

Figure 2. Percentage change in revenue and riders, carriers D and G.

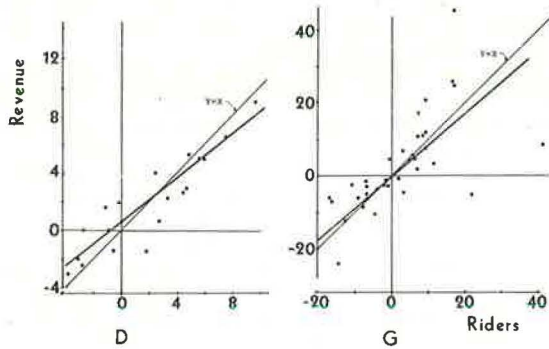
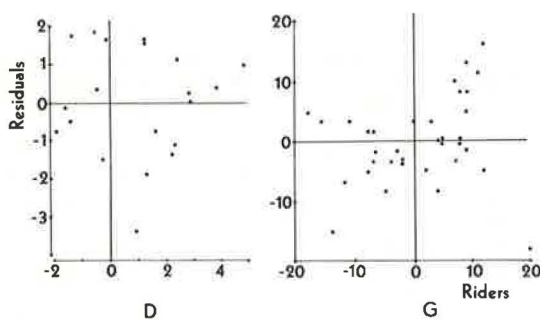


Figure 3. Plot of residuals and percentage change in riders, carriers D and G.



result of poor data quality.

The MSEs are valuable indicators of the average size of residuals even when the model may not explain a large proportion of the square deviations. A small size of deviations indicates a close grouping of observations around the regression line and small estimation errors. RTA carriers with "poor" or worse ratings exhibited MSEs in excess of 35. Carrier B with rather poor R^2 of only 0.42 but an MSE of only 3.40 was considered "acceptable" for its small deviations. Sources of its small but unexplained deviations may be found in its relatively minor error in data-gathering and reporting practices. Because MSE may be affected by a few large residuals, a visual check of residuals was made and

extreme residuals were removed when justified.

Test of Seasonality

Because seasonal, systematic patterns of changes in the data could affect regression equations, all models were examined for autocorrelation in residuals, that is, seasonality in errors after linear trend is taken into account. Only carriers B and I showed statistically significant annual seasonality. Seasonal parameters for these carriers, however, failed to decrease MSE or overall evaluation of their data.

Assessment of Data Quality

No single index of data quality has been suggested since each carrier must be considered in its own unique environment. Relative values of various statistics for the carriers must be compared with caution. The MSE is perhaps the single most important index to watch in any relative test, mindful that a single large residual may affect this value.

CONCLUSION

This study demonstrated an application of ordinary linear regression analysis to evaluate the consistency and reliability of revenue and ridership data of 12 RTA-Chicago carriers. Using percentage changes over sequential periods in revenue and ridership, the simple linear models provide a useful mechanism to examine the quality of data, compare carriers in their revenue-ridership relationships irrespective of their size or location, and enable the tracking of changes in the composition of riders that affects revenue.

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Abridgment

Bus Costing Information in Short-Range Planning: Survey of Principles and Practice

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This paper discusses the major principles involved in the use of bus transit cost information for planning and policymaking purposes. It is argued that there is no such thing as comprehensive costing, which is immediately and uniformly applicable to all kinds of decisions. Rather, the types and treatments of the costs that should properly be considered vary with the nature of the decision being contemplated. Particular emphasis is placed on the relevance, structure, and valuation of cost items. Three major categories of decisions that require different approaches are considered. These are characterized as service changes,

innovation, and the allocation of deficits and subsidies. The paper also provides a brief critical review of currently available procedures for employing cost information in short-range transit planning. A direct estimation of costs may be made by planning proposed service changes in full operational detail, but this is cumbersome and expensive. Short-cut techniques include computerized operational research models (so far, they are not well developed), simple average cost procedures, and more sophisticated causal factor allocation methods. Enhancements to the widely used causal factor approach attempt to take better

account of peak and off-peak cost differentials and to focus more closely on marginal rather than average costs.

The literature on bus transit costs often makes for confusing reading. Past studies have varied considerably in their motives, focus, depth, and relevance to planning and policy. This paper discusses some of the general principles involved in the collation and use of cost information, categorizes the practical decisions to which cost information is relevant, and reviews procedures commonly in use to appraise the costs of implemented or proposed service changes. It is a shortened version of part of a more comprehensive paper by us (1) that summarizes the applicability of current knowledge and procedures regarding bus costs for practical planning and policymaking purposes.

Much of the information in the bus costing literature is not directly relevant to practical problems of this nature. Many studies have suffered from a lack of attention to the reasons for wanting cost information and to the relation between the information and the decisions being made. It is important to establish that the types of costs that are relevant to a particular policy decision vary with the nature of the decision. Moreover, the relevant costs depend not only on the nature and level of output being sought, but they are also tied inseparably to the details of the methods chosen to achieve that output. For instance, a property wishing to expand its services (reduce headways on a particular route, perhaps) has several options open to it: (a) use existing resources more intensively, perhaps only temporarily; (b) reallocate resources internally, taking buses and drivers from other routes; (c) acquire extra resources; or (d) contract with an external company to provide the desired service increment. The actual costs of each of these approaches differ, and so do the types of costs that are relevant. The purchase price, for example, of new buses is germane to an intended fleet expansion but not to an internal reallocation of resources.

It must also be remembered that cost information is rarely of value in isolation from associated information about demand and revenues. A change in services provided is likely to lead to a change in demand as well as to a change in costs. For financial planning purposes, it is the impacts on systemwide net costs (or net revenues) that are of primary interest. A minimum cost solution to providing a given increment in service on one part of the system may well be one involving changes in revenue on some other part.

CATEGORIES OF TRANSIT MANAGEMENT DECISIONS

To exemplify and build on the principle that different management decisions require different types of cost information, it is useful to distinguish between three major categories: service changes, innovation, and allocation of support decisions.

When a planning decision considers only the types of resources and procedures currently in use by the firm, it is classed as a service change. It might involve, for example, adjustments to headways or service periods, changes in the service area or route structure, or any combination of such policies. The costs attributed to these actions vary for several reasons. First, operating conditions may differ between routes and by time of day. Operating costs are constrained by geography, traffic conditions, union agreements, and other factors. Geographical factors can lead to different costs even when the same wage rates and types and

ages of buses prevail. Second, the prices paid for inputs can vary over time and across the system. For instance, a headway change might affect the average rate per driver hour because of work rules governing split shifts, spread time, and the like. Finally, costs may vary because the aggregate volume of resources employed expands or contracts. If total output is to be expanded under fixed production conditions, new assets must be purchased, personnel hired, and so on; if contracted, assets are to be sold and employees laid off. Forming new transit properties, or merging or divesting old ones, also raises the question of how costs vary with the size of the organization.

By comparison with service changes that use only procedures and types of resources already in use, innovation involves some new feature in the way output is produced. For instance, transit management might be asking whether new types of buses can be substituted for old, whether cheaper sources of labor might be used, whether a new way of organizing services might be beneficial, and so on. Bus operations face make or buy decisions; for example, they must decide whether to contract for maintenance work or provide it in-house.

These are all examples of what economists characterize as shifts in the production function or the cost function with which the decision maker is concerned. Recognizing such shifts is important because it affects the interpretation of the empirical evidence on costs. Investigators frequently assume that the conditions of production are held constant, so that the observed costs reflect attempts to make the best of a given set of circumstances. If conditions can change because of innovation, costs must be reinterpreted. Changes in the operating environment may have potentially far-reaching effects on costs, too. For example, a traffic management improvement that results in the speeding up of buses can affect labor productivity, capital productivity, maintenance, and other types of cost, as well as open the door to substitution of different equipment. The potential of innovation can be realized most efficiently if the possibilities are scanned systematically. Analysis of costs by type of function and input is a necessary step in the search for improvement: The aim is to concentrate attention where total costs stand to be changed the most.

The third major category of decisions relates to the allocation of deficit or subsidy support among jurisdictions served by a transit property. Cost measurements are significant here in that, for example, computing the avoidable costs associated with each jurisdiction's services may well show total costs to exceed the sum of the avoidable costs. The unexhausted costs are called common costs and are by definition not allocable by reference to output changes. To attribute these to jurisdictions or to specific services, one has to appeal to other considerations, notably to ideas about what is a fair basis. Costs can enter this discussion in another way, in that it is possible to make hypothetical costs a basis of agreement about what is "fair."

IDENTIFYING AND MEASURING THE RELEVANT COSTS

As a general principle, one should only count costs when they are relevant--that is, when they can affect the decision being contemplated. As shown, relevance varies with the nature of the decision. For service change and innovation decisions, the costs of past investments are irrelevant, at least from an economic efficiency point of view. Once a bus has been bought, the outlays concerned cannot be

varied, and they are not relevant to any currently pending decisions about how the bus is to be used. However, if an expansion of the bus fleet is under consideration, the current price of extra buses is relevant; if a contraction is contemplated, the values of buses to be sold in the second-hand market are relevant as a credit. If a contractual obligation cannot be changed, once made it cannot affect the costs incurred. They are unavoidable and, hence, irrelevant for deciding the best course of action in a future decision. The longer the time period contemplated in a decision, the more cost elements become avoidable and, hence, relevant.

A second feature of costs that enters the decision is their structure: Costs may vary with output changes to different degrees. Outlays on bus acquisition and use are lumpy with respect to the services provided. A 50-seat bus costs roughly the same whether one or 50 people are carried, and (running costs and maintenance aside) whether 50 000 km or 80 000 km per year are run. By contrast, fuel is more variable relative to outputs, provided that it can be contracted for freely. Labor may or may not be variable with service levels over the short run.

Fixed and variable costs, as these elements of structure are sometimes called, subject the enterprise to varying degrees of risk. Fixed elements provide opportunities to lower unit costs by expanding output but involve the enterprise in a greater liability to varying financial results if planned output is not realized because of market and other fluctuations. In the case of transit bus operation, the fixed elements (and the associated economies) are of little significance in the aggregate for most bus properties. The main unit of capital, the bus, is small by comparison with the total capacity typically used. Compared with many manufacturing businesses, the opportunities to realize savings by increasing the scale of operation are few. Thus one does not expect to find economies of scale over most bus operations, and this expectation has been verified empirically.

The third important feature of costs is their valuation. Inputs such as buses and labor have prices that may or may not be affected by the property itself. One manifestation of this is in the terms negotiated with outside parties: Prices paid for buses or labor will be affected by the property's bargaining power. Costs will be affected accordingly, and these effects are usually distinguished from those arising from relevance and structure.

Another point about the valuation of costs is that the values appearing in the property's balance sheets or other financial records may or may not be relevant. For service planning and innovation decisions it is appropriate to use some measure of the opportunity costs for the resources employed--that is, the value to the enterprise of those resources in their best alternative use. Sometimes market prices may understate or overstate the opportunity costs; and sometimes the bookkeeping entries may more closely reflect accepted accounting conventions than either market prices or opportunity costs.

From this review, it should be very clear that there can be no such thing as comprehensive costing, which is suitable for all kinds of decisions. The first step is always to define the options now open; the appropriate cost calculations follow. Of course, short cuts and approximations can be made. Many different decisions will not involve different avoidable costs, but the initial questions about what are the context and content of decisions must always be asked, otherwise incorrect and misleading

statements about costs are very likely to follow.

CURRENT COSTING TECHNIQUES USED FOR SERVICE CHANGE DECISIONS

The necessity of abridging this paper means that insufficient space is available to review the full range of current planning practices that use cost information in appraising bus service policies; the interested reader will find a comprehensive survey and discussion in McGillivray and others (1). Space limitations permit only a cursory categorization of techniques here.

The procedures used to estimate the costs of potential service changes can be divided broadly into two types--those that attempt a direct estimation of the costs and those that use cost formulas derived by statistical or accounting methods. For any proposed service change, particularly one that involves no innovation in operating procedures and equipment, it is possible to plan that change in maximum feasible detail--to the extent necessary if the change were to be put into effect tomorrow, for instance. With schedules in place and with specific vehicles and operators allocated to the service, it is then possible to make a quite accurate estimate of what the associated relevant costs are likely to be. Because this approach to estimating the costs of proposed changes is applicable at any level of planning sophistication, it is a procedure that has always been available to bus properties; consequently, it is widely used when major changes are being contemplated. The primary disadvantage is the level of effort required to apply it. This is particularly true where scheduling and run-cutting are handled manually, but it remains true (at least for now) even when these functions are computer-aided. The high costs involved make the technique inappropriate for sifting through many possible changes in examining the relative cost implications of each one.

One can conceive of making a fairly accurate forecast of the costs of incremental service changes without necessarily going all the way to producing crew-duty schedules. What is required for costing purposes is some estimate of the least costly method of staffing a given service timetable, given specified physical and work rule constraints. If one could predict the premium-pay work involved, it should be possible to come up with fairly accurate crew-cost estimates. This is the philosophy underlying the macro approach to transportation planning of the Urban Transportation Planning System (UTPS) (2). Although it is much more parsimonious of computer and staff time than the most widely used scheduling and run-cutting program, it has certain practical deficiencies that have thus far limited its use. Developments of this approach, however, promise to provide a flexible and accurate tool for short-range planning purposes.

Short of these direct estimation methods, transit properties obviously require some short-cut cost formula methods for appraising the likely cost implications of proposals. But accurate short-cut techniques are not easy to devise. The simplest of all approaches is to calculate a systemwide average cost, averaged over some principal unit of output, and to apply this value to proposed changes in output. For instance, companies can compute their average cost per vehicle kilometer or per vehicle hour and can assume that this value also holds for the increment of service under consideration. The deficiencies of the method are easy to see. If the total operating costs are used as the numerator, these include many cost items that are not relevant to the decision under consideration or are not

measured in an appropriate way. There is also a strong assumption that the proposed increment of service is produced in a cost environment that matches the average for the rest of the system.

A simple development of the method restricts attention to the variable costs only and uses the short-run average variable costs at the current level of output. A further extension to these average cost methods is made by noting that certain variable cost accounts are highly associated with one unit of output while others are more closely associated with another unit. Thus, driver costs could be expected to be determined primarily by the vehicle hours operated (compared with other measures), while fuel costs are more closely associated with the vehicle kilometers of service. Arguing in this fashion, each variable cost account can be associated with a particular descriptor of the delivered service. The costs associated with vehicle kilometers can then be summed, as can the costs associated with each of the other descriptors of service; unit costs can be obtained by averaging in each category.

Application of the method typically involves four major steps. The first is to develop cost totals, by account, to whatever level of accounting detail it has been determined to work. It is at this stage that one should be asking whether each individual account is relevant to the decision at hand, whether it is measured appropriately, and whether it is likely to be associated linearly with any measure of output. Second, each account is allocated to one or more of the causal factors chosen. When all relevant accounts have been treated in this way, the costs allocated to each of the factors are summed and averaged over the numerical value of that factor in order to obtain a unit cost estimate. Finally, these unit cost values are applied to specific segments of the system or to proposed changes.

The original methods of this type used just two service descriptors, vehicle kilometers and vehicle hours. Further factors are frequently used nowadays: peak-hour vehicles, to which is assigned many of the fixed costs (3,4,5); a patronage measure (revenues or riders) (6,7); and the number of drivers required for peak or all-day operation (8,9). The basic approach has a number of problems. First, though many accounts can be unambiguously allocated to a particular service descriptor, it is a matter of fine judgment how several of them should be allocated. Second, the unit cost figures produced by the method are still estimates of average rather than marginal costs.

There have been several studies attempting to build on this basic causal factor method. One focus has been on categorizing costs not only by a service descriptor but also by the timescale over which operational changes will produce cost changes (10,11). This provides a wider segmentation of unit costs from which to pick the cells relevant to a particular decision. Another focus has been on identifying separate unit costs appropriate to the peak and off-peak periods (5,12). The principal problems involved in doing this are (a) that the allocation of common costs must be arbitrary from an economic efficiency point of view (although one may appeal to equity or fairness notions) and (b) that the conclusions are likely to be quite sensitive to the arbitrary definition adopted for the duration of the peak period. We tend to doubt whether the actual segmentation of peak and off-peak costs is very helpful for short-range planning purposes, with the possible exception of pricing policy. It should be possible to estimate costs that take better account of the peaking profile of the service without actually allocating costs.

Along these lines, some workers have sought to develop simple statistical relations between crew costs and the degree of service peaking (10,13). Tests of two of these methods have revealed a significant improvement in accuracy over average costing when premium pay amounts were substantial (14).

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Fare Changes and Prepaid Pass Programs: Honolulu's Experience

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This paper documents Honolulu's efforts to establish a prepaid bus pass program at the time of a major fare increase. It also discusses the revenue-forecasting techniques used for estimating fiscal impact of change in fare structure. A comparison of the forecasted values with the results of the actual fare structure change is also presented. In FY 1980, the Honolulu bus system carried more than 60 million passengers and used about 300 buses. The system coverage is more than 95 percent of the island population of approximately 720 000. On November 1, 1979, the basic cash fare of \$0.25 was increased to \$0.50. At the same time, the sale of prepaid monthly bus passes was initiated with the basic cost of \$15.00; this significantly reduced the impact of the fare increase on frequent riders. As a result, the system did not experience any noticeable reduction in patronage. The average monthly revenue of \$850 000 for FY 1979 has increased to a current level of \$1.5 million. The system's major objective of increasing revenue was successfully accomplished without significant economic impact to the system riders. This was accomplished through the combination of fare increase and the initiation of discount prepaid passes.

On November 1, 1979, the City and County of Honolulu instituted a bus pass fare program and an increased fare schedule for its bus operation, TheBUS. The purpose of the fare program was to increase fare revenues to offset rising operating and maintenance costs. This paper documents Honolulu's efforts to establish a prepaid bus pass program at the time of a major fare increase. The paper also discusses the revenue-forecasting techniques used for estimating the fiscal impact of the fare structure change.

BACKGROUND

In 1967, the Hawaii state legislature authorized Hawaii's four counties to own, operate, and maintain mass transit systems. The City and County of Honolulu established bus service in the rural areas of Oahu not covered by private mass transit carriers in 1969. Three months following a strike by the employees of the private mass transit carrier in urban Honolulu, the city initiated urban Honolulu bus service in March 1971 with 67 buses. During a 10-month period, the 67-bus fleet carried some 17 million riders. Over the last eight years, the city's system has grown rapidly in terms of level of service and area served. In FY 1980, the Honolulu bus system carried more than 60 million passengers using about 300 scheduled buses. The system covers more than 95 percent of the island population of approximately 720 000.

Total passengers using the bus system grew from 54 300 000 in FY 1975 (July-June) to 68 800 000 in FY 1979—a 37 percent increase during this period. Revenue vehicle hours increased by only 21 percent, most of which occurred between 1975 and 1976 (1). Ridership gains were considerably greater than the increase in service provided.

Operating expenses grew from \$14 900 000 in FY 1975 to \$29 500 000 in FY 1979, a gain of 98 percent. Since the system's average fare per total

passenger remained nearly constant during this interval, the operating deficit went from \$6 900 000 in FY 1975 to about \$19 500 000 in FY 1979, an increase of 183 percent.

On November 1, 1979, the basic cash fare of \$0.25 was increased to \$0.50. At the same time, however, the sale of monthly bus passes was instituted; this significantly reduced the impact of the fare increase on frequent riders.

PAST FARE STRUCTURE

The fare structure for the bus system in Honolulu has traditionally been low. It is noteworthy that student fares decreased in 1971 after the city and county assumed control over the bus system.

Until March 15, 1974, Honolulu's bus system had a system of zone fares. In large part, these zones were carryovers from the private operators' policies. In 1973, the bus fares in Honolulu were as follows:

Item	Fare (¢)		Leeward Bus Co. Four Zones
	City and County Buses Zone 1	Zone 2	
Adult	25	50	15-60
Student	10	25	20-35
Child	10	25	-

Leeward Bus Company operated on a four-zone system until the termination of their operation in March 1974. This zone fare structure was eliminated to provide more equitable fares and service to all residents on Oahu.

Free bus passes for senior-citizen and ambulatory handicapped riders began in February 1970 and July 1976, respectively. These users can ride the bus system at all hours of operation at no charge. This policy is currently in effect. A curb-to-curb Handi-Van service was established in June 1977. The initial one-way fare was \$0.50/ride.

PROGRAM DEVELOPMENT

Several studies were made to determine feasible alternatives for obtaining additional funding and revenue to offset increased operating and maintenance costs of TheBUS. The first study was a bus passenger survey that sought to elicit bus rider's perceptions on increased bus fare options and on other funding alternatives. The second study involved an analysis of funding and fare options to determine the fiscal impact of a proposed subsidy limit considered by Honolulu's City Council.