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A test of inter-modal performance measures for transit investment decisions

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Key words: decision-making, investment, management performance, public transit

Abstract. Choices among alternative transit capital investments are often complex and politically controversial There is renewed interest in the use of performance indicators to assist in making rational and defensible choices for the investment of public funds To improve the evaluation of rail and bus performance and provide more useful information for transit investment decision-makers, it is important to use performance indicators that fairly and efficiently compare different transit modes This paper proposes a set of inter-modal performance indicators in which service input, service output, and service consumption are measured by total cost, revenue capacity miles/hours, and unlinked passenger trips/miles respectively based on economic principles and evaluation objectives The proposed improvements involve the inclusion of capital as well as operating costs in such comparisons, and the recognition of the widely varying capacities of transit vehicles for seated and standing passengers Two California cases, the Los Angeles – Long Beach Corridor and the Market/Judah Corridor in San Francisco, are used for testing their usefulness in the evaluation of the efficiency and effectiveness of rail and bus services The results show substantial differences between performance indicators in current use and those proposed in this study The enhanced inter-modal performance indicators are more appropriate for comparing the efficiency and effectiveness of different modes or a combination of transit modes at the corridor and system levels where most major investment decisions are made

Introduction

Decisions regarding transit investments affect the mobility and accessibility of the population and constitute major expenditures of public funds They also may influence land use patterns and future development of urban areas. These decisions are inherently political in nature, but in the United States and elsewhere there is increasing interest in requiring that transit investment decisions be informed by systematic comparisons among alternative courses of action. For example, the Transportation Equity Act for the 21st Century (TEA-21) enacted on June 9, 1998 requires that the Federal Transit Administration (FTA) evaluate and rate candidate "New Start" projects according to certain criteria (FTA 1999) It is also becoming more common in many states and metropolitan areas to require systematic comparisons of alternatives according to sets of "performance indicators." Performance measurement has long been used by governments to monitor and evaluate a wide variety of programs in many sectors, but it has been observed that interest in performance measurement waned in the eighties and appears to be on the rise once again as part of the movement to "reinvent government" and to introduce market principles into government operations (Poister 1997).

It is one thing to state that the performance of complex alternatives ought to be systematically measured and compared, and quite another thing to do this effectively. While performance measurement is intended to inform and restrain political decision making, it is not terribly surprising that performance measurement itself has become the subject of major political debates. These debates often focus on performance comparisons between bus and rail, partly because bus is traditionally a dominant transit mode while rail is advocated by some as a superior solution for current urban transportation problems.

Rail proponents have advocated light rail as a cost-effective solution to urban mobility problems. They claim that light rail is less expensive to build than other types of rapid transit systems and cheaper to operate than bus because of a potential reduction in labor – a major component of operating cost They also assert that rail can deliver higher levels of performance such as faster, more comfortable and more reliable service, and attract more transit riders because rail is operated on exclusive rights-of-way Furthermore, rail proponents argue that expansion of rail can foster investment and redevelopment in the areas that it serves, encourage more compact land use patterns, and stimulate economic development because it is a long-term infrastructure investment (Mitchell & Rapkin 1954: Warner 1962, Vuchic & Olanipekun 1990, Parkinson 1989, 1992 and Cervero & Landis 1995).

However, critics contend that *total* costs for rail transit are much higher than those of buses. They argue that the capital cost of rail is much higher than that of buses and that its operating costs may not be lower than those of buses because the potential savings due to larger numbers of seats per operator may be offset by higher expenses for maintaining light rail vehicles, rail stations, and rights-of-way. They counter that in areas where there are low to medium densities, bus services can provide greater operational flexibility than rail and can match or even outperform rail transit in ridership appeal, travel time and frequency of service if a bus system is carefully designed. In addition, they believe that there is a weakening connection between transportation and land use patterns because transportation systems are already well developed and underpriced. urban land use patterns are well established, and location decisions are affected by many other complicated considerations beyond transportation (Wachs 1975; Gomez-Ibanez 1985; Biehler 1989: Hensher & Waters 1993; Giuliano 1995; Boarnet & Crane 1997).

Decisions with regard to the choice of new transit services have to be made by balancing all the objectives that the new service is expected to achieve. One of the objectives is to make efficient and productive use of public expenditures. In order to achieve this objective, it is important to incorporate all the comparable variations between alternatives; bus versus rail, peak versus base services, or fixed-route versus flexible demand responsive services. In the case of comparisons between bus and rail, it is crucial to incorporate variations in cost and vehicle capacity between the two modes, because on the one hand, buses are more labor intensive while rail is more capital intensive. On the other hand, bus and rail provide different vehicle capacities. The inclusion of the variations in cost and vehicle capacity are important if performance measurement is to be done meaningfully where alternative investments are under consideration that involve different mixes of modes.

This paper introduces two improvements to some widely used transit performance indicators and examines their usefulness in efficiency and effectiveness comparisons between bus and rail using data from the Los Angeles County Metropolitan Transportation Authority (MTA) and the San Francisco Municipal Railway (Muni) at the level of the travel corridor. The study shows that changes in the performance indictors that are employed do result in different conclusions as to the most socially desirable transit investments in different situations. We believe that the inter-modal performance measures tested in this study are an improvement over those that are commonly used because they provide a more systematic and objective basis for comparison among alternatives

In the following sections, we critique the current standard transit performance indicators, introduce enhanced measures for bus and rail performance comparisons, describe data and procedures for case studies, present the empirical results of performance comparisons between bus and rail, and then discuss their implications. The concluding section summarizes the findings.

Inter-modal performance indicators

To understand the inter-modal performance indicators used in this study and their advantages, it is necessary to review the current standard indicators and their limitations. A review of the literature on transit performance measurement shows that although there are some differences in methods of performance comparison and selection of performance indicators, most researchers agree that transit efficiency and effectiveness should be measured primarily according to three dimensions: *inputs* used to produce service, which can be measured by various monetary costs, the number of employees or employee hours, the number of vehicles, the amount of fuel, etc., *outputs*, namely service provision, usually measured in terms of miles or hours of service; and *service* *consumption* – services utilized by transit users, which can be measured by the number of linked (or unlinked) passenger trips, operating revenues, passenger miles, or passenger hours. Performance indicators corresponding to the three dimensions can be grouped into three categories: *cost efficiency indicators*, which measure relationships between inputs and outputs; *service effectiveness indicators*, which measure relationships between service consumption and outputs; and *cost effectiveness indicators*: which measure relationships between inputs and service consumption. Each performance indicator is calculated as a ratio between two operating statistics that deal with service inputs, service outputs, and service consumption (Fielding et al 1985a, 1987)

An examination of widely-used performance indicators reveals that the most commonly used indicators 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 miles per revenue vehicle hour (see Table 1). These indicators have three features in common. First, monetary input for providing transit service is measured by operating cost only Second, service output is appraised by revenue vehicle hours and revenue vehicle miles.[1] Third, service consumption is measured mostly by passenger boardings

These performance indicators have two major deficiencies, especially when used for performance evaluations and comparisons across different transit modes First, capital cost is generally absent in the existing cost efficiency and effectiveness indicators and capital-related performance indicators are often not used by the transit industry. Performance indicators based solely on operating cost do not enable valid inter-modal performance comparisons Cost comparisons among different modes should be made on the basis of total cost including operating and capital costs because the provision of transit service incurs both types of costs. Both capital and operating costs of transit service represent opportunity costs forgone for alternative activities To invest in a particular project, transit agencies or governments must give up opportunities to expend those resources on other projects. And quite obviously, comparisons of operating costs between modes may not be appropriate if one mode relies to a far greater degree on capital expenditures than another. In the United States, many local transit agencies have relied on federal and state grants of capital funds for system construction, while financing transit operations with fares and local tax subsidies. This may explain the tendency of local governments to evaluate performance in terms of operating costs alone. But, it is important to maximize the efficiency with which all public funds are used, and in addition it is important to acknowledge that over time larger shares of transit investment projects are being financed by local governments, which have greater flexibility designating funds for either operations or capital investments.

Second. commonly used indicators do not take into account differences in vehicle capacities among modes. They make comparisons on the basis of costs per vehicle-hour or per vehicle-mile among vehicles that can have dramatically different passenger capacities. They therefore offer meaningless information for inter-modal performance comparisons when and where variation across modes in vehicle capacity are very large For instance, the capacity of a light rail car can be more than twice the capacity of a conventional bus. Even within the same mode, vehicle capacity can vary significantly. While a minibus provides a passenger capacity of 15 to 40, a conventional bus may have a capacity of 55 to 85, and the vehicle capacity of an articulated bus can be 100 to 110 (National Research Council 1985).

Inter-modal performance indicators offer two improvements over existing indicators in transit performance comparisons. (1) they include capital costs of transit modes; and (2) they incorporate variations in vehicle capacities of various modes. As seen from Table 2, service input is measured by *total cost*, service output is measured by *revenue capacity miles* and *revenue capacity hours*, and service consumption is measured by both *unlinked passenger trips* and *passenger miles* Unlike the indicators that are commonly used by many transit agencies, service input in the improved indicators includes capital and operating costs of service. Revenue capacity hours or revenue capacity miles equal the revenue vehicle hours or revenue vehicle miles multiplied by vehicle capacity Both seating capacity and standing capacity are included in the calculation of vehicle capacity because together, they represent full vehicle capacity. Since there is a trade-off between seating and standing capacities, excluding either one in performance comparisons could lead to illusory conclusions In addition, different transit agencies have unique policies with regard to service standards and vehicle capacity. Some transit agencies have a goal of providing a seat for every passenger while others deliberately eliminate seats in order to provide more space for standing passengers Some agencies also have different standards for peak and off-peak services and for different modes To objectively compare the performance of different modes, both seating and standing capacities should be included in the calculation. Like existing indicators, Unlinked passenger trips refer to the number of passengers who board public transportation vehicles. A passenger is counted each time he/she boards a vehicle. Passenger miles is the sum of the distance traveled by all passengers, which equals the product of unlinked passenger boardings and miles of passenger travel associated with each boarding

Table 1 Performance indicators currently used in California.

Property	Cost efficiency	Cost effectiveness	Service effectiveness
Sacramento Regional Transit System (SRTA)	Operating cost / Equivalent vehicle mile	Operating cost / Passenger boarding Fare revenue / Operating cost	Passenger boardings / Equivalent vehicle hour Passenger miles / Equivalent vehicle mile
Bay Area Rapid Transit (BART)	Operating cost / Revenue vehicle hour	Operating cost / Passenger boarding	Passenger boardings / Revenue vehicle hour Passenger boardings / Revenue vehicle mile
Alameda/ Contra Costa (AC Transit)	Operating cost / Revenue vehicle hour	Operating cost / Passenger boarding	Passenger boardings / Revenue vehicle hour Passenger boardings / Revenue vehicle mile
San Francisco Municipal Railway	Operating cost / Revenue vehicle hour	Operating cost / Passenger boarding	Passenger boardings / Revenue vehicle hour Passenger boardings / Revenue vehicle mile
Los Angeles (LACMTA)	Operating cost / Revenue vehicle hour	Passenger revenue / Operating cost	Passenger boardings / Revenue vehicle hour
CALTRAIN Commuter Rail	Operating cost / Revenue vehicle hour	Operating cost / Passenger boarding	Passenger boardings / Revenue vehicle hour Passenger boardings / Revenue vehicle mile
San Mateo Transit (SamTrans)	Operating cost / Revenue vehicle hour	Operating cost / Passenger boarding	Passenger boardings / Revenue vehicle hour Passenger boardings / Revenue vehicle mile

Table 1. Continued

Property	Cost efficiency	Cost effectiveness	Service effectiveness
Santa Clara County Transit (SCCTD)	Operating cost / Revenue vehicle hour	Operating cost / Passenger boarding	Passenger boardings / Revenue vehicle hour Passenger boardings / Revenue vehicle mile
San Diego Transit Corp (SDTC)	Operating cost / Revenue vehicle hour Operating cost / Revenue vehicle mile	Operating cost / Passenger boarding Operating cost / Passenger mile	Passenger boardings / Revenue vehicle hour Passenger miles / Revenue vehicle mile

Source "Comprehensive Transit Performance Indicators," Lem, Li & Wachs 1994

Table 2 Inter-modal performance indicators

Categories	Indicators
Cost efficiency	Total cost per revenue vehicle capacity mile (TC/RVCM) Total cost per revenue vehicle capacity hour (TC/RVCH)
Cost effectiveness	Total cost per passenger trip (TC/Pass) Total cost per passenger mile (TC/PM) Passenger revenue per total cost (PR/TC)
Service effectiveness	Passenger trips per revenue vehicle capacity mile (Pass/RVCM) Passenger trips per revenue vehicle capacity hour (Pass/RVCH) Passenger miles per revenue vehicle capacity mile (PM/RVCM) Passenger miles per revenue vehicle capacity hour (PM/RVCH)

Source Lem, Li & Wachs 1994

Case studies

To examine the usefulness of inter-modal performance indicators for bus and rail performance comparisons, we selected the Los Angeles County Metropolitan Transportation Authority (MTA) and San Francisco Municipal Railway (Muni) for case studies. The two agencies were chosen because of two main considerations. First, they are the largest transit agencies providing multiple transit services in California. Second, they represent two different operating environments. one is characterized by a relatively large central business district (CBD) that attracts a significant proportion of the region's peak period trips while the other is distinguished by a multi-centered land use pattern and dispersed trip making Since rail services provided by the two agencies cover only parts of their service areas, it is useful to focus our analysis on rail corridors rather than on entire urban systems. The two travel corridors studied were the Los Angeles – Long Beach Corridor and the Market/Judah Corridor in San Francisco. We used data from the 1994 National Transit Data Base (Section 15) reports for MTA and Muni. And we also utilized capital accounting information and line-based operating information obtained directly from the agencies

To use the enhanced indicators, we first calculated the annual total costs of bus and rail in a corridor. The estimation procedure included four steps. (1) We annualized capital costs of bus or rail components based on a 7 percent discount rate and the economic lives of the components The annual capital cost of a bus or rail component was calculated by multiplying a capital recovery factor by the cost of the component.[2] The annual capital recovery factor (A) is computed as:

$$A = \frac{i * (1 + i)^n}{(1 + i)^n - 1}$$

Where n is the assumed useful life of the asset component and i is the discount rate. The 7 percent discount rate was recommended by the Office of Management and Budget in 1993, and has been employed in Major Investment Studies (MISs) for public transit since January 1994. The standard useful lives listed in the "Procedures and Technical Methods for Transit Project Planning" (Ryan et al. 1990) were used to calculate the annual equivalent capital costs of bus and rail components.[3]

(2) Using the cost allocation method – a widely used cost estimation method in the transit industry, we allocated the annual capital and operating costs of system-wide bus and rail components to associated operating statistics such as vehicle miles, vehicle hours, peak vehicles, route miles, etc. and derived average unit costs of those operating statistics The cost allocation was based on our assumptions about the relationships between the types of costs and operating statistics. For example, we assumed that labor costs including wages and fringe benefits for vehicle operation were associated with vehicle hours. Similarly, costs of fuel, materials and supplies for vehicle maintenance were related to vehicle miles and vehicle costs were linked to number of peak vehicles. Other miscellaneous costs, such as utilities, administration, taxes, insurance, etc were assigned to the operating statistics in a similar fashion.

(3) Based on calculations in the first two steps, we developed the following models for estimating the annual capital and operating costs of buses and rail

$$KC_{MB} = U_{PV} * PV + U_{VM} * VM \quad (1)$$

$$OC_{MB} = U_{PV} * PV + U_{VM} * VM + U_{VH} * VH \quad (2)$$

$$KC_{LR} = U_{PV} * PV + U_{DRM} * DRM \quad (3)$$

$$OC_{LR} = U_{PV} * PV + U_{CM} * CM + U_{CH} * CH + U_{S} * S + U_{DRM} * DRM \quad (4)$$

Where KC_{MB} and OC_{MB} respectively represent the annual capital and operating costs of motor buses; KC_{LR} and OC_{LR} stand for annual capital and operating costs of light rail, PV stands for peak vehicles; VM and VH are vehicle miles and vehicle hours for buses; CM and CH are car miles and car hours for rail cars; S is the number of light rail stations; DRM is directional route miles;[4] U_{PV}, U_{VM}, U_{VH}, U_{CM}, U_{CH}. U_{S}, and U_{DRM} are unit costs of peak vehicles, vehicle miles, vehicle hours, car miles, car hours, rail stations, and directional route miles, respectively [5] Notice that the unit costs in one model differ from those in other models Similarly, the unit costs also vary from one mode to another and from one agency to another. For example, the cost per vehicle mile in the capital cost estimation model for MTA bus lines is $0.46 while the unit cost in the operating cost model for MTA bus lines is $1.95 The peak vehicle unit costs in the capital cost models for Muni are $31.489 for buses and $57,090 for light rail Furthermore, the cost per vehicle hour in the operating cost models for buses is $44.09 for MTA and $37.50 for Muni.

(4) Based on the above models and operating statistics, we estimated the total annual cost of a particular transit line. The costs of transit lines operated in a travel corridor were summed up by mode to get the total annual cost of a mode in a travel corridor.

After estimating costs, we computed service outputs of bus and rail services through a three-step procedure. First, we computed the maximum design capacities of bus and rail services by multiplying their vehicle seating capacities by their passenger loading factor respectively. For example. a typical MTA bus can seat 43 passengers and the maximum passenger loading factor is 1 5 Thus the maximum design capacity of a MTA bus equals approximately 65 Similarly, the buses running on the Muni bus lines included in this study have seating capacities of 26, 40, and 44 and passenger loading factor of 1 5, and their capacities are 39, 60, and 66 respectively After the computation of the maximum design capacities, we then multiplied the capacities by the reported service outputs, namely revenue vehicle miles and revenue vehicle hours, to derive revenue vehicle capacity miles and revenue vehicle capacity hours of bus and rail lines. Finally, we summed up the bus and rail service outputs newly derived in the second step separately to obtain the corridor-wide information.

Based on data derived from the above calculations, we computed the bus and rail performance indicators. As indicated above, cost efficiency indicators are calculated by dividing total annual costs by service outputs. Cost effectiveness indicators are ratios between service input and consumption. And service effectiveness indicators equal service outputs divided by service consumption.

To compare the evaluation results of existing and inter-modal performance indicators, we first used existing performance indicators to examine and compare the performance between bus and rail services in each travel corridor. We then repeated the same analysis using inter-modal performance indicators. Finally, we analyzed the results produced by the existing and inter-modal performance indicators.

Empirical results

Bus and rail in the Los Angeles – Long Beach Corridor

The Los Angeles – Long Beach Corridor, shown in Figure 1, stretches from downtown Los Angeles to downtown Long Beach. It is approximately four miles wide, extending about 2 miles on either side of the Long Beach Blue Line. The corridor crosses four political jurisdictions: the City of Los Angeles, the County of Los Angeles, the City of Compton, and the City of Long Beach. This corridor is generally composed of communities having high concentrations of minorities with a relatively high population density, low income and low auto ownership. In FY1994, transit services running approximately within and parallel to the corridor included the Metro Blue Line – a light rail line travelling a distance of 22 miles from Long Beach to Los Angeles, 14 local bus lines, one limited bus line, and four express bus lines. Among the motor bus lines, line #60 was a long-distance bus line running parallel to the Los Angeles – Long Beach Blue Line. Some 56 million passenger trips were made annually on all the transit lines in the corridor.

Figures 2 through 4 summarize the performance evaluation results on the basis of existing and inter-modal indicators. As seen from the figures, existing indicators and the enhanced indicators produce different results for bus and rail performance comparisons. Existing indicators show that although light rail was less cost efficient than buses, it was more effective than buses. For example, existing cost efficiency indicators show that operating cost was about $8 per revenue vehicle mile for buses and about $29 per revenue train mile

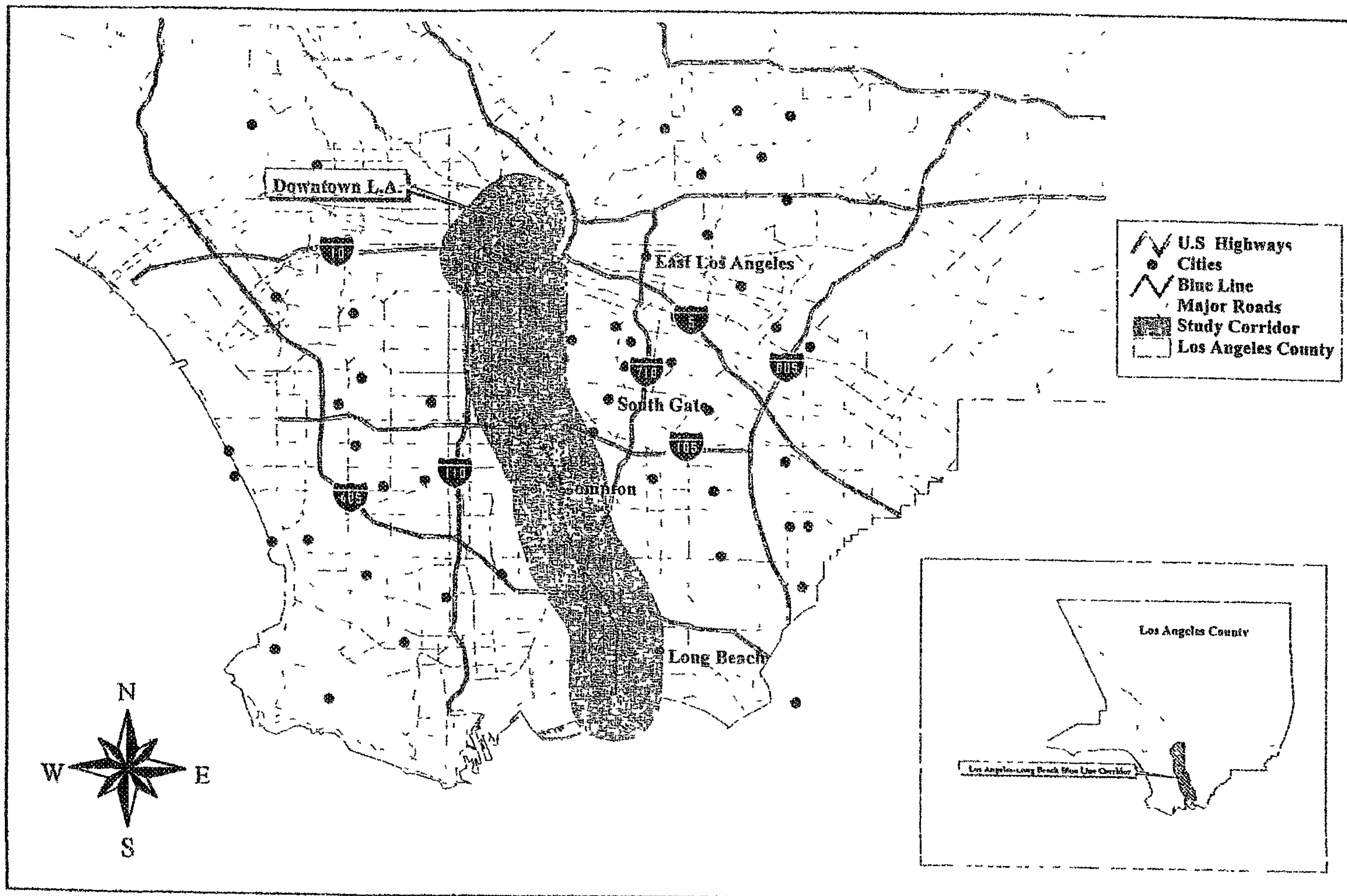
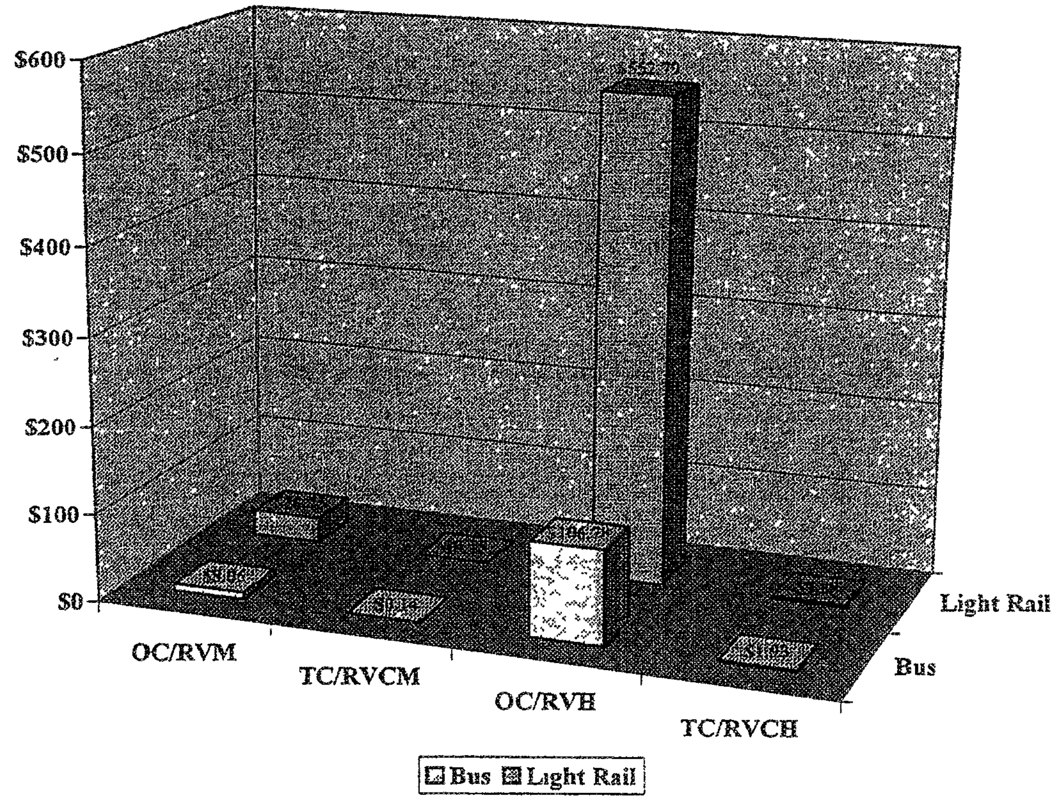


Figure 1 The Los Angeles – Long Beach Corridor



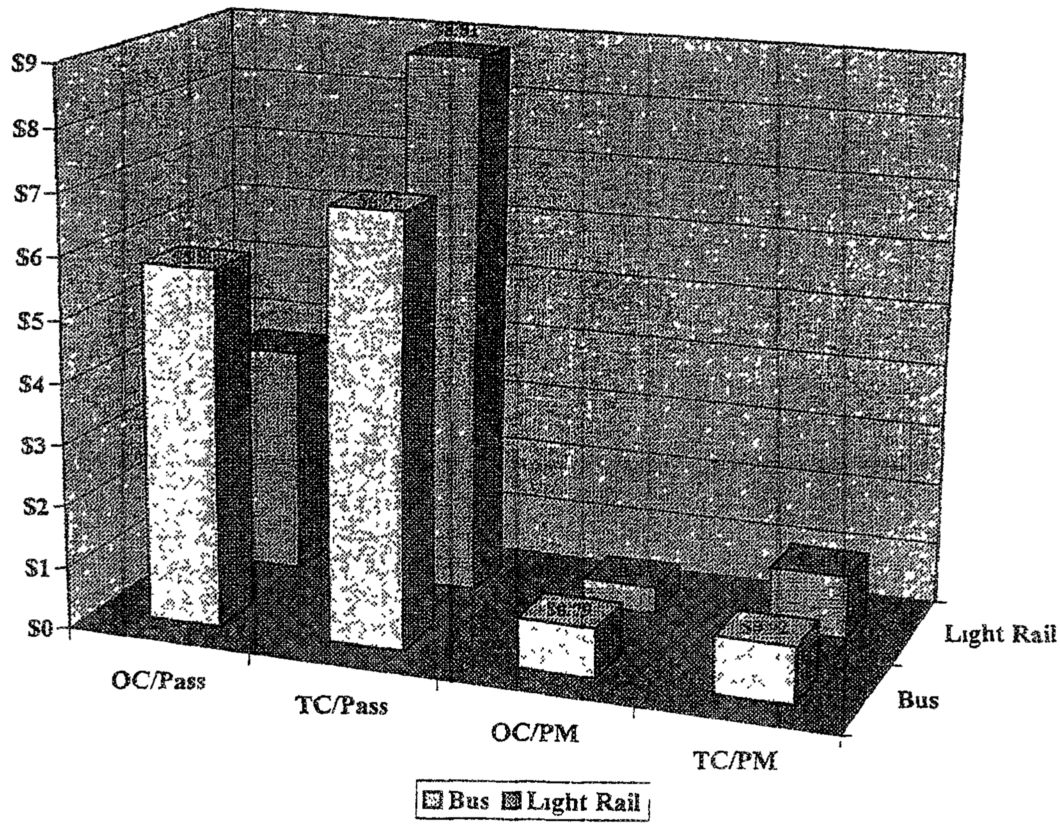
The Los Angeles-Long Beach Corridor

Figure 2 A comparison of cost efficiency indicators

for light rail. Operating cost was about $107 per revenue vehicle hour for buses and about $553 per revenue train hour for rail, indicating that the unit costs of bus services provided by MTA were about $20 to $450 less than those of rail. On the other hand, existing cost effectiveness indicators report that operating costs per passenger and passenger mile of buses were about half a dollar to two dollars more than those of rail, indicating that rail is more cost effective than buses. Similarly, existing service effectiveness indicators show that rail carried about 4 to 110 more passengers and 55 to 1,143 more passenger miles per unit of service outputs than buses did.

However, results based on the proposed inter-modal performance indicators confirm that rail is not only expensive to operate, but also not necessarily more effective than buses. According to the enhanced cost efficiency indicators, total cost per revenue vehicle capacity mile for bus services was about $0.01 less than that of the Blue Line. Consistently, total costs per revenue vehicle capacity hour were $1.93 for bus and $2.88 for rail, indicating that bus services were about 49 percent more cost efficient than the Blue Line.

Unlike the results produced by the existing indicators, the enhanced cost



The Los Angeles-Long Beach Corridor

Figure 3 A comparison of cost effectiveness indicators.

effectiveness indicators reveal that bus services were 10 percent to 27 percent more cost effective than the Blue Line. While the average total cost per passenger for buses in the corridor was $6.95, the cost for the Blue Line was $8.81. Total costs per passenger mile were $0.92 for buses and $1 01 for the Blue Line, respectively. The farebox recovery rate was 0.24 for buses versus 0.06 for rail. These results imply that the unit costs of providing rail service are notably higher than those of bus services in the Los Angeles – Long Beach corridor. Indeed. government subsidies cover 94 percent of the total cost on the rail line, as compared to 76 percent of the total cost for the bus services.

Three service effectiveness measures indicate that bus services are more effective than rail in the corridor. Only one measure – passenger miles per revenue vehicle capacity hour – indicates that rail carries about 19 percent more passenger miles per unit of revenue vehicle capacity hour than bus services in the corridor.

In short, the analysis indicated that although existing indicators and intermodal performance indicators provide consistent information on cost-efficiency

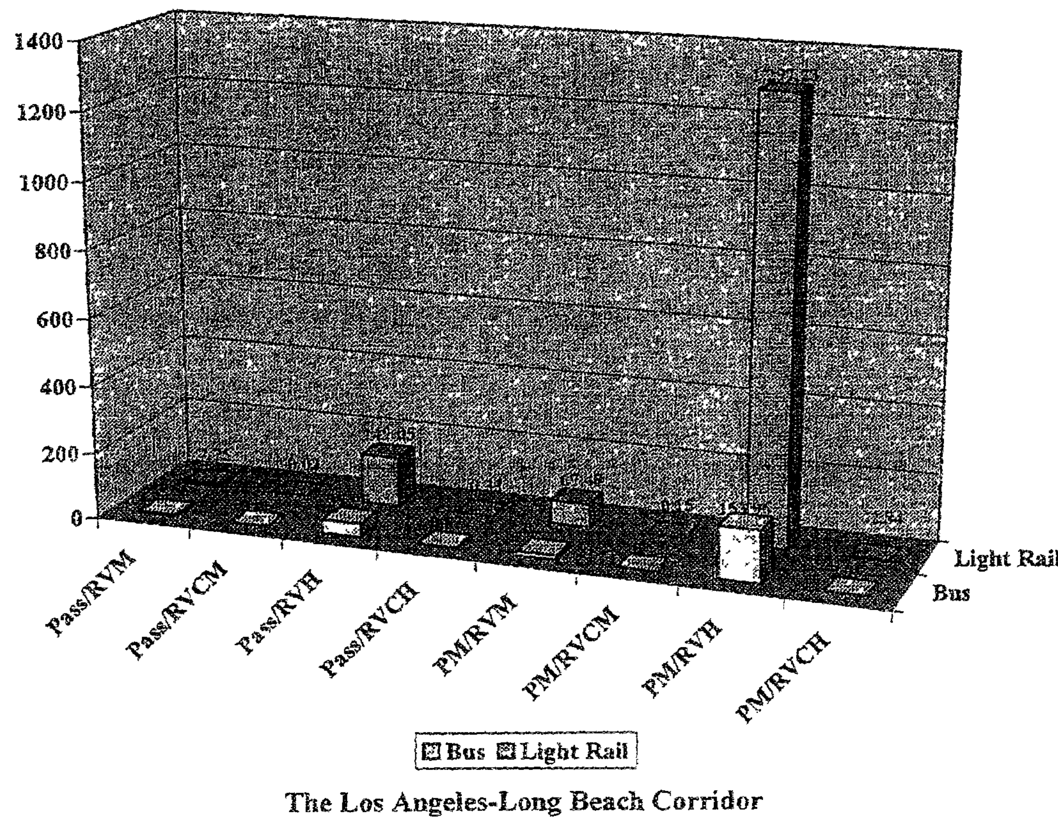


Figure 4 A comparison of service effectiveness indicators

comparisons between bus and rail, they provide different information on cost effectiveness and service effectiveness.

Bus and rail in the Market/Judah Corridor in San Francisco

The Market/Judah Street Corridor, shown in Figure 5, is a half-mile wide strip running from the Great Highway in the west to Market Street in the northeast near the San Francisco Bay. According to the 1990 census, population density in the corridor was slightly higher while household income was lower than the city and county average. Correspondingly, the rate of driving alone to work was lower, and the proportion of work trips by public transit was higher than the city and county average. Multi-modal transit services were provided in the corridor. These services included one light rail line, two local motor bus lines, one limited motor bus line, two express motor bus lines, and two regular trolley bus lines. In fiscal year 1994, more than 19 million passenger trips were taken on these lines.

Figures 6 through 8 display the evaluation results of bus and rail in the

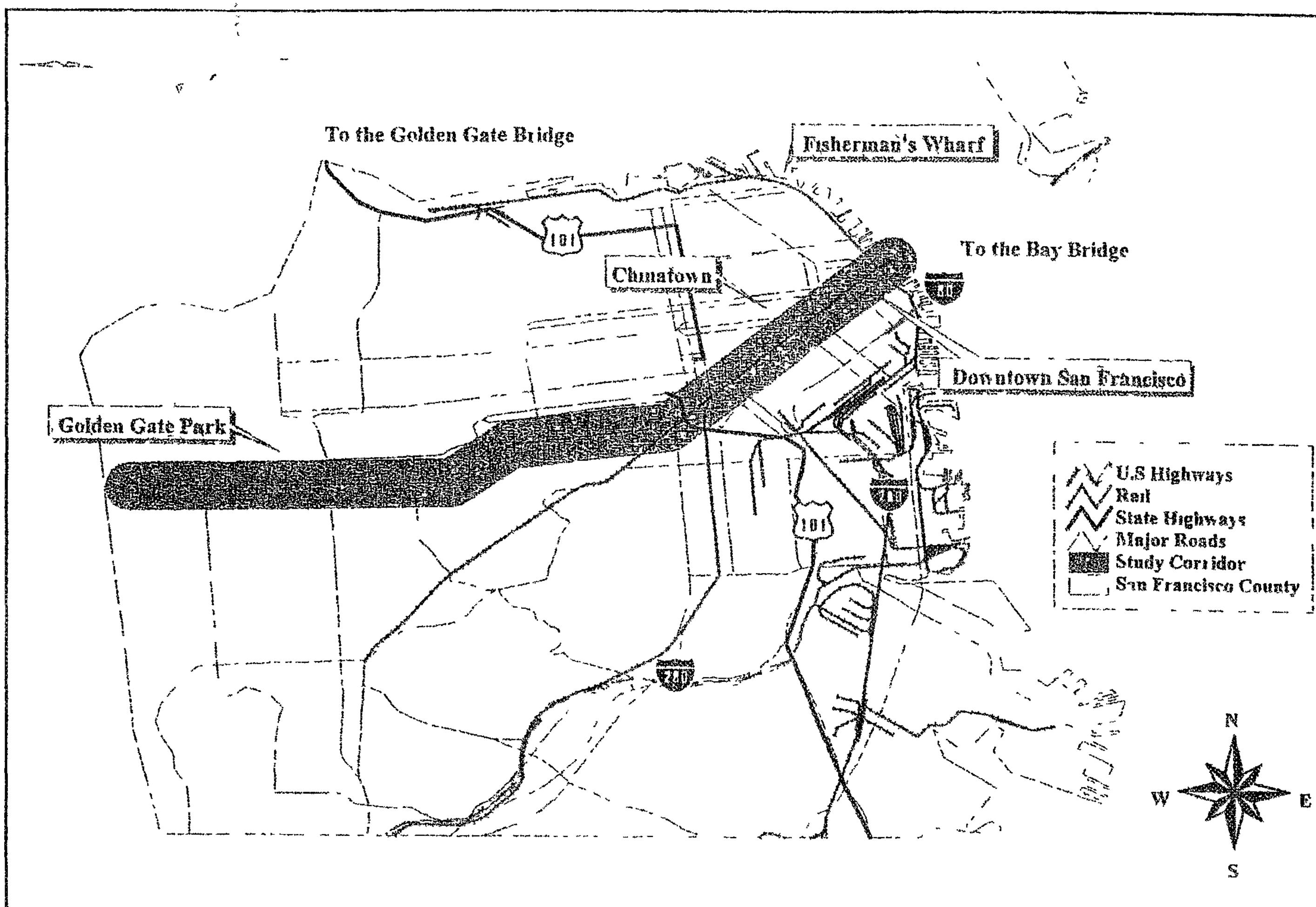
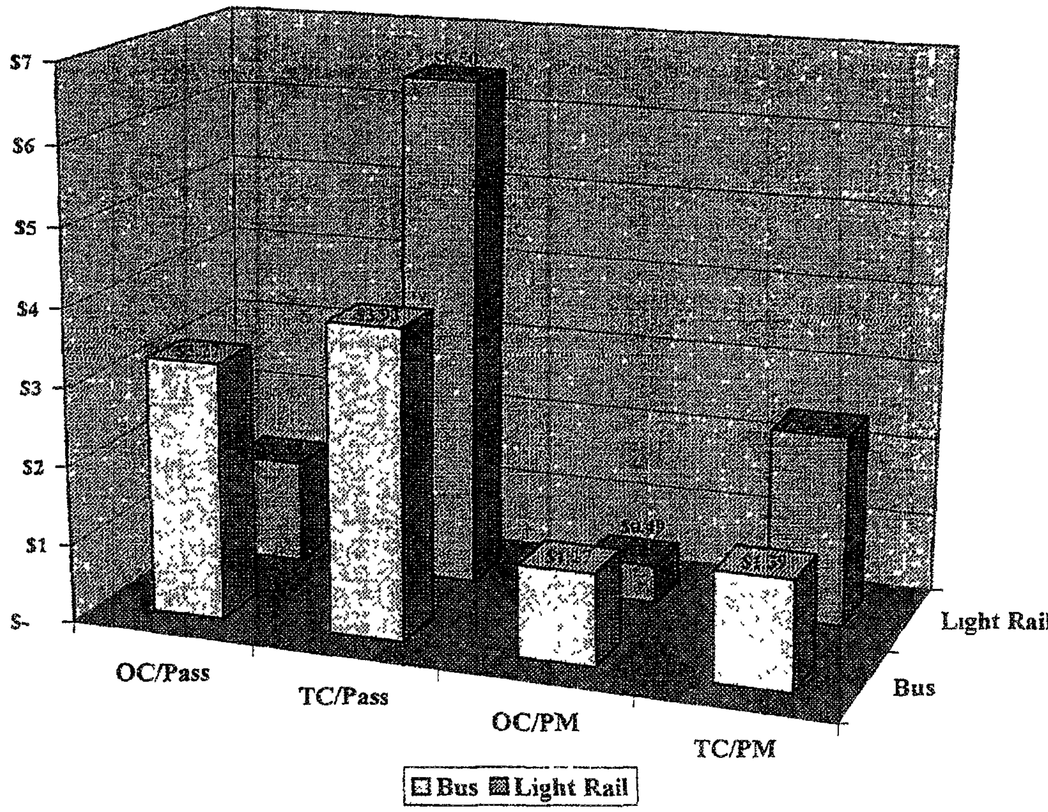


Figure 5. The Market/Judah Corridor in San Francisco.



The Market/Judah Corridor, San Francisco

Figure 7 A comparison of cost effectiveness indicators

the rail cost). Analysis also indicates that total cost per passenger mile for buses was $1.03 less than that of rail while the cost per bus passenger trip was $2.57 less than the cost per rail passenger trip.

When comparing service effectiveness between the two modes, results based on the enhanced indicators – passengers or passenger miles per revenue vehicle capacity mile or hour – show that the bus was about 6 to 28 percent more effective than rail. The analysis based on data from San Francisco Muni once again demonstrates the differences in results generated by existing and inter-modal performance indicators for bus and rail comparisons.

Explanation of the empirical results

Both case studies show that there are differences between results produced by existing and inter-modal performance indicators for bus and rail comparisons. The principal reason for such differences is the inclusion of capital

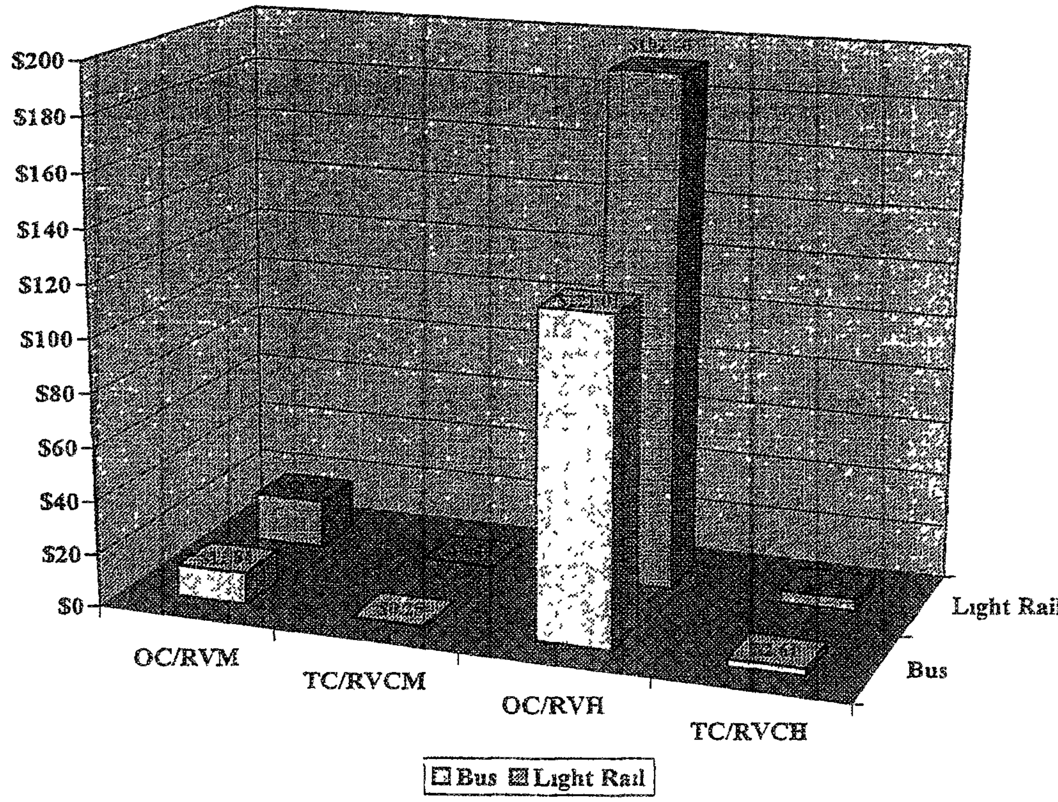
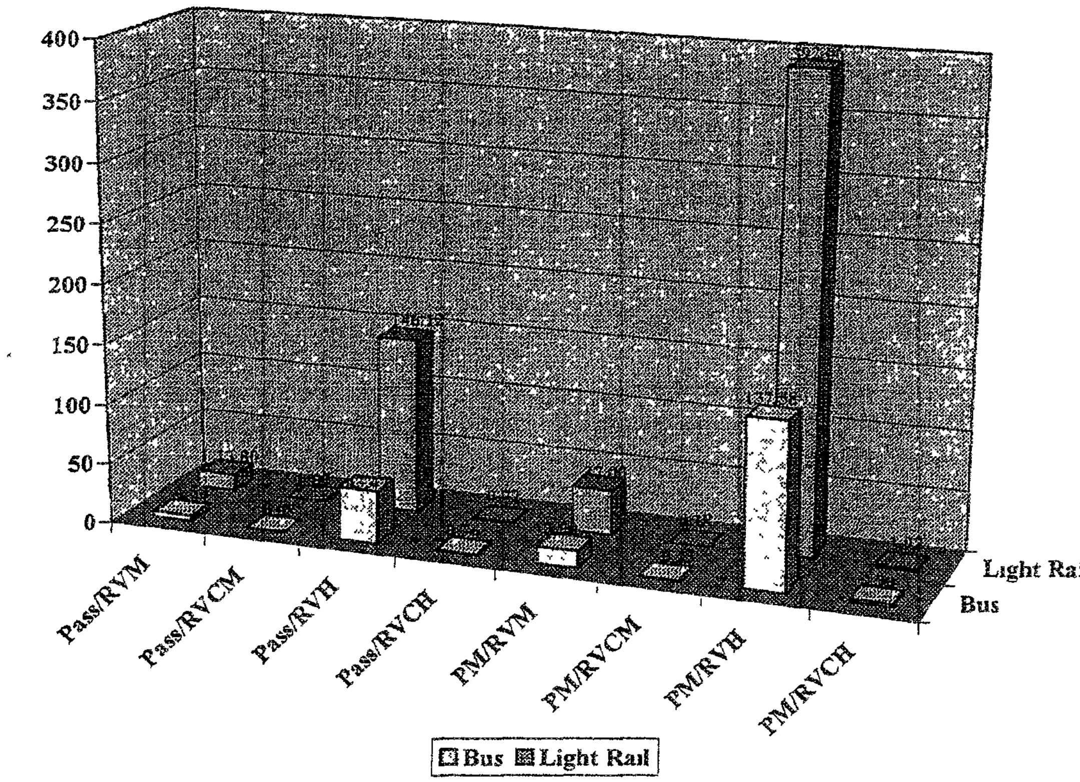


Figure 6 A comparison of cost efficiency indicators

Market/Judah Corridor based on existing and inter-modal performance indicators. Similar to the Los Angeles – Long Beach Corridor, the results produced by existing indicators differ from those by the enhanced indicators While existing indicators imply that motor bus service is more cost efficient but less effective than rail in the corridor, the improved indicators suggest that motor bus services are not only cost efficient but also more effective than rail service in the corridor. For instance, existing cost efficiency indicators show that operating cost per revenue vehicle mile was about $12 for motor buses versus about $18 for light rail. Operating cost per revenue vehicle hour for motor buses was about $72 less than that of rail. On the other hand, existing indicators demonstrate that operating cost per bus passenger was about $2 higher than the cost per rail passenger while rail carried about 9 to 102 more passengers per unit of service output than motor buses. Other existing cost effectiveness and service effectiveness indicators also lead to the same conclusion.

The inter-modal performance indicators show that total costs per unit of bus service were only about half of the cost of rail service (56 to 57 percent of



The Market/Judah Corridor, San Francisco

Figure 8 A comparison of service effectiveness indicators

cost and vehicle capacity in the comparisons. The effects of including capital cost and vehicle capacity can be illustrated in the following using data from the Long Beach – Los Angeles Corridor.

Table 3 shows that including different cost components in performance comparisons results in different conclusions. For example, if a comparison is based on operating cost only, the indicator reports that the cost per bus rider is 56 percent more expensive than that per rail passenger. However, the comparison on the basis of operating plus capital cost would favor motor bus since capital cost per rail rider is more than four times the cost per bus passenger A very simple cause of such a different conclusion is that bus is more labor intensive while rail is more capital intensive. Comparing the modes on either partial measurement will result in misleading conclusions The use of total cost as a measure of input can eliminate this problem and make the comparison more appropriate because total cost represents a complete accounting of all the labor, capital and material resources used in the delivery of transit services. This example shows that the definition of performance measures is critical for transit planning, especially for transit investment

Table 3. Inter-modal cost comparisons (cost per passenger, the Los Angeles – Long Beach Corridor)

	Operating cost	Capital cost	Total cost
Bus	$5.80	$1 15	$6 95
Light rail	$3 71	$5 11	$8 81

decisions, and that shifting from one definition to the other dramatically impacted the comparison that resulted.

The effects of vehicle capacity on transit performance comparisons can be demonstrated by measures of "passengers per unit of service output" and "total costs per unit of service output." As seen from Tables 4 and 5, the inclusion of seated capacities in service output measures results in values that are less than those of the original indicators, and the inclusion of total capacity (seated and standee capacities) results in further reduction in the values of the indicators. However, the decreases are smaller for bus than for rail, indicating that vehicle capacity does have effects on performance outcomes For example, Table 4 shows that after incorporating vehicle capacities in the indicators, the values of service effectiveness indicators – "passengers per unit of service output" – decline from 3.56 passengers per revenue vehicle mile to 0 08 per seat mile and 0.06 per revenue vehicle capacity mile for buses.[6] The values for rail change from 7.75 to 0.05 and 0.02 correspondingly. Notice that the changes for rail range from 7.70 to 7.73, which are larger than those for bus (3.48 to 3.50) because rail vehicles have larger capacity than buses.

Similar results can be seen from Table 5 For example, before taking vehicle

Table 4 Inter-modal effectiveness comparison (passengers per unit of output, the Los Angeles – Long Beach Corridor)

Output measures	RVM only	RVM + Seated capacity	RVM + Seated + Standee capacity
Bus	3 56	0 08	0 06
Light rail	7 75	0 05	0 02

Table 5 Inter-modal efficiency comparison (total cost per unit of output, the Los Angeles – Long Beach Corridor)

Output measures	RVM only	RVM + Seated capacity	RVM + Seated + Standee capacity
Bus	$9 33	$0.22	$0.14
Light Rail	$68 34	$0 45	$0 15

capacity into account, the cost efficiency indicator shows that cost per unit of output for rail is about $59 greater than the cost of bus. After incorporating seated capacity, the indicator shows that the cost per unit of rail service is about 23 cents more expensive than that of bus. The inclusion of full capacity in the service output measure indicates that the cost difference between bus and rail in the corridor is only about 1 cent per unit of service output. These changes indicate that without taking vehicle capacities into account, existing indicators overrate the performance of modes or alternatives with large vehicle capacities in service effectiveness comparisons while penalizing them in cost efficiency comparisons. By incorporating full vehicle capacities, the enhanced indicators provide more accurate information for cross-modal performance comparisons which help policy makers make more informed and more effective planning decisions.

In brief, since some transit modes are labor intensive while others are capital intensive, the absence of either cost component in cross-modal performance comparisons could provide misleading information. Similarly, because vehicle capacities differ from one mode to another, it is important to incorporate full vehicle capacity in performance comparisons of transit alternatives with different modes.

Implications

The findings above show that the proposed inter-modal performance indicators are improvements over the commonly-used transit performance indicators. The proposed indicators are also more comprehensive than the efficiency and effectiveness indices newly released by the Federal Transit Administration (FTA) for evaluating new start projects. After several years of revision and circulation, the FTA published the *Technical Guidance on Section 5309 New Starts Criteria* to explain the criteria used for evaluating and rating proposed new start projects seeking federal funding and to assist local agencies in developing such proposals (Federal Transit Administration 1999). As specified in the document, all proposed new start projects are subjected to a comprehensive review based on four criteria: mobility improvements, environmental benefits, operating efficiencies, and cost-effectiveness. The operating efficiencies and cost-effectiveness are measured respectively by the incremental operating cost per incremental passenger mile and the incremental cost per incremental passenger in the forecast year, compared to the no-build and Transportation System Management (TSM) alternatives. While the cost-effectiveness index does include the capital cost factor, both indices exclude the capacity element of transit vehicles – a critical constituent of alternative comparisons between different transit modes. As demonstrated above, due to potentially large variations in vehicle capacities among different transit modes, failure to take full account of vehicle capacities could result in misleading information. It is imperative to include both full cost and vehicle capacity in project evaluations and funding decisions, since most new starts are likely to be large-capacity, capital-intensive projects, and the baselines, namely the no-build and TSM alternatives, for comparisons are likely to consist of small-capacity, labor-intensive options.

The enhanced indicators can assist transit agencies in identifying efficient and effective options for provision of transit services and for investment decisions. For example, the enhanced indicators enable cross-modal comparisons – comparisons of efficiency and effectiveness of two or more different modes – particularly when a decision must be made regarding whether to substitute one mode of service for another along a single travel corridor. They are also suitable for multi-modal measurements, when passenger trips include linked segments that rely on different modes This may be particularly helpful when collector and/or distributor segments depend upon vans or buses while rail transit serves the line haul function Thus, planners can use them to more fully and systematically evaluate a wide range of transit options, and supply more accurate information for transit managers to improve provision of existing services and for decision makers to make better and more-informed choices for new investments. Accurate information is particularly important in an environment in which diminishing resources may require one type of service to be reduced in order to expand another type of service

The enhanced indicators also enable transit agencies and local governments to calculate their share of cost for any proposed investment options and benefits that may result from the investment options Although the current federal transit subsidy policies heavily favor capital intensive projects, they require matching funding commitments from state and local governments. Fully and objectively estimating costs and benefits of investment options as well as the financial responsibilities of local governments will help transit agencies in the long run.

The enhanced indicators can smooth transit agencies' progress when preparing funding proposals and improve the possibility of obtaining an award. Because the enhanced indicators allow both cross-modal and multi-modal comparisons among transit investment alternatives, transit agencies obviously can use the indicators to make a strong case for funding competition.

Conclusions

Using data from the Los Angeles MTA and San Francisco Muni, this study compared existing and improved indicators for evaluating the efficiency and effectiveness of bus and light rail in the Los Angeles – Long Beach Corridor and the Market/Judah Corridor in San Francisco. The inter-modal performance indicators provide an alternative to traditional performance comparisons between different transit modes and address some of the incomparability problems that previous studies had making cross-modal performance comparisons The analyses in this paper demonstrate that in both cases, the use of inter-modal performance indicators leads to different conclusions from existing indicators in cost efficiency and effectiveness comparisons between bus and rail The inclusion of capital costs and vehicle capacity in performance comparisons contributes to the observed differences between results produced by the traditional measures and the inter-modal performance indicators

The findings imply that failure to consider variations among transit modes may lead to misleading information for transit investment decision making and the inter-modal performance indicators provide a promising alternative to the comparisons that are frequently made between alternative transit investment proposals. The principle of incorporating variations in cost and vehicle capacity can be applied in other performance comparisons, such as comparisons between express and regular services and fixed-route buses versus flexible paratransit Because the improved indicators can more completely measure the efficiency and effectiveness of various transit services and alternatives, the use of these indicators may help researchers enhance the quality of their research projects, transit managers improve the efficiency and effectiveness of transit operations, and policy makers make more efficient investment decisions

While the enhanced transit performance indicators provide a technical alternative to comparisons of transit services and investment options, the indicators themselves cannot prevent other influences on project evaluations and investment decisions As has long been acknowledged, the cost and effectiveness comparisons between alternatives can be influenced by many factors, including the extent to which each of the alternatives is optimized and how costs are allocated It is not uncommon, for example, that security costs of rail systems are internalized to other budgets of transit agencies and excluded from the cost calculation as part of the operating cost. It is also not unusual that agencies eager to implement rail do more iterations of service planning for rail to optimize the relationship between supply and demand and do less for bus alternatives. Examples of political influence on technical forecasting have been documented in many previous studies (Kain 1990; Richmond 1991; Pickrell 1992; Rubin & Moore 1996). Hence, applying the enhanced indicators objectively is necessary to ensure the advantages of the indicators. Technical guidance may be required to assist transit agencies using these indicators in evaluations and comparisons of transit options when performing project evaluations and making investment decisions.

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Notes

1 "*Revenue vehicle hours*" and "*revenue vehicle miles*' refer to hours and miles that a vehicle travels when it is in service They equal the total amount of hours or miles minus the time or distance for "deadhead travel". The term "*deadhead travel*" refers to travel time or distance when vehicles are driven from an overnight storage facility to the first stop of a 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 (Cervero et al 1980)
2 Both MTA and Muni maintain a database of the agencies' fixed assets The database contains information on up-to-date asset value and cumulative depreciation of each fixed asset Based on the data, we first calculated the net present value and remaining economic lives of bus and rail components, then computed their annual capital costs
3 Both the 7 percent discount rate and the standard economic useful lives are contained in the "Technical Guidance on Section 5309" (FTA 1999)
4 The variable "DRM" is defined as the mileage in each direction over which transit vehicles travel while in revenue service It counts the mileage in both directions but regardless the number of lanes in each direction See "Reporting Manual for Section 15 Report (1994)" for examples of DRM calculation
5 See Li (1997) for detailed information on procedure of developing cost models
6 "Revenue vehicle miles," "revenue vehicle seat miles," and "revenue vehicle capacity miles" are three different service output measurements which incorporate different levels of vehicle capacities. For example, if a vehicle with 20 seats and 10 standing capacity is in service for 1 mile, the output is measured as 1 "revenue vehicle mile," 20 "revenue vehicle seated miles," and 30 "revenue vehicle capacity miles"

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