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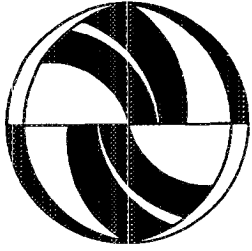
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**The University of California
Transportation Center**

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Comprehensive Transit Performance Indicators

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ABSTRACT

Transit properties increasingly provide multiple modes of transit service, creating a need for intermodal transit performance indicators. Transit performance indicators currently in use do not have the capability of comparing the performance of different modes. In addition, most indicators in current use incorporate only operating costs, while for many transit modes capital costs constitute a significant proportion of total costs. The research conducted reviewed the use of performance indicators by urban transit properties in California, and found that the most common measures in use are operating cost per revenue vehicle hour, operating cost per passenger boarding, farebox revenue per operating cost, passenger boardings per revenue vehicle mile, and passenger boardings per revenue vehicle hour. Three critical limitations to commonly used performance indicators are identified, and new intermodal performance indicators are proposed which overcome the limitations of current single mode indicators by incorporating mechanisms for comparisons of one mode to another, for rating the performance of systems which include multiple modes, and by incorporating both capital and operating costs. The proposed comprehensive transit performance indicators are total cost per revenue capacity kilometer, total cost per revenue capacity hour, total cost per passenger kilometer, passenger revenue per total cost, passenger kilometers per revenue capacity kilometer, and passenger kilometer per revenue capacity hour.

KEYWORDS

Intermodal
Transit
Performance
Indicators
Measures

INTRODUCTION

Statement of the Problem

Public transit moves people within regions. While most transit properties rely upon buses to serve this function, increasingly urban transit systems are utilizing multiple modes. Vans and buses of varying capacities are now used for local, express, and demand responsive services. At grade light rail, grade separated heavy rail, and metropolitan commuter rail services have increased in number and amount of service over the past twenty years. As a result, transit systems have grown increasingly complex in their multi-modal service options and transfer of passengers between modes.

With the increasing complexity of transit systems, a need has arisen for intermodal performance indicators - standardized measures which can indicate performance for all modes of transit for which service is provided. Intermodal performance indicators can be used for cross-modal comparisons - comparisons of performance of two different modes - particularly when a decision must be made whether to substitute one mode of service for another along a single travel corridor. Intermodal performance indicators can also be used for multi-modal measurements, when passenger trips include linked segments which rely upon different modes. This may be particularly helpful when the collector and/or distribution segments rely upon vans or buses while rail transit serves the line haul function.

Intermodal performance indicators are particularly important at the present time for three reasons. First, most of the existing literature and analysis of performance indicators appeared when most properties provided buses as the sole mode of transit. It is necessary to update the literature on performance indicators in order to focus discussion on contemporary issues and problems in transit system management.

Second, intermodal performance indicators can provide more accurate information for both cross-modal comparisons and multi-modal comparisons. Accurate measurement of performance using indicators which are applicable to all modes of transit service should result in better, more informed choices by transportation planners and other transit decision makers, particularly in an environment where diminishing resources may require one type of service to be reduced in order to expand another type of service.

Third, and perhaps most importantly, transit properties can use intermodal performance indicators to improve provision of existing services. Consistent use of and reference to performance indicators over time can contribute to service which is more efficient, more effective, and more equitable.

Description of the Study

This study has three objectives:

- (1) to review performance indicators currently in use in California;
- (2) to evaluate current methods of measuring performance; and
- (3) to propose promising intermodal performance indicators.

California transit properties provide a range of service modes which is representative of transit properties nationwide, including local bus, express bus, at-grade light rail, grade separated heavy rail, and commuter rail. Transit systems in California function within a broad variety of operating environments, from relatively high density central city environments like downtown San Francisco to lower density areas which characterize most of suburban southern California. At the same time, California transit properties operate within the same regulatory environment and face standard data collection and reporting requirements at the state and national levels, making comparisons of data more reliable.

This study presumes that intermodal comparisons will only be made within the same operating environment, defined as a single metropolitan area. The costs of goods and services can vary significantly between metropolitan areas, resulting in disparate costs among otherwise similar transit service providers. Within the same metropolitan area policy makers are often asked to trade-off dedication of some resources between operators and services in different parts of the region. In addition, individual citizens make travel mode choice decisions among the transportation options available within a metropolitan region. As a result, the most immediate need is for a set of intermodal performance indicators for transit within a single metropolitan region.

TRANSIT PERFORMANCE INDICATORS

Categories of Performance Indicators

Performance indicators are usually organized into three related categories: measures of cost efficiency, cost effectiveness, and service effectiveness. Each category of performance indicators is calculated as a ratio between two operating statistics for service inputs, service outputs, and service consumption. Cost efficiency indicators are calculated as the ratio of service inputs to service outputs, measuring the efficiency of allocation and use of resources within the organization. Cost effectiveness indicators compare service inputs to service consumption, providing a measure of the amount of resources which are expended in relation to the level of transit actually used by the public. Service effectiveness indicators measure service consumption relative to service outputs, providing information about the capacity utilization of the transit service provided (1).

Service input statistics may include the number of employees, number of vehicles, amount of fuel, or any other type of service input. The most common measure of inputs used is the total dollar cost of operating expenditures, since it incorporates all types of inputs and reduces them to a single metric. Most transit properties measure service output in terms of revenue vehicle miles or revenue vehicle hours, while service consumption is measured most often as the number of passenger boardings or farebox revenues.

A survey of California transit properties has found that the most commonly used indicator of cost efficiency is operating cost per revenue vehicle hour, the most common indicators of cost effectiveness are operating cost per passenger boarding and farebox revenues per operating cost, and the most common service effectiveness indicators are passenger boarding per revenue vehicle mile and passenger boardings per revenue vehicle hour. Table 1 shows which performance indicators are commonly used by eleven California transit properties.

Usage of Performance Indicators

Performance indicators can provide essential information when several different kinds of decisions must be made regarding transit planning, management, and finance. Performance indicators are commonly used in three different situations and have the potential for use in one important additional situation.

Currently, transit performance indicators are being used in California for operations planning, resource management through trend analysis, and funding allocation. Operations planners use performance indicators to make decisions regarding the increase or reduction in the number of revenue vehicles to existing lines of service and regarding the addition or elimination of entire lines of service. Resource managers compare performance indicators measured over an annual basis in order to identify trends in costs, service output, and service consumption and make decisions regarding allocation of resources which seek to improve efficiency and effectiveness of existing services. Finally, transit funding agencies and governing boards use performance indicators in order to make decisions regarding the most appropriate allocation of public funds among existing services.

In addition to their current uses, performance indicators have the potential to inform long term capital investment decisions. Currently, capital investment decisions are made through a consideration of alternative means of providing comparable levels of service. Expected costs and ridership are estimated in a process which often does not take into account the past and current performance of existing service. These methods often lead to substantial underestimates of costs and overly optimistic estimates of ridership (2). Extrapolations of past performance indicators may be used to estimate future performance of proposed alternative services, providing additional data for a more informed decision making process regarding capital spending for large scale expansions to transit service.

Limitations of Current Performance Indicators

A review of the literature and of current usage of performance indicators led to an identification of three issues to be resolved in the process of developing promising intermodal performance indicators.

First, indicators of cost efficiency and cost effectiveness which measure service inputs in total dollar costs should have some means to include capital costs as well as operating costs. Comparisons

of operating costs between modes may not be reliable if one mode relies to a far greater degree on capital expenditures than another. While transit planners are most often concerned about operating costs on a day-to-day basis, political decision makers, transit funding authorities, and taxpayers should have some means to compare total costs.

Second, cost efficiency and service effectiveness indicators which incorporate measures of service output should be able to take into account the varying passenger capacities of differently sized buses, rail cars, and other transit vehicles. For example, directly comparing cost per bus revenue vehicle hour to cost per light rail car revenue vehicle hour does not take into account the different vehicle capacities of the two modes. Revenue Capacity Kilometers, incorporating seating capacity and an estimate of standing capacity, is likely to be more useful as a measure of service output.

Third, indicators of cost effectiveness and service effectiveness which incorporate levels of service consumed should provide some means to consider the varying lengths of typical passenger trips on different modes. For example, a simple comparison of passenger boardings between local buses and commuter rail may show that local buses carry more passengers, but may not consider the fact that most passengers on commuter rail travel longer distances than passengers on local buses. Passenger Kilometers may be a more appropriate measure of service consumed than passenger boardings, because the former measure is sensitive to trip length.

INCLUDING CAPITAL EXPENSES IN COST ESTIMATION METHODS

The most common means of measuring service inputs for transit efficiency and effectiveness ratios is by calculating the dollar costs of resources consumed by the service. While some analyses may require a measure of non-dollar units of inputted goods, most often inputs are measured in dollar costs. As a result, the usual measures of transit efficiency and effectiveness utilized by transit agencies are cost efficiency and cost effectiveness indicators.

Since dollar costs are used to measure inputs, it is essential to assess the reliability of the cost estimates which contribute to performance measures. Cost estimating methods which are used for intermodal performance indicators should, as accurately as possible, represent the best available approximations of the average costs of inputs.

Existing Cost Estimation Methods

Most cost estimation methods for transit systems have focussed on operating expenses for bus routes. The general goal has been to help operations managers decide whether to make incremental changes to largely pre-existing bus systems (3).

Since the focus of cost estimates has been on incremental changes, transit planners have generally considered the capital costs associated with small changes to be insignificant for their purposes. In almost all cases, the capital costs associated with land and buildings would not be affected by an incremental change in service. However, almost every incremental change in service involves some change in allocation of capital resources, at least in terms of transit vehicles used.

Transit properties generally account for capital expenses on a capital budget separate from operating revenues and expenses. Funds for capital expenses are often drawn from sources of revenue entirely separate from operating revenues and subsidies. In addition, federal and state intergovernmental grants to transit agencies are often strictly designated for either capital or operating purposes. As a result, methods of cost estimation have generally included only operating expenses while ignoring the capital expenses involved in changes to service levels.

A review of the literature and practice of cost estimation methods has found that two related methods exist. The first method, the partially allocated model, seeks to estimate costs of service by incorporating a few of the major operating expenses in an estimation formula. The partially allocated model requires fewer sources of cost and service data and involves calculations which take less time than the second method, the fully allocated model. The fully allocated model incorporates all expenses into a cost allocation formula which seeks to provide as accurate an operating cost estimate as is reasonably possible. Among the greatest differences between partially and fully allocated cost models is the omission of general overhead or administrative expenses from partially allocated cost models, and the attempt to include them in fully allocated cost models.

Both existing cost estimation methods assume that expenses are linearly related to the amount of input utilized and both are based upon estimates of the unit costs of service as measured by service characteristics such as vehicle miles, vehicle hours, and peak vehicles. The general formula for cost allocation used in both the fully allocated and partially allocated methods is the summation shown in Equation (1):

$$\text{Estimated Cost} = \sum_{x=1}^n u_x * T_x \quad (1)$$

(Sigma)

where

- x = measurable service characteristic which represents the scale of operations
- n = number of service characteristics included in the model
- u_x = unit cost of characteristic x
- T_x = total number of units of characteristic x in the analysis

Existing Partially Allocated Models

The most simple partially allocated cost estimation method is based upon a formula with one service characteristic (i.e. $n=1$), most often Vehicle Hours (VH), as shown in Equation (2), or Vehicle Miles (VM), as shown in Equation (3):

$$\text{Estimated Cost} = u_{VH} * VH \quad (2)$$

$$\text{Estimated Cost} = u_{VM} * VM \quad (3)$$

The decision to rely upon Vehicle Hours rather than Vehicle Miles depends upon which types of inputs contribute the largest portion to total costs of operations. For example, in many transit agencies, the largest operating cost is wages for drivers, often making up more than half of the total operating costs. A transit planner in one of these agencies seeking to quickly estimate costs for a change in service could simply multiply the number of hours of service in question by the unit cost of wages (i.e. the cost per vehicle hour for wages involved in producing each hour of service). The result represents a rough cost estimate which is accurate in terms of order of magnitude, but not particularly precise, since many other types of expense involved in providing service are not taken into account.

The allocation formula used for partially allocated models is not necessarily limited to one service characteristic. Partially allocated estimation may incorporate two or more service characteristics, depending upon the types of inputs to be incorporated into the estimate. For example, estimates of costs of service for the San Diego Trolley sometimes use an allocation formula which includes expenses for wages as well as for the cost of electric power. While the unit cost of wages is associated with the number of vehicle hours of service, the unit cost of electric power is more closely associated with the distance traveled, and therefore with the service characteristic Vehicle Miles. The resulting cost allocation formula using these two types of expenses is then the product of the cost per vehicle hour for wages and the total number of Vehicle Hours added to the product of the cost per vehicle mile for electric power and the total number of Vehicle Miles, as shown in Equation (4):

$$\text{Estimated Cost} = u_{\text{wages}} * VH + u_{\text{power}} * VM \quad (4)$$

While the unit cost for wages and for electric power may be relatively easily determined using labor contracts and electric power bills, the unit costs for other types of inputs such as parts for vehicle maintenance are often not easily determined. For many types of inputs the unit costs are estimates, having been calculated as averages based upon annual data from the accounting records and service records of the agency from the previous fiscal year. Equations (5) and (6) illustrate how

average unit costs of wages and power are calculated on the basis of annual totals:

$$\text{Average } u_{\text{power}} = \frac{\text{Total Annual Cost for power}}{\text{Total Annual Vehicle Miles}} \quad (5)$$

$$\text{Average } u_{\text{wages}} = \frac{\text{Total Annual Cost for wages}}{\text{Total Annual Vehicle Hours}} \quad (6)$$

When more than one input applies to a service characteristic, the unit costs for each input are added together, with the sum representing an estimate of the total unit cost for the service characteristic used. In practice, the partially allocated cost estimation model used by the San Diego Trolley company is concerned with all operator labor costs, including both wages and fringe benefits. As a result, the unit cost per Vehicle Hour of service is estimated as a sum of the unit cost per Vehicle Hour of wages and the unit cost per Vehicle Hour of benefits, as shown in Equation (7):

$$u_{\text{VH}} = u_{\text{wages}} + u_{\text{benefits}} \quad (7)$$

The costs of any additional number of inputs can be included in the sum to increase the accuracy of the estimate of unit costs per Vehicle Hour and Vehicle Mile. Just as adding the cost of employee benefits to the model increases the accuracy of the estimate, including the cost of additional inputs further increases the reliability of the resulting estimate. It is important to note, however, that the cost estimates which result from this process are actually estimates based upon estimates, since the unit costs of inputs, unlike service characteristics such as Vehicle Miles and Vehicle Hours, are not usually directly measurable. The advantage of partially allocated models of cost estimation is that they require only a handful of data measurements, and calculations may be done by hand or with a calculator. The resulting cost estimates are not precise, though they are useful for providing a general range of the costs involved in a given increment of service. Often, however, financial managers of transit agencies would like to have as precise an estimate of costs of service as possible, calling for the use of the fully allocated model with the aid of computer-based calculations.

Existing Fully Allocated Model

The fully allocated model of cost estimation is an elaboration of the partially allocated model, incorporating the costs of all inputs rather than just a few inputs. Any number of service characteristics could be included in the model, though the most common are Vehicle Hours (VH), Vehicle Miles (VM), and Peak Vehicles (PV). Equation (8) shows a commonly used cost estimation formula which includes these three characteristics:

$$\text{Estimated Cost} = u_{\text{VH}} * \text{VH} + u_{\text{VM}} * \text{VM} + u_{\text{PV}} * \text{PV} \quad (8)$$

Other formulae in common use include Total Passengers (TP), Total Revenues, and Vehicle Pullouts. Whatever the service characteristics chosen, the transit agency usually measures them on an annual basis. As in the partially allocated model, these measures of annual service levels are compared to annual expenses in order to estimate the average unit costs of service. Each type of input is linked to the service characteristic most closely associated with it.

Each association of a type of input with a particular service characteristic is based upon simplification of reality. In the case of the drivers' salaries, the total number of hours which drivers are being paid wages is not exactly the same as the number of hours that they are driving vehicles. In reality, drivers are often paid wages for time spent at the station, for time spent between split shifts, and sometimes for performing non-driving duties. While linking driver salaries to vehicle hours does not result in a completely accurate estimate of annual costs, vehicle hours is the service characteristic most closely associated with driver wages in the three factor model.

To the extent that each service characteristic included in the fully allocated model accurately represents the true basis of costs for each type of input, the resulting cost estimate approaches the true costs of operation.

The unit costs for each service characteristic included in the fully allocated formula are calculated in a similar fashion as in the partially allocated model, except that the unit costs include the expenses for all inputs which are associated with each service characteristic. Inclusion of indirect or overhead expenses, such as a transit system's expenditures on data collection, planning, and management may be complex, since it is difficult to allocate such costs to measures of the scale of operations. Often, simple multipliers are used to incorporate overhead costs. For example, if administrative costs amount to twenty percent of the direct costs, an equation can be used to estimate the direct costs, which are then multiplied by a factor of 1.2 to arrive at total costs. Equations (9) through (11) show how average total unit costs are calculated for the three service characteristics most commonly used:

$$\text{Average } u_{VH} = \frac{\text{Total Annual Costs of Inputs Associated with Vehicle Hours}}{\text{Total Annual Vehicle Hours}} \quad (9)$$

$$\text{Average } u_{VM} = \frac{\text{Total Annual Costs of Inputs Associated with Vehicle Miles}}{\text{Total Annual Vehicle Miles}} \quad (10)$$

$$\text{Average } u_{PV} = \frac{\text{Total Annual Costs of Inputs Associated with Peak Vehicles}}{\text{Total Annual Peak Vehicles}} \quad (11)$$

The cost estimation method used by the Los Angeles County Metropolitan Transportation Authority (LACMTA) for the annual cost of bus service provides a good example of a fully allocated model. The allocation formula used by the LACMTA is given in Equation (12):

$$\text{Annual Cost} = (u_{PV} * PV + u_{VH} * VH + u_{VM} * VM + u_{TP} * TP) * F \quad (12)$$

where F represents a multiplier to factor in fixed overhead costs. Using a PC-based spreadsheet program, the LACMTA allocates several hundred input expenses to the formula, resulting in estimated unit costs of \$34,495 per Peak Vehicle, \$34.971 per Vehicle Hour, \$1.0870 per Vehicle Mile, and \$0.11453 per passenger (4).

Reasons for Including Capital Costs

While the operations managers of transit properties may not be primarily concerned with capital costs because their emphasis may be on balancing operating revenues with operating costs, system-wide estimates of transit costs should include capital expenses. The clearest argument for considering capital costs may be that since most transit properties rely on public subsidy for both capital and operating expenses, citizens and public officials should be concerned about finding the most efficient and effective use of all taxpayer dollars.

The findings of any comparison between different transit properties may be significantly affected by whether or not capital costs are included in the analysis. Often one may face the situation where some types of service depend to a larger degree upon operating expenses rather than capital expenses while another type of service relies to a greater degree upon capital expenses to provide equivalent levels of service.

Analytical Framework for Including Capital Costs

The temporal unit of analysis of cost estimation models is usually the fiscal year. Since capital costs constitute expenses for inputs that are in use for longer than one fiscal year, one must estimate the annual costs of capital expenses in order to include them in the cost estimation formula.

In order to annualize capital costs, one must determine or estimate the lifespan of each type of capital equipment. Simple depreciation divides the total capital costs by the expected lifespan, which provides the annual costs in dollars at the year of purchase. For future projections, one may estimate current year costs by applying a discount rate, while analyses of past years may utilize a price index for the capital equipment in question.

The resulting annual costs reflect what the expenses would be for the capital equipment each fiscal year that the equipment is in use. The data should represent what the costs of equipment would be if the transit agency rented the capital equipment for its entire lifespan and made annual payments that in total equalled the costs of the capital expenditure.

These annualized capital costs can be included in cost estimation formulas by applying their costs to the most closely associated service characteristics in the same manner as annual operating expenses. For example, the capital costs for bus garages would be applied to unit costs for the service characteristic Peak Vehicles, since the expense for the garage would be most closely associated with the total number of vehicles to be housed. Table 2 illustrates how some categories of capital expenses for bus service might be associated with service characteristics in a hypothetical case.

The capital expenses incurred most often by bus transit are costs of vehicles, land, and buildings to house vehicles, operations, and equipment. Rail transit modes will incur additional types of capital expenses, most notably costs for rights-of-way, track, and switching/signaling equipment.

However, there is no absolute distinction between the types of capital costs which rail transit may incur in comparison with buses. For example, bus service providers might be responsible for right-of-way expenses in the cases where they own and operate exclusive busways.

Incorporating capital expenses into cost estimation methods would require one additional service characteristic to be included in allocation formulas. For expenses like rights-of-way purchase which are associated with the length of the service routes in use, the most appropriate service characteristic is not Vehicle Miles or Vehicle Hours, but rather Route Miles (RM). Equation (13) illustrates a possible formula for fully allocated costs for rail and bus transit that includes four service characteristics:

$$\text{Estimated Cost} = (u_{VH} * VH + u_{VM} * VM + u_{PV} * PV + u_{RM} * RM) * F \quad (13)$$

Table 3 provides an illustration of the service characteristics which may be associated with major categories of capital expenses for rail service in a hypothetical case.

REFLECTING VEHICLE CAPACITY IN MEASURES OF SERVICE OUTPUT

The two most common measures of service output used by California transit properties are Revenue Vehicle Hours and Revenue Vehicle Miles. Usually these data are calculated as total vehicle hours or total vehicle miles minus the time or distance for "deadhead travel,"--when the vehicle is driven from the overnight storage facility to the first stop of the service line at the beginning of the service day and from the last stop of the service line back to the storage facility at the end of the day.

Vehicles as a Summary Measure of Capacity

Measuring service in terms of Revenue Vehicle Miles and Revenue Vehicle Hours is useful as long as all vehicles have approximately the same passenger capacity. For many transit properties which provide bus service using a single type of vehicle, this measure continues to be of use. However, if the capacity of vehicles in service varies across time or between lines of service, then comparisons of the data decline in usefulness.

Vehicles have been used as a summary measure of capacity. While at one time it was reasonable to use this summary measure, in many transit systems the number of vehicles no longer provides a reliable measure of the service output. Transit properties increasingly use vehicles of different capacities within the bus mode and provide more than one mode of service. Table 4 illustrates the wide variation in the capacities of some transit vehicles currently in service.

Continuing to rely upon output measures which assume that vehicle capacities are the same can lead to inaccurate performance data, and may bias service toward one type of transit vehicle over

another. For example, light rail cars can have more than twice the capacity of conventional buses. A comparison of cost efficiency between a light rail service and a conventional bus service using revenue vehicle miles as the measure of output could give the impression that light rail has a much higher cost of service relative to conventional buses than it actually does. In fact, the light rail service is providing more capacity per vehicle than the conventional bus service.

Even comparisons within the same mode of transit can be misleading. Since the largest conventional buses have more than 25% greater capacity than the smallest of conventional buses, transit properties using buses of both sizes cannot always depend upon the summary measures of Revenue Vehicle Miles and Revenue Vehicle Hours for service output.

Measuring Capacity of Output Directly

Increasing the accuracy of service output measures requires a direct measurement of capacity, rather than the summary measure of the number of vehicles. Such a measure needs to be accurate for the full variety of current transit vehicles and for any new types of transit vehicles which may come into use in the future.

Instead of using Revenue Vehicle Miles and Revenue Vehicle Hours as measures of service output, Revenue Capacity Kilometers and Revenue Capacity Hours appear to be more precise and more generalizable measures. Capacity should include both seating capacity and standing capacity since the measure should accurately indicate the full, reasonable capacity of service that is being offered to potential passengers.

In order for these measures to be applicable to intermodal performance indicators, a common standard of measuring capacity would need to be accepted and used. One likely standard for measuring maximum scheduled load capacity is provided in the Highway Capacity Manual published by the Transportation Research Board, which recommends a specific number of square feet of floor space typically required for seated and standing passengers on bus transit, rail transit, and commuter rail (5). The Highway Capacity Manual standards for measuring vehicle capacity should be readily adoptable for transit properties, since knowledge of the specific capacities of vehicles is usually required at the time of purchase.

INCORPORATING TRIP LENGTH INTO MEASURES OF SERVICE CONSUMPTION

The most common measure of service consumption among California transit properties is Passenger Boardings. The number of passenger boardings is a particularly useful measure for service scheduling since vehicle headways can be set according to the highest level of expected boardings at different times of the day.

However, the variable Passenger Boardings measures service consumption along a limited dimension since it does not take into account the length of passenger trips. As a result, the measure does not accurately reflect the amount of output (as measured in Revenue Capacity Kilometers or Revenue Capacity Hours) which is actually consumed by passengers.

Passenger Kilometers as a Measure of Service Consumption

When the service provided by transit properties consists entirely or mostly of local bus service, Passenger Boardings data is still useful because the average length of local bus trips often does not vary significantly over time or between different lines of service. However, if the length of passenger trips varies significantly between lines of service or changes over time, then the Passenger Boarding data is of only limited use.

Passenger Kilometers provides a measure of service consumption which is applicable to and comparable between all modes of transit service. Using Passenger Kilometers will both increase the precision of service consumption data for intra-modal use and allow for intermodal comparisons of service.

Passenger Hours as a Possible Measure of Service Consumption

While the argument for using Passenger Kilometers as a measure of service consumption is fairly straightforward, the proposition that Passenger Hours should be used to measure service consumption is a more complicated matter. One complication is that consumption measured in distance traveled is positively related to passenger utility while time traveled is inversely related to passenger utility. Passengers are generally willing to pay a higher fare to travel a longer distance, but would usually choose to pay more if they can arrive at their destination in less rather than more time. As a result, it is not clear that service effectiveness and cost efficiency indicators which incorporate service consumption measured in Passenger Hours would provide as much useful information as indicators which incorporate Passenger Kilometers.

Another reason why using Passenger Hours for intermodal performance indicators is problematic is that the travel speed of transit vehicles varies quite widely, both in terms of mode of travel and area traveled. Urban heavy rail and commuter rail systems which often use a grade-separated, exclusive right-of-way can travel at an average speed as high as forty-eight kilometers per hour (thirty miles per hour), while light rail vehicles and buses which have to navigate through mixed flow street traffic often travel at an average speed of less than sixteen kilometers per hour (ten miles per hour). Likewise, buses traveling in suburban environments can travel three times as fast, on average, as buses operating in central business districts of large cities (6).

As a result, service consumption measured in passenger hours is relatively meaningless unless information about the mode and the area of service are also provided. The variable itself has little comparative use between modes or areas since local buses cannot be expected to travel as fast as grade-separated rail vehicles and downtown bus service is not likely to match the travel speeds of suburban bus service.

For these reasons, it seems that Passenger Kilometers is a more promising measure of service output than Passenger Hours. Since most riders think of consuming travel primarily in terms of distance rather than time, Passenger Kilometers has the added appeal of being more intuitively useful than Passenger Hours.

PROPOSED INTERMODAL PERFORMANCE INDICATORS

The preceding analysis of transit performance indicators has identified three key limitations to existing indicators. This study has proposed means to overcome these three limitations by increasing the precision of measures of service inputs, outputs, and consumption. This section proposes an improved set of intermodal performance indicators which can provide essential information for both cross-modal and multi-modal comparisons of transit service.

Intermodal Cost Efficiency Indicators

Cost Efficiency indicators show the relationship between measures of service inputs and service outputs. Equations (14) and (15) show the proposed intermodal cost efficiency indicators:

$$\text{Cost per Kilometer} = \frac{\text{Total Cost}}{\text{Revenue Capacity Kilometers}} \quad (14)$$

$$\text{Cost per Hour} = \frac{\text{Total Cost}}{\text{Revenue Capacity Hours}} \quad (15)$$

Intermodal Cost Effectiveness Indicators

Cost Effectiveness indicators compare measures of service inputs to measures of service consumption. Equations (16) and (17) show the proposed intermodal cost effectiveness indicators:

$$\text{Cost per Passenger Kilometer} = \frac{\text{Total Cost}}{\text{Passenger Kilometers}} \quad (16)$$

$$\text{Farebox Recovery} = \frac{\text{Farebox Revenues}}{\text{Total Cost}} \quad (17)$$

Intermodal Service Effectiveness Indicators

Service Effectiveness indicators measure service consumption relative to service output. Equations (18) and (19) show the proposed intermodal service effectiveness indicators:

$$\text{Passenger Kilometers per Capacity Kilometer} = \frac{\text{Passenger Kilometers}}{\text{Revenue Capacity Kilometer}} \quad (18)$$

$$\text{Passenger Kilometers per Capacity Hour} = \frac{\text{Passenger Kilometers}}{\text{Revenue Capacity Hours}} \quad (19)$$

Adoption of Intermodal Performance Indicators

Transit service planners, managers, and funding authorities should find that the proposed intermodal performance indicators can be calculated and used without great difficulty. The indicators themselves are close enough to indicators in current use that they do not require a complete rethinking of transit performance measurement.

The required data on service inputs, outputs, and consumption is already collected at most transit properties. Capital expenses are documented in capital budgets, and can be partially and fully allocated to cost estimation formulas using similar procedures as are currently used for operating expenses. Revenue Capacity Kilometers and Revenue Capacity Hours can be calculated as the product of revenue kilometers (or hours) of each vehicle multiplied by the maximum scheduled load capacity of each type of vehicle in service. Finally, data on Passenger Kilometers is already estimated and reported to the federal government by most major transit properties in meeting the Section 15 reporting requirements.

The greater difficulty with adoption and implementation of intermodal performance indicators may lie in the acceptance of the idea of improved intermodal comparison. Advocates of particular modes of service may foresee that a comparison of transit performance will show that the service they support does not have as high a level of performance as other modes of service.

While in the long term the increased precision and applicability of intermodal performance indicators should lead to increased use, over the short term the potential reallocation of resources which can result from illuminated findings of transit performance may lead to some resistance against use of the indicators proposed in this report. However, the potential for significant improvement in transit service efficiency, effectiveness, and equity should lead to increasing adoption and use of intermodal performance indicators over time.

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TABLE 1 Performance Indicators Currently Used in California

<u>Property</u>	<u>Cost Efficiency</u>	<u>Cost Effectiveness</u>	<u>Service Effectiveness</u>
CALTRAIN Commuter Rail	<u>Operating Cost</u> Revenue Vehicle Hour	<u>Operating Cost</u> Passenger Boarding	<u>Passenger Boardings</u> Revenue Vehicle Hour <u>Passenger Boardings</u> Revenue Vehicle Mile
San Mateo Transit (SamTrans)	<u>Operating Cost</u> Revenue Vehicle Hour	<u>Operating Cost</u> Passenger Boarding	<u>Passenger Boardings</u> Revenue Vehicle Hour <u>Passenger Boardings</u> Revenue Vehicle Mile
Santa Clara County Transit (SCCTD)	<u>Operating Cost</u> Revenue Vehicle Hour	<u>Operating Cost</u> Passenger Boarding	<u>Passenger Boardings</u> Revenue Vehicle Hour <u>Passenger Boardings</u> Revenue
Los Angeles (LACMTA)	<u>Operating Cost</u> Revenue Vehicle Hour	<u>Passenger Revenue</u> Operating Cost	<u>Passenger Boardings</u> Revenue Vehicle Hour
San Diego Transit (SDTC)	<u>Operating Cost</u> Revenue Vehicle Hour	<u>Operating Cost</u> Passenger Boarding	<u>Passenger Boardings</u> Revenue Vehicle Hour
	<u>Operating Cost</u> Revenue Vehicle Mile	<u>Operating Cost</u> Passenger Mile	<u>Passenger Miles</u> Revenue Vehicle Mile

TABLE 1 Performance Indicators Currently Used in California (cont'd.)

<u>Property</u>	<u>Cost Efficiency</u>	<u>Cost Effectiveness</u>	<u>Service Effectiveness</u>
Sacramento Transit (STA)	<u>Operating Cost Equivalent Vehicle Mile¹</u>	<u>Operating Cost Passenger Boarding</u>	<u>Passenger Boardings Equivalent Vehicle Hour</u>
		<u>Fare Revenue Operating Cost</u>	<u>Passenger Miles Equivalent Vehicle Mile</u>
Bay Area Rapid Transit (BART)	<u>Operating Cost Revenue Vehicle Hour</u>	<u>Operating Cost Passenger Boarding</u>	<u>Passenger Boardings Revenue Vehicle Hour</u>
			<u>Passenger Boardings Revenue Vehicle Mile</u>
AC Transit (Alameda/Contra Costa)	<u>Operating Cost Revenue Vehicle Hour</u>	<u>Operating Cost Passenger Boarding</u>	<u>Passenger Boardings Revenue Vehicle Hour</u>
			<u>Passenger Boardings Revenue Vehicle Mile</u>
San Francisco Municipal Railway	<u>Operating Cost Revenue Vehicle Hour</u>	<u>Operating Cost Passenger Boarding</u>	<u>Passenger Boardings Revenue Vehicle Hour</u>
			<u>Passenger Boardings Revenue Vehicle Mile</u>

¹ Light Rail Vehicles are roughly considered as the equivalent of two bus vehicles.

TABLE 2 Hypothetical Allocation of Capital Costs in Bus Mode

<u>Types of Capital Expenditures</u>	<u>Associated Service Characteristic</u>
Land for Administrative Offices	Peak Vehicles
Building(s) for Administrative Offices	Peak Vehicles
Administrative Office Equipment	Peak Vehicles
Drivers' Rest Facilities	Vehicle Hours
Storage Yards and Garages	Peak Vehicles
Fueling Equipment	Vehicle Miles
Maintenance Equipment, Shops, and Yards	Vehicle Miles
Buses	Vehicle Miles

TABLE 3 Hypothetical Allocation of Capital Costs in Rail Mode

<u>Types of Capital Expenditures</u>	<u>Associated Service Characteristic</u>
Land for Right of Way	Route Miles
Guideway Construction	Route Miles
Trackwork, Power, Control	Route Miles
Stations	Route Miles
Land for Administrative Offices	Peak Vehicles
Building for Administrative Offices	Peak Vehicles
Administrative Office Equipment	Peak Vehicles
Drivers' Rest Facilities	Vehicle Hours
Storage Yards and Garages	Peak Vehicles
Fueling Equipment	Vehicle Miles
Maintenance Equipment, Shops, and Yards	Vehicle Miles
Rolling Stock	Vehicle Miles

TABLE 4 Variation in Transit Vehicle Capacities (5)

<u>Type of Vehicle</u>	<u>Seating Capacity</u>	<u>Standing Capacity</u>	<u>Total Capacity</u>
Minibus	15-25	0- 15	15- 40
Conventional Bus	36-83	19- 32	55- 85
Articulated Bus	66-73	34- 37	100-110
PCC Cars	59	40- 80	99-139
San Diego Light Rail	64	124-136	188-200
Boston Light Rail	52	125-178	177-230
New York City IND Car	50	130-170	180-220
Commuter Rail	110	20-120	130-230