necessarily those of the University of California or the U.S. Government.

Publication of this paper sponsored by Steering Committee on Socio-Economic Evaluation of New Transit Technologies.

Feasibility of Profitable Transit Service in Radial Urban Corridors

EDWARD K. MORLOK and PHILIP A. VITON

ABSTRACT

In view of the rapid escalation of deficits in urban public transit operations and of the increased interest of private firms in providing transit services, this research investigates the possibility of profitable provision of service in a particular but highly significant market. A model is constructed in which a private carrier, competing with the automobile, chooses capacity, service quality, and price to maximize profits. The general conclusions of the study are that profitable operation is possible in corridors that have a wide range of market and automobile competitive conditions. This is true for corridors with volumes as small as approximately 1,000 persons per peak hour.

Results of research on the question of the feasibility of operating conventional fixed-route, scheduled bus transit service at a profit are presented. This question is important at present because of the rapid escalation of transit costs and deficits. Governments at all levels are resisting further increases in subsidies from general tax monies, and the federal government is planning to eliminate operating subsidies. This naturally raises the question of whether at least some transit service might be operated at a profit, with passenger revenues exceeding costs by an appropriate margin, thereby obviating the need for any government funding.

The specific question addressed in this paper is whether it is possible to operate for profit fixed-route, scheduled bus services in radial urban corridors. These services are envisioned as connecting central business districts (CBDs) and outlying areas that are predominantly residential. The study also focuses on relatively long trips in which a portion of each bus run could be operated essentially as an express, making few or no stops. Although this represents only one type of transit service, it is a type found in almost all medium and large metropolitan areas and hence is important.

Because discussions of profitability in urban transit often become highly emotional, it is important to note that the present discussion is focused exclusively on the question of the possibility of a profit. Even if a profit is possible, that does not mean that services designed to be profitable should replace existing services. The question of desirability is quite distinct and cannot be settled by analysis alone. Some aspects about which analysis can provide guidance are covered in Viton et al. (1).

APPROACHES TO THE PROFITABILITY QUESTION

There are basically two approaches to the question of whether a profit can be made in transit service: (a) examination of actual systems in case studies and (b) mathematical modeling of transit markets. Each of these approaches has certain desirable features and certain weaknesses.

Case studies are particularly attractive because they represent results achieved in the real world. They are not subject to the problem of misleading outcomes of modeling efforts, which result from poor or unrealistic assumptions, incorrectly estimated model parameters, and so forth. Case studies are also usually persuasive to decision makers. However, to yield generalizable results, the cases must be sufficient in number and in variety of conditions to span the spectrum of influencing factors. Herein lies the problem of the case study approach to the question of the possibility of profitable transit service in the United States.

Regulatory and legal constraints prohibit private firms from providing transit service in almost all U.S. metropolitan areas in which exclusive franchises have been given to regional public authorities. These authorities certainly do not have profit as a primary goal; they typically seek other goals according to their charters and legislation. Among these goals are to ensure adequate transit service, to keep fares as low as possible, to provide mobility for the handicapped, and to use transport to further regional land use objectives. Other objectives and considerations also enter in as a result of the political context of many critical decisions regarding transit, such as the magnitude of operating subsidies and of capital grants. Most of the relatively few remaining private transit firms are regulated as to routes, fares, service quality, and capacity and are subsidized in accordance with the same considerations as apply to public authorities. Virtually none of the present providers of transit are actively seeking to maximize profit based on fare-box revenue, and thus the fact that they do not turn a profit is not sufficient evidence to conclude that a profit is not attainable. For this reason the case study approach, applied to U.S. transit systems as a whole, is inappropriate as a means of dealing with the question.

Modeling offers a means of dealing with the question of the possibility of a profit in transit. It provides a means of analyzing what would happen if barriers to provision of transit by profit-maximizing firms were eliminated, and enables the exploration of the effect of providing transit service with characteristics of the product, in quality and price, that differ from those of transit service now offered.

For these reasons, the modeling approach was used for this study. This approach should be helpful in understanding the influence of various conditions such as size of the market on the possibility of obtaining a profit. Moreover, the modeling results could be tested against the case studies of profitable transit (2). A satisfactory model would presumably be able to replicate the conditions and profitability of the relatively few recently observed profitable firms.

MARKET MODELING APPROACH

The general approach to modeling a transit market can be understood by considering the case of a single route, which can easily be generalized to many routes or to an entire system. The basic question asked is: How would a carrier that wishes to maximize profit supply transit service? This carrier presumably would attempt to select all the characteristics of its service in such a manner as to maximize profit. The characteristics under the control of the carrier are the fare charged (F), quality of service features such as the percentage of passengers seated (T), the frequency of buses operated on the route (V), and the capacity of the buses (Q). (In practice most carriers operate with the standard 40-ft bus.) The choices made by the carrier providing this service will naturally influence the demand realized (D) for that bus service. Potential riders will presumably compare the bus service features with those of an alternative means of transport (A), which for these purposes is presumed to be the private automobile. The carrier's choices with regard to some of these features will also determine its costs (C). In particular the frequency of bus trips and the size of the buses will determine capital and operating costs.

The problem, for maximum F, V, and Q, can thus be written in the following form, in which the decision variables are selected to maximize profit (P) with demand related to transit price and service characteristics and those of the automobile alternative:

$$P = F \cdot D - C \tag{1}$$

$$D = f(F,V,P,A) \tag{2}$$

$$C = g(F,Q) \tag{3}$$

$$T = h(D,FQ) \tag{4}$$

where

D = demand,
C = cost,
T = percent seated, and
lower case letters = functions.

This can be viewed as a constrained optimization problem. Depending on the situation, various interactions, such as the influence of the number of riders of the bus system on the number of automobiles on the highways and hence on highway congestion, would have to be taken into account. In some situations this influence would be significant, whereas in other situations, such as those in which the bus line serves essentially CBD-bound trips and the bulk of highway traffic is to non-CBD locations, this effect might be ignored.

The general form of these relationships is shown in Figure 1. In this figure, the effect of variations in the frequency of service both on travel demand, and hence revenue, and on costs are shown. In this case the revenue function follows the general form that would be expected; that is, for a given or fixed fare, it is proportional to traffic that follows the normal logistic curve of most demand (mode choice) models. This figure is of course drawn holding fixed all other service choices of the carrier.

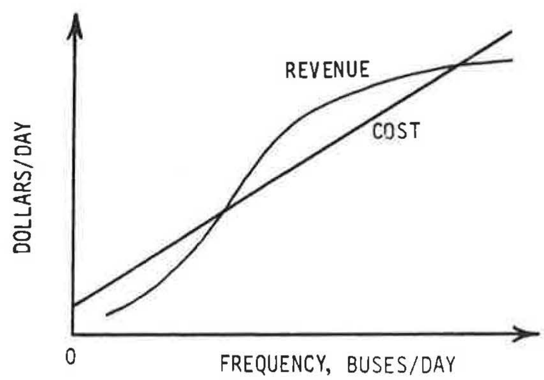

FIGURE 1 Profit related to management choice of frequency, with other service features and fare constant.

More generally, the problem is one of optimization in many dimensions. Figure 2 shows this for the case of two dimensions, fare and service frequency. This figure presents a profit surface, or contour map, on which are shown lines of constant profit (isoprofit lines). The profit levels in the applicable Figure 1 would be represented as a plane inter-

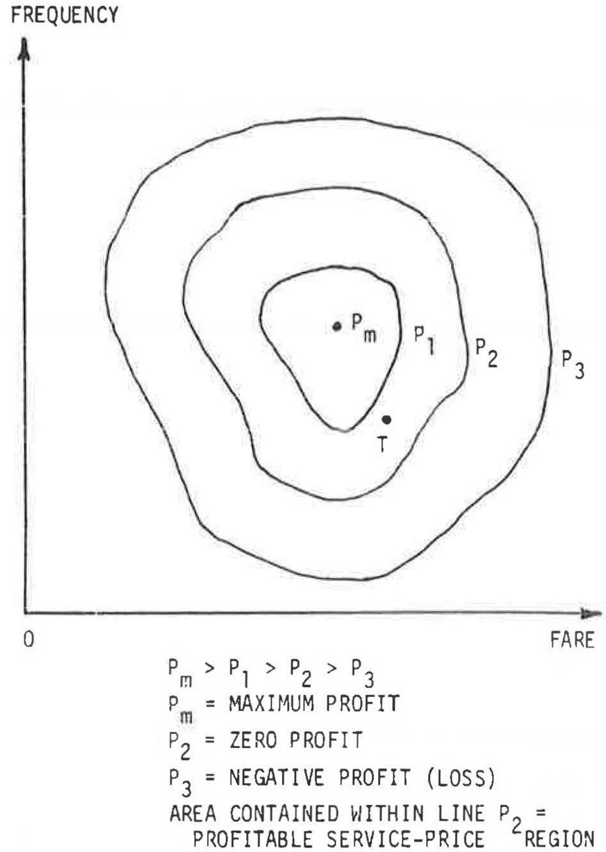

FIGURE 2 A profit contour map showing the profitable service-price region.

secting the fare axis at the applicable fare, parallel to the frequency axis, and perpendicular to the plane of this figure.

Although the primary interest is in the maximum-profit selection of service features and price, it is also important to obtain information on the degree to which a profit could be realized at levels of price and service different from that optimum. This question is important partly because demand information is known only imperfectly, and in fact so are cost characteristics, although to a far lesser extent. With such imperfect information, a carrier would not normally select the true maximum-profit characteristics of output, but would deviate from them to some extent. The important question is: Could the carrier still operate profitably? To answer this, the range of service features and price over which a positive profit is still possible can be identified. This range can be termed the "profitable service/price region." In Figure 2, a positive profit is possible anywhere within the boundary of the isoprofit contour (P_2), which means that any combination of price and frequency in this boundary would yield a profit. When a carrier has entered the market at some point in this region (e.g., T), various techniques including market surveys and actual experimentation could be used to identify higher profit positions, and there might be some change in service offerings. The significance is that if the profitable output region is rather large, it is relatively easy for a carrier to enter the industry and to make a profit, even if the initial choice of price and service is nonoptimal. This substantially diminishes the risk of loss. Therefore, in addition to identifying the maximum-profit service features, an attempt is made to identify this profitable service/price region.

MARKET AND MODEL

Now that the general approach has been described, the specific urban travel market and bus and automobile transportation alternatives can be described. As mentioned earlier, this research specifically focuses on a bus service connecting suburban areas with the central business district. The buses operate in an express mode between the suburban area and the downtown and make no or perhaps a few stops at connecting routes.

Market

The market to be considered is shown schematically in Figure 3. There is a circular residential area of radius r miles, connected by an expressway or major arterial to a central business district. It is assumed, for mathematical convenience, that all types of trips with which the model is concerned take place in this market in the following way: For automobile trips, the driver first drives along the residential streets to the expressway entrance at A. She then proceeds along the expressway to C, a distance of L + XL/2 miles. The driver then proceeds along city streets a distance (XL + 1)/2 miles to a parking lot near the work location.

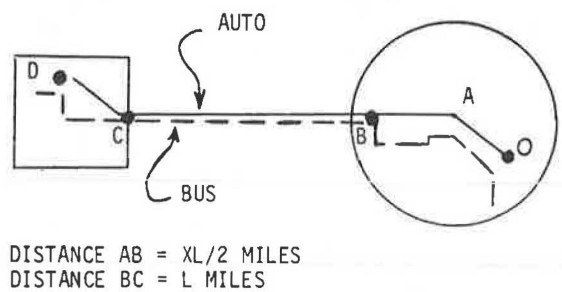

FIGURE 3 The transit market.

The bus trip is somewhat more complicated, because the fact that, in general, bus trips are more circuitous than automobile journeys must be taken into account. Proceeding along the residential streets, the bus collects its passengers. Instead of getting on the expressway at A, however, the bus proceeds a further XL/2 miles on residential streets before joining the expressway at B. From this point on, the trip is the same as the automobile trip except that the expressway portion is only L miles. Thus, the disadvantage of the bus trip (for modal choice) is not that it covers a greater distance but that it takes longer than an automobile to cover the same distance. The parameter XL is referred to as a "circuity factor" in what follows although, as the previous discussion indicates, it is actually a proxy for circuity. The assumption that the circuity in the residential area equals the circuity in the relevant part of the downtown distribution area is made only to economize on parameters; clearly, it is easily modified. The additional 1 mile of distance at the CBD end of the trip is included to allow analysis of the case in which circuity is zero. Without the additional distance, zero circuity would be equivalent to assuming the expressway delivers the commuter directly to the parking lot.

In the analyses the speeds at which all vehicles move on the expressway (S), and the different automobile (ASPD) and bus (SPD) speeds on residential and city streets are taken as parametric. This is a reasonable approximation, if residential-area-to-CBD traffic is not a large proportion of the total expressway traffic. Moreover, as will be noted later, these are varied to replicate various road types and levels of congestion.

Demand models developed for transit/automobile choices typically reveal three measures of transit service that are important to consumers: fare, in-vehicle time, and excess time. For fixed speeds in-vehicle time is given. Excess time is the sum of access time to get to the nearest stop and time spent waiting for a bus. Each of these measures of service quality is determined by the bus carriers' selection of three variables: the number of routes covering the residential area (R), the bus headway (H) as observed on the expressway, and the fare (F). The connection between these is derived in the research report (1,pp.2-17), and the relationships are

$$\text{Walk} = \pi r/6R \tag{5}$$

$$\text{Wait} = HR/2 \tag{6}$$

Bus Cost Model

The bus cost model is of the unit cost variety, in which the total operating and capital costs (C) are related to the number of vehicles required (B), the number of driver pay hours required (G), and the vehicle-miles operated (M). In a situation in which the number of buses required to operate the service during weekday peak periods is sufficient to enable the service to be provided at any other period during weekdays and weekends, and in which the number of drivers required during weekday peak periods is greater than that required during the midday and evenings periods, unit cost models are typically written of the following form:

$$C = \alpha B + \beta M + \gamma_1 G_1 + \gamma_2 G_2 + \gamma_3 G_3 + \gamma_4 G_4 \tag{7}$$

The vehicle-mile parameter (β) is normally the same regardless of the period of day, reflecting such expenses as fuel consumed and maintenance, and hence there is no distinction between miles logged in different periods. However, the vehicle-hours of operation variable differs for weekday peak periods (G_1), weekday middays (G_2), weekday evenings (G_3), and weekends (G_4) because many drivers working during the weekday peak periods are paid for hours between those peaks even when they operate no vehicle. To the extent that this is the case, the additional cost of operating a more frequent service during midday periods would consist simply of the mileage-related cost because drivers for those buses are available and are already being paid as a result of their working during the peak periods. Thus parameter γ_2 will often take on a value of zero. This is the case in the Northwestern bus transit cost model, which is the only model calibrated for the United States that was singled out in a recent review of bus cost models conducted by Simpson and Curtin for UMTA (3,p.92) as a model especially well suited to dealing with peak/off-peak cost variations and incremental service charges. Further details on this model are provided elsewhere (4). The significance of these cost characteristics will be apparent in a later section.

Demand Submodel

The demand submodel takes a given total volume of trips between each residential area and the downtown (specified exogenously and varied as a market characteristic) and estimates the number of travelers who would use the bus service (and the alternative, the automobile) as a function of bus service and cost characteristics and similar measures for the automobile. The model used is one developed for this type of market by Train (5) for a similar situation of work travel in the San Francisco Bay area. The model is a relatively standard logit model. The probability of choosing the automobile (p^a) is

$$p^a = \exp[\theta'(z^a - z^b)]/\{1 + \exp[\theta'(z^a - z^b)]\} \tag{8}$$

where z^a and z^b are vectors of cost and service characteristics for the automobile and bus, respectively, and θ is an estimated weighting vector.

In the particular implementation used, the characteristics of the automobile and the bus transit mode include the cost of travel divided by the post-tax wage of travelers, the in-vehicle travel time, and the out-of-vehicle travel time. Thus the model is sensitive to the major service characteristics to be chosen by the bus operator, with the exception of comfort level (e.g., percent seated). In the case of this feature, it is assumed conservatively that the bus service must provide sufficient seats for all travelers. This consideration did not characterize transit alternatives in the sample, and thus demand for transit was probably underestimated at least slightly.

The model's parameters were estimated using a sample in the San Francisco Bay area in 1973. Therefore income distribution data for travelers in the San Francisco region for the same period were used, and the costs of traveling by automobile for that same year were estimated. It should be noted that these data are for a period before the oil embargo when gasoline became difficult to obtain and there were long waiting lines at service stations. It is possible to claim that Bay Area automobile costs are atypically high; however, demand and cost data from other regions of the United States did not significantly alter qualitatively the nature of the conclusions presented here. After the model was run, these costs were inflated to more recent values for purposes of comparison, using the Consumer Price Index.

In principle, a similar demand model for travel for purposes other than work could be used for the remainder of travel. However, because a model that was entirely satisfactory in terms of including all of the relevant price and level of service features, and encompassing the range of purposes desired, could not be identified, it was impossible to approach nonwork (presumably nonpeak) travel in the same way. Nonpeak analyses were also hampered by a surprising lack of information on travel volumes of trips to central business districts via all modes relative to peak-period flows. The solution to this problem follows.

Peak-Period Versus All-Day Travel

Rather than rely on guesses about total volumes and on relatively unsatisfactory demand models, it was decided to focus the analysis on peak periods only. This was done in a manner that would underestimate the daily profit, and hence the analysis gives a conservative answer to the question of potential profitability of all-day service. It should be borne in mind that, although a firm might attempt to initiate a profitable peak-period-only transit service, it is also likely that one would initiate an all-day service, as is typical of many of the line-haul services that have been profitable (2).

To understand why the estimated profitability is almost certain to err on the conservative side, it is useful to reexamine the revenue and cost relationships in a manner that distinguishes between these items for different periods. If the weekly operating activities are divided into the four periods defined previously, the revenue and cost picture is as follows:

$$P = FD_1 - \gamma_1 G_1 - \beta M_1 + FD_2 - \gamma_2 G_2 - \beta M + FD_3 - \gamma_3 G_3 - \beta M_3 + FD_4 - \gamma_4 G_4 - \gamma\beta - \beta M_4 \quad (9)$$

where D_i is the demand for period i (1 is weekday peak, 2 weekday midday, 3 weekday evening, and 4 weekends). Vehicle-hour related costs, which have different values for each period, are paired with the corresponding revenue term and the corresponding vehicle-mile term.

The estimate of profitability would be understated if the incremental profit from the nonpeak periods taken together were positive or, more conservatively, if the incremental profit in each nonpeak period were positive. That this is likely to be the case can be readily seen. First, with respect to the weekday midday period, the only incremental cost associated with operating buses is the mileage cost because q_2 is typically zero as noted earlier. The one-way fares that are calculated as optimal in the ensuing analysis are typically at least twice the cost of operating a bus for 1 mile, and hence a midday bus run need only have a number of riders equal to half the miles run, on average, to fully cover its additional cost.

This is certainly a likely situation. For weekday evening services, the additional cost of operating a bus would consist of the mileage cost plus a labor cost that is substantially less than that of the nominal wage rate. The reason is that if bus service were operated after the evening peak period, a single bus driver who in the peak-only case operates a bus in both the morning and the evening peak periods would be replaced by two drivers. One driver would operate in the morning and continue to work into the middle of the day and be paid straight time rather than overtime. A second driver would operate the evening peak period and continue to work into the evening. The replaced single driver would typically work and be paid for 10 or 11 hours, with time-and-a-half after 8 hours, for a total of approximately 12 or 13 pay hours. Two straight-time drivers would be paid only for 16 hours. Thus the incremental cost of bus service in the evening is relatively low, and again relatively minimal passenger loading should more than cover these expenses.

Weekend service would typically be operated in a manner that avoids any significant amount of overtime payments, and hence it is likely--although somewhat less so than in the preceding cases--that revenue would cover the additional cost of both mileage and labor. Note that in all of these cases the entire cost of bus ownership is determined by the peak period, so that none of the other three periods must generate additional revenue to pay for vehicles. Thus it is highly likely that the operation of any or all of these nonpeak services would increase total profit as a result of the relatively low incremental cost associated with such additional operation. If this is the case, then the analyses to follow understate profits and hence err conservatively in estimating the condition for profitable operation. It might be noted that this conclusion is similar to that reached by others in analyzing bus cost-revenue relationships (6,pp.116-119).

Conditions for Profitability

To identify conditions under which peak-period service could be profitable, a wide range of travel market characteristics and competitive characteristics with the automobile was explored. The characteristics that were varied included

- Length of line-haul portion, L (8-15 miles, 13-24 km);
- Line-haul speed, S (20-50 mph, 32-80 km/hr);
- Residential area transit speed, SPD (7-12 mph, 11-19 km/hr);
- Residential area automobile speed, ASPD (12-25 mph, 19-40 km/hr);
- Circuity, XL (0-4 miles, 0-6.4 km); and
- Total demand from residential area to CBD (600-5,000 persons per hour).

In the following paragraphs an attempt is made to identify the general pattern of these results and their interpretation.

Maximum Profit Analysis

It is useful to begin by examining the general pattern of profitability, assuming that the carrier does select the service characteristics and price in a manner that in fact maximizes its profit. For this a formal optimization model was solved; a separate run of the model corresponded to each market/service condition.

Typical results characterized by a single residential-area-to-CBD service are presented in Table 1 that gives the profit and selected optimal bus service and fare characteristics and the modal split. In general, the optimal fare increased with total corridor (automobile and transit) volume as of course did frequency.

Figure 4 shows the results for various situations. The variation in profit level is explained primarily by the total travel volume, as would be expected, and to a somewhat lesser extent by other market characteristics. First, for the highest level of potential profits, the circuity via transit had to be low and the speed at which transit could operate had to be relatively high, with line-haul speed between 30 and 50 mph. As can be seen from the figure, profitability under these conditions seems to be possible down to total corridor volumes (i.e., automobile plus transit) of 600-800 persons per hour.

A substantial reduction in potential profit, and truncating of the range of volumes over which profit is possible, occurs with a reduction of transit speed--in this case, a reduction of local speeds to approximately 7 mph. Profitable service is possible down to a volume of approximately 1,300-1,500 passengers per hour.

A further reduction of profit potential occurs when the circuity increases; the lowest band of results refers to a situation with extreme circuity of 4 miles. It might be noted that this implies that each bus run requires an additional 20 minutes more than that with zero circuity. Hence this result is not surprising.

Region of Profitable Service Characteristics

In addition to the maximum-profit situation, the degree to which the achievement of profit is dependent on choosing the precise profit-maximizing values for service and price characteristics is of interest. If the range of possible profitable service and price characteristics in any market is large,

TABLE 1 Example of Optimal Profit Bus Service: Profit, Fare, Level of Service, and Mode Split

Market (persons per peak hour)[a]	System Profit ($ per day)	Fare ($)	No. of Routes	Buses per Hour	Overall Bus Share[b]
5,000	22,596	3.27	9.0	38.7	0.387
4,000	16,368	3.13	8.0	30.2	0.378
2,000	4,988	2.55	5.3	13.5	0.338
1,000	632	2.14	3.7	6.7	0.254
800	45	1.98	3.2	5.0	0.213
600	(deficit)				

Note: S = 30 mph, L = 8 miles, XL = 0 mile, ASPD = 25 mph, and SPD = 12 mph; fares and profits are in 1981 dollars.

[a]Total corridor volume via automobile and transit.

[b]Total transit volume is share times corridor volume (e.g., 0.387 x 5,000 = 1,935 persons per hour for the 5,000 persons per hour corridor, and 0.213 x 800 = 170 persons per hour for the 800 persons per hour corridor.

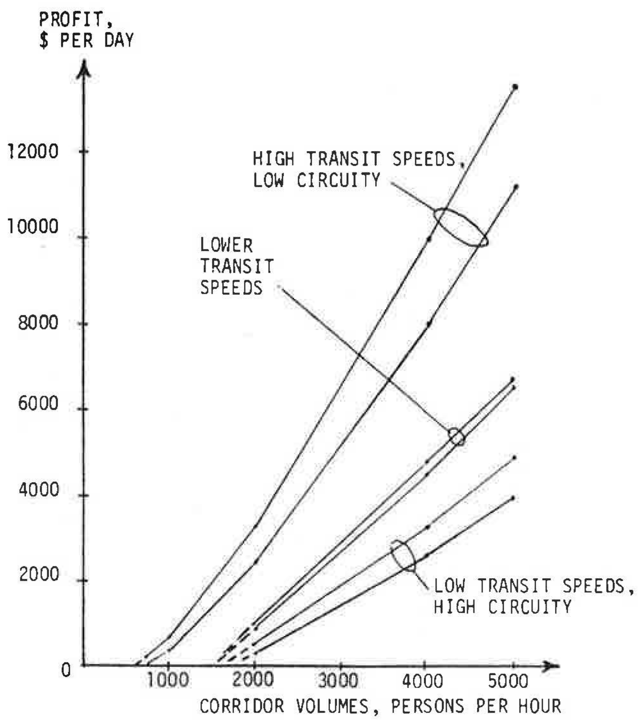

FIGURE 4 General patterns of profitability and market characteristics for maximum profit choices.

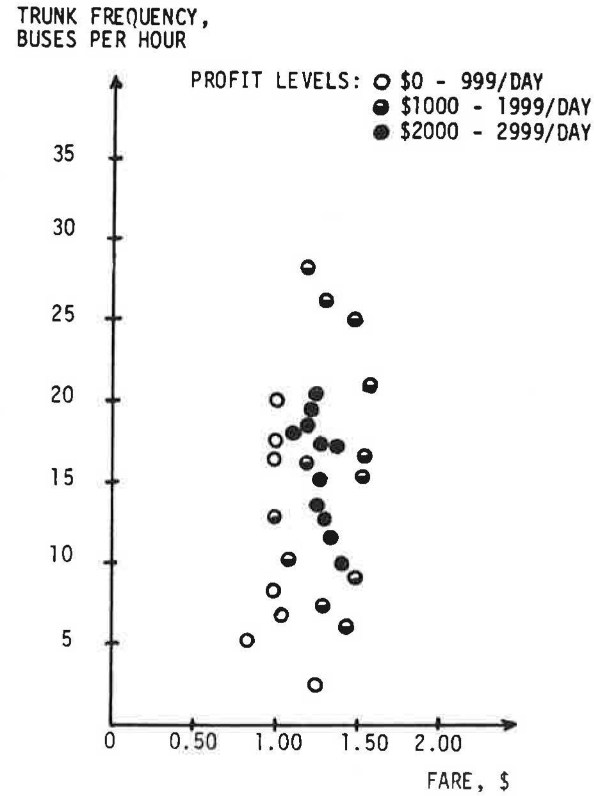

FIGURE 5 Example of ranges of fare, trunk frequency, and profit for peak-hour travel volume of 2,000 persons per hour. Other conditions are S = 30 mph, SPD = 12 mph, ASPD = 25 mph, XL = 0 mile, and L = 8 miles.

this reduces the risk to the carrier that results from imperfect market information and makes entry into the industry much more attractive.

By a serendipitous exploration of the feasible region of service characteristics, a large collection of feasible points for selected market characteristics was obtained. Although these points do not necessarily indicate the precise boundaries of the region of profitability, they do give some idea of the size of that region.

The general pattern of the results is shown in Figure 5, which is for a market situation of 2,000 travelers per peak hour and other conditions as given in the figure. Profitable points are obtained for a range of frequency from 2.5 to 26.1 buses per hour and for fare values from $0.83 to $1.53 (1973 dollars). The general pattern here is roughly an ellipsoidal shape covering a substantial range of values. The highest profit seems to be toward the center of this region. This is the general pattern obtained from analysis of other markets as well. It clearly indicates that a carrier can select a value of price and of service characteristics anywhere within a substantial range and still operate at a profit.

Competitive Conditions

In interpreting these results, it is important to bear in mind three features of the situation modeled. First, the transit firm is left completely free to choose its service and fares. It is not limited in any way by a regulatory agency of the sort that has existed in all states and has regulated transit when it was provided by private firms. Such an agency could set fares or other conditions of service such that a profit was impossible, and thus the existence of such an agency would act as a deterrent to private investment in transit.

Second, the private transit firm does not face any transit competitors, in particular one that is subsidized. A subsidized competitor could easily set its fares or service levels so as to drive a private firm out of business. This situation was modeled with an extension of the model presented earlier, and under almost all conditions an unsubsidized operator could be driven from the market (3).

Finally, there is only one transit operator in each market. Behavior and results for more than one operator could be quite different. The reason for assuming a single operator is that at present this is the general pattern. With this situation a profit-maximizing transit operator could be either the present transit authority or a new private firm. Allowing more than one operator in a market may be desirable but was not analyzed here.

Comparison of Fares and Service Characteristics

In this section the fare and level of service offered by the profitable bus operation are compared with those of typical U.S. transit systems. In the case of fare, comparison is done with reference to the major U.S. bus transit systems as well as one large commuter or regional rail service. The latter comparison was done because the average trip length considered is rather long compared to that for bus systems, but it is similar to the average for commuter rail systems. In the comparison of level of service, vehicle frequency of the profitable bus service is compared with peak-period frequencies typically found on bus routes with the same passenger volume.

Figure 6, taken from Morlok and Schueftan (8,pp. 2-168), shows the average fare and trip length for Chicago Transit Authority (CTA), Massachusetts Bay Transportation Authority (MBTA), New York City Transit Authority/Manhattan and Bronx Surface Transportation Operating Authority (NYCTA/MABSTOA), Southeastern Pennsylvania Transportation Authority (SEPTA), and Washington Metropolitan Area Transit Authority (WMATA) systems and those for profitable bus operations for the year 1979. For the profitable bus operation, the range of fares corresponding to maximum profit, as well as the lowest fares in the profitable service-price region, are shown. These ranges apply to peak hourly travel volumes of 5,000 and 2,000 persons per hour for the spectrum of the conditions described earlier. Lines L1 and L2 mark the upper and lower bounds of fare per unit distance prevailing in the major U.S bus systems. It is clear that in the case of maximum-profit operation the fares per unit distance for profitable bus operation are well within the upper bound. As for the lower fare per unit distance (with positive profit) they are much less than even the lower bound of the existing major U.S. bus systems. Of course, the total fare for the profitable bus service is considerably higher than that for the city bus services, reflecting in part the considerably longer trip length.

Figure 7 shows the minimum fares with positive profit of the profitable bus service and commuter rail fares of SEPTA's Philadelphia Division (excluding the state of Delaware) as of March 1982. The SEPTA fares were obtained by dividing the unlimited calendar monthly fare over 44 trips, assuming 22 workdays in a month. It is clear that for both the 5,000 and the 2,000 persons per hour cases, the minimum fares are in most cases about the same as SEPTA fares.

A final comparison focused on the quality of service, specifically frequency. In general, transit operators increase frequency with increasing passenger volume (above the peak-load point), so the relationship between frequency and passenger volume for the maximum profit express bus service was compared to the relationship observed on the CTA bus routes [a regression equation, $f = 4.10 + 0.013p$, with f in buses per hr, p in passengers per hr (8,p.16)]. The results of the comparison were that the maximum-profit service frequency was greater for any given passenger volume of more than about 590 passengers per hour. In general, the trunk portion of radial transit routes would be expected to have a passenger volume greater than 590 persons per hour, so in general the profitable service would have a higher frequency than the usual public authority service. Furthermore, even the apparent superiority of the CTA service at low volumes should be considered in the light of the fact that the Chicago relationship was developed from data for a 2-hour peak period. It is highly likely that if data were available for the peak hour alone, the profitable bus service would be superior in frequency even at low volumes. This is based on the general observation that virtually all large city radial transit routes have many standees

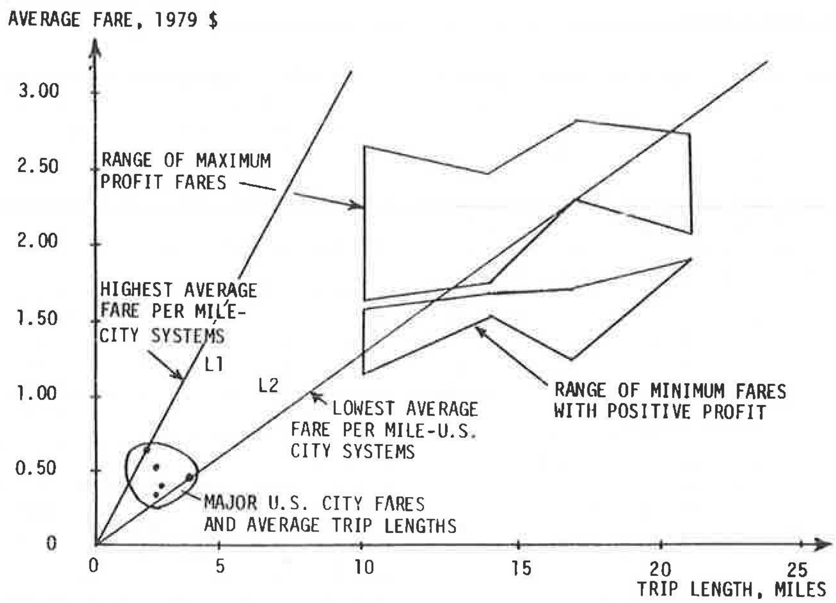

FIGURE 6 Comparison of fares in profitable service-price region with major U.S. bus system fares (in 1979 $) for various trip lengths *(8)*.

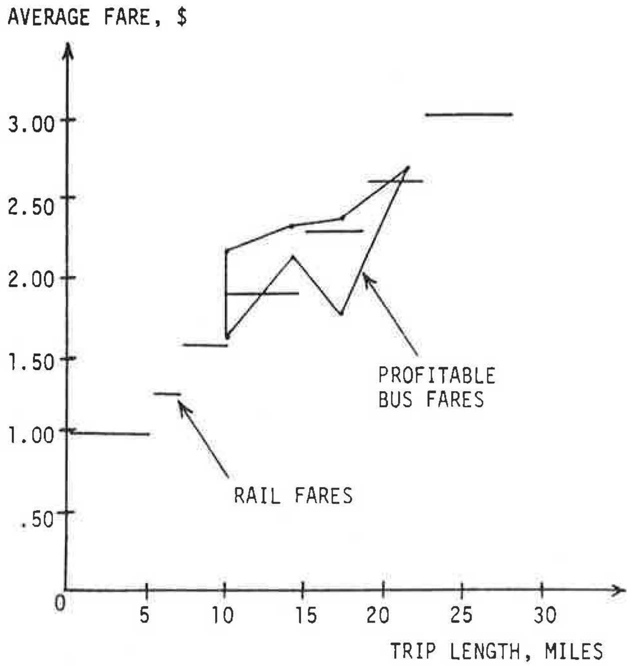

FIGURE 7 Comparison of lowest fares in profitable service-price region with Philadelphia (SEPTA) regional rail fares (in 1982 $) for various trip lengths.

at peak hours, whereas a profitable bus service is modeled to provide seats for all.

Empirical Validity

An important question is naturally the empirical validity of these results, by which is meant the extent to which real-world observations conform with (or vary from) the results. Such an analysis is naturally hampered by the very fact that led to the choice of the modeling approach in the first place, namely that virtually all providers of public transit in the United States do not have as a primary goal the maximization of profit. However, there are a few instances of profitable transit in the United States, and some tests can be applied to conventional, unprofitable U.S. transit.

The only large-scale example of profitable conventional bus transit identified in the literature appears to be the express bus services connecting the Manhattan business district with the residential boroughs of New York City. This type of service was introduced in 1967 by a private firm operating a route from Queens to Manhattan, under a franchise granted by the city's Board of Estimate, which controls rates, fares, and certain aspects of service quality (2). This initial route was a success in terms of passenger traffic and profit, and its success stimulated other private firms as well as the city-owned transit authority to seek approval for routes, which now number more than 50. Until recently those routes operated by private firms were provided without any form of subsidy; fares were increased to cover cost increases. These routes were surely profitable, for firms willingly entered the business and service was sustained. Moreover, detailed studies made by the city of New York of costs and revenues of selected express routes indicated profitability.

These services fit the pattern of profitable service resulting from the preceding modeling analysis. Almost all of the express routes serve person-trips from 12 to 18 miles (19 to 29 km) in length, and the fares are higher than traditional transit (typically two to three times the flat city transit fare). Service quality is very high compared to conventional transit; buses are usually of the suburban or intercity design with high-backed seats and air-conditioning, and most operators provide seats for most if not all passengers.

Although the services offered and fares charged are qualitatively as predicted by previous modeling work, the institutional structure is not ideal from the standpoint of a profit-maximizing operator. The Board of Estimate must approve any fare change, and in a period of rapid inflation refusal to grant increases could result in deficits. In addition, the city-owned transit authority provides regular lower quality transit service (rapid rail or bus) parallel to the express lines and could engage in predatory competition designed to drive the private express bus lines out of business. But apparently many New York firms have been willing to take the associated risks.

In recent years some minimal subsidy has been offered to private express bus operators, but the two largest private express bus operators have refused such subsidies, operate profitably, and pay the city a 4.5 percent gross receipts tax. Four other operators are covered by state data for 1980. Of these, three had passenger revenue (before subsidy) exceeding costs, and the fourth had a deficit of less than 10 percent of revenue before subsidy (9,pp.68-71). The profit or closeness to profit--despite direct competition from subsidized transit, offers of subsidy, fare regulation, and the gross receipts tax--certainly does not contradict the results of the modeling.

A few other instances of provision of medium-distance transit service (10-18 mile routes) by private firms exist in the United States, including service in the metropolitan areas of New York (from New Jersey), Hartford, Boston, Houston, and Los Angeles (2,10). Fares, routes, and in some cases schedules are regulated for all of these services. Thus management is not free to choose service and price to achieve a profit. That most operate at a deficit is not inconsistent with the previous analysis.

Commuter bus clubs represent another relevant set of examples. Because these clubs are not for-hire carriers, fares and service are usually not regulated. Such clubs exist in many areas, but data are largely unavailable. However, the clubs must usually cover all costs from fares (generally monthly tickets). One club operates between Columbia, Maryland, and Washington, D.C., with about 600 passengers per day each way, at a fare of $2.55 for the approximately 30-mile trip. In the Chicago area Spartan Services totaling about 75 buses each way serve suburb-to-CBD trips at about one-half the corresponding fares on the regional rail lines. Again these data are broadly consistent with the results of the present modeling.

An interesting study was recently completed in the Los Angeles area of the degree to which some existing medium- to long-distance peak-period-only express bus services could be operated at a profit. Although all 13 regular-service routes now produce a deficit, six were estimated to be profitable under private operation because of lower cost alone, and an additional five were estimated to be profitable with fare increases of up to 53.0 percent (11,pp. 28-31). The resulting service would be similar to that emerging from the modeling efforts.

Finally, there exist a number of profitable transit services abroad, and these have been reviewed

(12). Although they vary widely in service type, many of the profitable services, especially in higher income areas (relatively so, for developing nations), are of the high-quality and high-price type compared to other transit service in the same area or nation. Again, this is broadly consistent with previous findings.

To summarize this section, it must be reiterated, first, that in general private firms are prohibited from entering the transit field in most metropolitan areas of the United States and, second, that even if they did enter they would be subject to regulation of fares and service that could easily result in deficits or bankruptcy. Thus the fact that there are few instances of profitable privately provided transit is to be expected. However, the service offered by the express bus operators in New York City and the results of the independent analyses of potential profitability of such services in Los Angeles do conform to the modeling results.

CONCLUSIONS

The first conclusion is that, in general, it appears to be possible to operate a workday peak-period-only bus service for medium to long trips (longer than 8 miles) at a profit under a wide variety of conditions. With typical income distributions, this seems possible with a total corridor passenger volume of 2,000 persons or more per hour and often is possible at much lower volumes depending on corridor road and traffic conditions. Furthermore, service can be made profitable by offering a price-service package anywhere within a rather large range of fares and frequencies, indicating that it should be relatively easy to implement such a service even with imperfect knowledge of the demand function for transit. Such service would have fares comparable to those of commuter railroads, graduated by distance. These fares would be considerably higher than typical flat in-city transit fares but would be lower on a per mile basis. The frequency of buses would, in general, be higher than that found on typical bus transit routes today, and all travelers could be provided with seats. Thus the level of service would generally be higher than that of typical city bus transit services except possibly at very low volumes.

Some important limitations must also be pointed out. The analysis assumed that there is only one transit operator in each market; that the operator faces no subsidized transit competition; and that the operator can choose service quality and fares freely, unrestricted by a regulatory body. The creation of such conditions would require major changes in transit institutions.

On the other hand, it is equally important to note that the present results may be far more conservative than the discussion indicates, because costs typical of large regional public transit authorities were used. Recent research has revealed that small, competitive, private firms generally have lower costs--often 50 percent lower--than do public carriers (13). If such costs were used instead of those typical of public carriers, the range of profitability would certainly increase substantially. Finally, the minimum fares required for profits should be far less than those reported here.

ACKNOWLEDGMENTS

This research was supported by UMTA through University Research and Training grant PA-11-0027 and by the UPS Foundation Fund for Advanced Research in Transportation at the University of Pennsylvania. This support is gratefully acknowledged but implies no endorsement of the findings by these organizations. We also wish to thank P. Sudalaimuthu and R. Yaksick for making some of the computer runs, H. Bain and I.N. Pierce for information on profitable express services, and two anonymous referees for helpful comments.

REFERENCES

1. P.A. Viton et al. The Feasibility and Desirability of Privately-Provided Transit Services. Report UMTA-PA-11-0027-2. U.S. Department of Transportation, 1983.
2. E.K. Morlok et al. Self-Sustaining Public Transportation Service. Report NTIS PB 80-196157 (All). UMTA, U.S. Department of Transportation, 1980.
3. W. Cherwony, G. Gleichman, and B. Porter. Bus Route Costing Procedures: A Review. Report UMTA-IT-09-9014-81-1. Simpson and Curtin Division of Booz, Allen & Hamilton, Inc.; UMTA, U.S. Department of Transportation, May 1981.
4. E.K. Morlok, W.M. Kulash, and H.L. Vandersypen. Cost Models. In The Effect of Reduced Fares for the Elderly on Transit System Routes. Report NTIS PB-204058. UMTA, U.S. Department of Transportation, 1971.
5. K. Train. Work Trip Modal Split Models. Working Paper 7602. Travel Demand Project, Institute of Transportation Studies, University of California at Berkeley, 1976.
6. R.L. Oram. Peak-Period Supplements: The Contemporary Economics of Urban Bus Transportation in the U.K. and the U.S.A. Progress in Planning, Vol. 12, 1979, pp. 81-154.
7. National Urban Mass Transportation Statistics, Vol. 1. UMTA, U.S. Department of Transportation, 1981.
8. E.K. Morlok and O.K. Schueftan. Supply Characteristics of Chicago Bus and Rail Rapid Transit Systems. Research Report. University of Pennsylvania, Philadelphia, 1976.
9. 1982 Report on Transit Operating Performance in New York State. Transit Division, New York State Department of Transportation, Albany, 1982.
10. R.F. Teal and G. Guiliano. Increasing the Role of the Private Sector in Commuter Bus Service Provision. Built Environment, Vol. 8, No. 3, 1982, pp. 172-183.
11. Commuter and Express Bus Service in the SCAG Region: A Policy Analysis of Public and Private Operations. Report DOT-I-83-3. Southern California Association of Governments, Los Angeles, Calif., 1982.
12. G. Roth and G.G. Wyne. Free Enterprise Urban Transportation. Learning from Abroad Series 5. Transaction Books, New Brunswick, N.J., 1982.
13. E.K. Morlok and S.E. Krouk. Variations in Driver Wage Rates and Opportunities for Transport Cost Reductions. Proc., Transportation Research Forum, Vol. XXIV, No. 1, 1983, pp. 108-115.

Publication of this paper sponsored by Steering Committee on Socio-Economic Evaluation of New Transit Technologies.