PERFORMANCE EVALUATION IN PASSENGER TRANSPORTATION: WHAT ARE RELEVANT MEASURES?

David A. Hensher

Abstract

Measuring and monitoring the performance and productivity of passenger transportation has become a popular activity within public and private transit organisations. This lecture evaluates some of the indicators of performance that are widely used. We emphasise the need for data suitable for monitoring the performance of a single operator (i.e. what does the operator want to know to make operational decisions?) as well as data required for industry-based investigations. The contributions based on the economic interpretation of performance (i.e. measures of partial and total factor productivity) have tended to be industry-wide; however the need for translation down to individual operations is essential if the industry is to accept the new more relevant yet more complex measures of performance. Simple mapping procedures are available to implement the economist's approach at the operator level.

To highlight some of the practical problems associated with selection of measures of performance we draw on data collected in Australia in the context of private transit. Items of particular interest include the measurement of the cost of capital, the composition of labour, and heterogeneity of output. We highlight the potential for misleading inference from univariate measures of performance.

INTRODUCTION

The interest in alternative competitive and ownership profiles of a passenger transport enterprise stems from the premise that performance can be much improved by privatization, economic deregulation and competitive tendering. Organisations are assumed to respond to market forces in ways that encourage them to restructure their operations in the interest of maximising their efficiency and effectiveness. Although there is a large body of theoretical literature supporting this perspective, the empirical evidence is often limited due principally to the quality of available data and analysis methods used in the determination of indicators of performance.

The development of performance indicators is currently a thriving industry, with a multitude of measures of efficiency and effectiveness offered throughout the transport literature. While there have been many efforts to identify key measures (for example, Fielding et.al. 1985), together with a large number of studies offering a range of alternative methods for *correctly* measuring performance (often adding confusion for the practictioner who simply wants to know whether his enterprise has improved its performance or not), many operators are still searching for improved guidelines on how best to measure the overall and component performance of their organisation. The real question is: what are the relevant measures of performance that enable an operator to do something about improving performance?

This lecture concentrates on the cost-efficiency dimension of performance and is organised as follows. The next section sets the context for the interest in performance measurement, followed by a discussion of appropriate ways of treating the heterogeneity of inputs and outputs. The importance of recognising and accounting for input and output heterogeneity is highlighted with data from a sample of private bus and coach firms in Australia. Reference benchmark measures of input productivity are derived from an estimated cost model, and used in a detailed evaluation of the most popular univariate indicators of cost efficiency.

SETTING THE CONTEXT

A public transport firm is interested in knowing the levels of cost efficiency, cost effectiveness and service effectiveness for the enterprise as a whole as well as for each of its operating activities. A number of appealing reasons have accumulated as basic principles for selecting performance indicators which serve as guides to the relative efficiency of firms or to changes in efficiency over time:

- The indicators must relate to the objectives of an enterprise.
- They must be clearly definable and unambiguous in their interpretation such that a particular numerical value or change in value is unambiguously good or bad.
- Indicators must adequately distinguish between factors outside the control of an operator and those within it over well-defined time periods (e.g. recent fuel price rises in the short to medium term is likely to be beyond the control of the bus operator).
- They must be simple to comprehend by those who are in a position to influence the numerical magnitude, including those who directly contribute to the outcome.
- The results must be related to the overall analysis of performance. This requires an unambiguous definition of an improvement in performance.

To operationalise this set of principles it is desirable to establish some interface with the responsibilities of management throughout a firm. This is best represented by choice-determining basic principles. First we have a **roll-up** principle in which data collected at one level of the firm should be capable of being "rolled up" to the next level above it. Second there is a **responsibility** principle whereby managers should only be called to account for performance in their areas of control, responsibility and authority. Third there is the **hands-on** principle under which managers are assessed on the basis of agreed performance indicators that focus on outcomes. Finally there is an **ownership** principle requiring that a performance indicator be "owned" by one or more managers having responsibility and authority for all outcomes measured by that indicator. In exercising these principles, the choice of performance indicators has the character of negotiation of a contract.

At each level of disaggregation, it is important to identify the types and magnitudes of inputs used to produce the various outputs. This is complicated at some levels of disaggregation by the sharing of inputs. A transport operator has a number of levels of operation to consider, although many of them can be easily accommodated provided that the most disaggregate unit of activity or service provision is well-defined in respect of data. This encourages all operators to start thinking in a **bottom-up mode** rather than a "traditional" **top-down mode**. The most basic unit of analysis for a transit firm is the transit stop, followed by the route, then the route cluster (to allow for the complexities of integrated networks), stratified by bus run and time of day.

The relevant questions include: (i) how much labour (drivers, mechanics, other staff), fuel, and capital is currently outlayed to service a particular route?, what does it cost to supply these inputs, and what output do we obtain with this commitment (intermediate outputs such as vehicle hours and vehicle kilometres; final outputs such as passengers, passenger kilometres and revenue)? (ii) how much of the current resource input could be saved (i.e. is actually required) if the service outputs were provided more efficiently? In order to identify the saving potential, one has to either use a theoretical benchmark or an empirical benchmark from another service within the same operation or from another transit operator. It is in the context of such a question that the specification of data needs becomes much clearer. Knowing the resource ratio of say driver hours to total labour hours is not very useful unless we know how it influences technical, allocative and scale efficiency.

To make any comparisons (i.e. use the **empirical benchmark approach**), it is necessary to ensure that data from all sources of comparison are identical in content and definition. This is rarely the case. When it does occur it is often at the expense of sufficient detail as well as exclusion of the full range of operating contexts. In the USA, UMTA S15 data excludes non-subsidised operators; in Australia a comparison of all public transit operators fails to recognise the potential for profiles exhibited by private operators (such as multi-tasking, casual drivers etc.). The issue of the nature of the sampled population is crucial in understanding the potential for productivity improvement; many studies identify limited scope for improved efficiency simply because the sample is too "homogeneous"; for example the public-operator set.

We have a long way to go before the necessary data is in any sense ideal for efficiency and effectiveness-based decisions within a bottom-up performance monitoring context. There is a need to encourage a new approach to the collection of performance-related data. It will involve a major rethink of the way accounts are specified. Such accounts are predominantly budget-based rather than planning and control-based, and reported in a highly aggregate fashion, and consequently it is difficult in most operations to identify with the degree of confidence desired, the service inputs, outputs and consumption, as well as transit needs at the route level and any intermediate levels of service aggregation (e.g the route cluster, the depot, the division). Furthermore, the allocation of revenue to routes from non-cash fares is increasingly becoming a major concern as the incidence of non-cash fares increases (Hensher et.al. 1990).

The accumulated wisdom in the extant literature offers a large number of univariate indicators of cost efficiency (e.g. cost per vehicle kilometre), service effectiveness (e.g.

passenger kilometres per vehicle seat kilometre), cost effectiveness (e.g. cost per passenger kilometre) and market effectiveness (e.g. complaints per passenger kilometre). Each indicator typically requires two final measures for its construction, although the construction of the final measures is often quite complex if the heterogeneity of intermediate inputs is to be recognised and often dubious given the quality of available intermediate data.

Although many of the frequently cited univariate performance indicators are intuitively plausible, there has been inadequate attention given to how they can be translated into very specific policy action by the operator in order to increase efficiency and/or effectiveness. It is not clear as to whether the overall efficiency of the operation is improved by an action designed to improve one univariate interpretation of efficiency.

Some empirical effort has been made to establish the extent of relationship between univariate performance indicators (primarily efficiency indicators) and more global measures of cost efficiency such as total factor productivity (e.g. Hensher 1988, 1990; Windle, 1987; Obeng et al 1990, 1991); however all these studies are of limited value at levels of disaggregation down to the route level.

Route-based studies of cost efficiency limited to a single transit firm may generate an acceptable sample-size for comparisons, however typically the unit rates of inputs such as driver labour are constant at a given time point, making full comparisons of sources of performance variation difficult where unit costs are required in the calculations. Any variation is due to the varying mix of base and penalty working hours. The inter-route variation is then limited to resource input levels. Some variation in unit bus capital costs can occur if vehicles are dedicated to routes and have varying vintages. A desirable sample should include route-level sample points for a number of operators with different operating environments (legal, institutional, geographic etc.). Such a situation does exist in Australia with all the public and private operators, although data is currently not available at the route level.

The methods outlined below for identifying the productivity of factor inputs can and should be applied at the route level when suitable data becomes available. For the time being we have to content ourselves with firm-level data. The application of the procedures outlined below will provide a systematic basis for monitoring performance and for identifying very specific decisions which need to be made in order for improvements in performance to take place which are true statements of increased productivity.

SEARCHING FOR SOURCES OF VARIATION IN PERFORMANCE

Univariate cost efficiency which relates service inputs to service outputs is investigated in detail for the private bus sector in Australia. Three key indicators were investigated: total cost per vehicle kilometre, total cost per vehicle hour and total cost per vehicle. The data are drawn from a 1988 sample of operators who supply local scheduled route services and a mix of other services including permanent school contracts, interstate/intrastate scheduled route services, and charter/tour services locally and for long-distance contexts. We investigated the influence that a number of operating and contextual dimensions have on the three univariate indicators of cost efficiency, and found a very strong relationship with respect to:

- activity composition (the mix of scheduled route, charter/tour, and school contract services),
- labour composition (full time and casual),
- the operating environment (peak speed for scheduled route services), and
- geographic location (capital vs major regional vs minor regional centre).

The evidence (summarised in Table 1) raises concern about empirical enquiries which fail to make these types of distinctions in their definition of output and input.What we have identified are contributions to the guidelines for action to improve cost efficiency.

Table 1. Sources of Influence on Variations in Cost Efficiency (24 private firms)

(i) total cost per vehicle kilometre (r^2=0.49), mean = $1.61, std = $0.66

Explanatory Variable	Acronym	Parameter Estimate	t-value
Permanent School Contract Dummy	PSCDUM	-0.5618	-2.04
Long-distance Charter/Tour Dummy	ICHART	0.3738	1.51
Peak Period Average Speed Local Route	PSP	-0.0103	-1.70
Vehicle Kilometres per Labour Hour	TVKLHR	-0.0192	-2.33
Constant		2.4098	8.04

(ii) total cost per vehicle hour (r^2=0.59), mean = $43.86, std = $17.70

Explanatory Variable	Acronym	Parameter Estimate	t-value
Percent Op Hours as Charter/Tour	PERCH	-17.5301	-1.40
Major Urban-Regional Location Dummy	URBREG	-12.6500	-2.54
Labour Hours per Bus Op. Hour	LHRPVEHR	10.0087	3.09
Constant		39.3266	3.97

(iii) Total cost per vehicle (r^2=0.87), mean = $53,265, std = $21,959

Explanatory Variable	Acronym	Parameter Estimate	t-value
Permanent School Contract Dummy	PSCDUM	-18304	-4.52
Local Scheduled Route Kilometres	LSRKM	0.000086	6.66
Charter/Tour Operating Hours	CTWK	42.3877	4.00
Limited Liability Family/Others Coy	LLCFMO	11468.5	2.36
Ratio of All Labour Hrs to Driver Hrs	PLHRDHR	-2257.1	-3.15
Constant		60027	14.10

The evidence highlights the need to recognise the heterogeneity of output and inputs, especially labour. Output defined in terms of vehicle kilometres or passengers or revenue has three primary components - scheduled route services, permanent school contracts, and chartert/tour services. Labour input is heterogeneous and multi-tasking in the private sector. Categorisation of labour typically occurs as three components - drivers, maintenance/cleaning, and administration. In a multi-tasking environment, this classification is best defined with respect to actual hours of labour devoted to each task rather than to the actual number of persons, otherwise the notion of a primary task has to be introduced, which is a source of bias. Fuel and non-labour maintenance can be treated as homogeneous, but capital is somewhat more complex and requires special treatment (see below).

An important question is which indicator is the best measure for monitoring productivity changes, or should all three indicators and/or some other indicators be selected as measures of cost efficiency? One useful way of assisting the process of determination is to develop an overall index of total factor productivity or an overall index of technical efficiency, and then use this to establish the degree of correspondence between this reference index and each of the univariate indicators. The empirical exercise highlighted in Table 1 however is very useful in pinpointing the influences on univariate indicators of performance; and as a means of selecting potentially important influences on total factor productivity.

A single index for each input and for output should be defined in such a way that it is comparable between firms and within firms over time. The formula is:

$$(1)\qquad \ln\left(\frac{TFP_k}{TFP_b}\right) = \frac{1}{2}\sum_i (R_{ki}+\overline{R}_i)(\ln Y_{ki}-\overline{\ln Y_i}) - \frac{1}{2}\sum_i (R_{bi}+\overline{R}_i)(\ln Y_{bi}-\overline{\ln Y_i})$$
$$- \frac{1}{2}\sum_n (W_{kn}+\overline{W}_n)(\ln X_{kn}-\overline{\ln X_n}) + \frac{1}{2}\sum_n (W_{bn}+\overline{W}_n)(\ln X_{bn}-\overline{\ln X_n})$$

where
k = each individual observation, k = 1, ..., K
b = base observation (a particular or average observation)
i = outputs, i = 1, ..., I
n = inputs, n = 1, ..., N

R_i	= weights for each output	$\overline{R}_i$ =	arithmetic mean of output weights over all firms and years
W_n	= weights for each input	$\overline{W}_n$ =	arithmetic mean of input weights over all firms and years
$\ln Y_i$	= unit measure of output	$\overline{\ln Y_i}$ =	geometric mean of unit measure over all firms and years
$\ln X_n$	= unit measure of input	$\overline{\ln X_i}$ =	geometric mean of unit measure over all firms and years

This formula establishes transitive comparisons across all firms through binary comparisons between each of the firms and the mean of the data. The aggregate price index for an input is obtained by dividing the total cost of an input by the aggregate quantity index for the input.

These input and output indices were used in the construction of the measure of output and the unit prices of inputs for the estimation of a total cost model of the translog form. The properties of such flexible functional form cost models are well documented in many papers (e.g. Diewert 1989, Hensher 1991), but the essential appeal of the approach is that we are able to empirically impose a minimum of maintained hypotheses, and thus exploit the investigation of testable hypotheses such as economies of scale, economies of scope, economies of density, interdependence between inputs and between inputs and output (Gillen et.al 1985). The translog cost function provides all the information required to derive measures of partial and total factor productivity, the reference benchmark for identifying those univariate performance indicators which have some qualification as measures of performance from a cost-efficiency persepective.

The translog cost model results are summarised in Table 2. Each input and output item is the ratio of the firm-specific value to the sample mean, the latter selected as the approximation point for the translog form which provides a second-order approximation of the true cost function at a point. To further ensure that the cost function satisfies the linear homogeneity of degree one in prices condition, we divide each of the price variables and cost by the price of one of the factor inputs, selected as overheads (i.e. the remaining inputs after allowing for labour, fuel, maintenance and capital). Output is defined by vehicle kilometres and the output weights are revenue shares associated with each of the three activities.

Table 2 Total Cost Model: Translog Form Estimated by Maximum-Likelihood

Explanatory Variable	Acronym	Parameter Estimate	t-value
Constant	A	14.317	56.8
Ln (output)	LQ	0.4216	2.59
$(Ln(output))^2$	LQSQ	0.0269	1.44
Ln(price of labour)	LPL	0.4484	24.6
$(Ln(price\ of\ labour))^2$	LPLSQ	0.01368	2.97
Ln(price of fuel)	LPF	0.11408	17.8
$(Ln(price\ of\ fuel))_2$	LPFSQ	-0.0093	-1.79
Ln(price of maintenance)	LPM	0.0834	11.2
$(Ln(price\ of\ maintenance))_2$	LPMSQ	0.01927	4.03
Ln(price of capital)	LPK	0.18581	15.9
$(Ln(price\ of\ capital))_2$	LPKSQ	0.08381	32.1
LQ*LPL	LQLPL	-0.0144	-2.08
LQ*LPF	LQLPF	0.00056	0.23
LQ*LPM	LQLPM	0.00524	1.85
LQ*LPK	LQLPK	0.00686	1.54

Log-Likelihood at Convergence = -29.01

Descriptive Statistics	**Mean**
Output Quantity Index	8,716
Price Index for labour	1,203
Unit price of fuel ($/km)	0.176
Unit price of maintenance ($/km)	0.151
Unit price of vehicles ($/op. hr)	7.57
Unit price of other inputs ($/op hr)	6.33

The partial productivity indices (PPI_i's) are obtained by simple partial differentiation of the total cost function with respect to the price of input i and the level of output: $(dLnC/dLnP_i)/(dLnC/dLnQ)$. The partial and total factor productivity indices for each of the 24 sample firms are depicted in Figure 1. Although these indices are of intrinsic value per se, especially in alerting an operator as to their positioning with respect to the efficiency of other operators, of much more interest is the identification of sources of variation in TFP and PPI's across all firms.

When previous studies have mapped TFP and PPI's against contextual variables, they have treated each source of contribution to TFP as independent effects. However, like any measure estimated from an econometric model, there are sources of error due to unobserved effects, which are assumed to be represented by a particular distribution assumption on the error term. Some of the unobserved effects are likely to be shared by more than one partial productivity index. Thus an appropriate technique for investigating the operational sources of variation in productivity should treat the PPI equations as a system of equations with correlated unobserved effects. Seemingly unrelated regression (SUR) is used to jointly estimate the PPI equations. There is little value in investigating TFP without recognising that it is simply the sum of the partial productivity indices for each factor input, and thus the relationship between input productivity and contextual effects is of most interest; this is the level at which decisions can be taken to modify specific input levels.

The results of the SUR productivity assessments are summarised in Table 3. The evidence suggests that operators who provide charter/tour services (75% of sample) display lower productivity with respect to labour and fuel relative to firms not in this activity market. The evidence raises the question for predominantly local scheduled route operators of the merits of entering this specialised market when a firm's prime activity is route and school services. Charter/tour services require coaches and hence incur higher unit capital costs, fuel costs and labour costs as confirmed in Table 1. Maintenance productivity tends to be lowered as the number of leased vehicles increases suggesting that more effective maintenance practices may be adopted where vehicles are purchased. The average number of leased vehicles is 9.8 with a standard deviation of 15.3. The aging of buses has a significant influence on the productivity of vehicles. The weighted average age of buses (not including coaches) is 10.9 years with a standard deviation of 3.8. The analysis confirms evidence from previous studies that increasing the proportion of kms which are scheduled route-based (but not at the expense of permanent school contracts) will have a positive influence on labour productivity.

Table 3. Operating and Contextual Influences on Input Productivity

Explanatory Variable	Acronym	Parameter Estimate	t-value
PPIL: Partial Productivity of Labour (single eqn r^2=.43)			
Provision of Charter/Tour Dummy	ICHART	-0.2471	-3.09
Percent of kms that are scheduled route	PSRK	0.0888	2.33
Total employed labour	TLAB	-0.0009	-3.28
Constant		1.3802	18.5
PPIF: Partial Productivity of Fuel (single eqn r^2=.28)			
Provision of Charter/Tour Dummy	ICHART	-0.0448	-3.35
Fuel Costs as a Percent of Total Cost	PFLC	-0.1467	-2.19
Constant		0.3388	23.09
PPIM: Partial Productivity of Maintenance (single eqn r^2=.50)			
Number of Leased Vehicles	LEASE	-0.0007	-2.37
Permanent School Contract Dummy	PSCDUM	0.0184	2.02
Operating Hours per Vehicle	OPHRPVEH	0.00002	2.42
Constant		0.1721	12.32
PPIK: Partial Productivity of Capital (single eqn r^2=.29)			
Urban-Regional Location Dummy	URBREG	-0.1568	-4.39
Weighted Mean Age of Buses	WB	-0.0165	-3.50
Constant		0.7221	12.3

These contextual influences on PPI's are not in the definitions of the popular univariate performance indicators to which we now turn for comparative examination.

RELATIONSHIP BETWEEN TFP, PPI'S AND THE MOST POPULAR UNIVARIATE COST EFFICIENCY INDICATORS

Seven of the ten most cited performance indicators (summarised in Table 4) were regressed against the benchmark productivity measures to establish which arbitrary, albeit intuitive, performance indicators can be justifiably interpreted as indicators of productivity.

Table 4. The Ten Most Popular Univariate Cost Efficiency Indicators of Performance (1-5 = best marker indicators, 6-10 = alternative marker indicators; Fielding and Babitsky 1985)

		Mean
1.	Revenue vehicle hours per operating expense (RVHPOE1) or 7	0.027
2.	Total vehicle hours per employee (TVHPL2) or 8	12020
3.	Vehicle kilometres per active vehicle (TVKPVEH3) or 9	38564
4.	Vehicle kilometres per maintenance employee or 10	-
5.	Revenue vehicle capacity kms per total recurrent cost (CE5) or 6	46.66
6.	Revenue vehicle capacity hours per total recurrent cost	-
7.	Vehicle kms per operating expense (TVKPTC7)	0.705
8.	Revenue vehicle hours per employee hour (RVHPLHR8)	0.728
9.	Vehicle hours per peak vehicle requirements (VHRPTV9)	1467
10.	No. of peak vehicles per maintenance and support service employees	-

Performance indicators 1-3, 5, and 7-9 are studied. Data on maintenance employees is unavailable because of the multi-tasking nature of private bus firm employees, whose input is best represented by working hours.These seven indicators have been calculated for each of the 24 firms.

SUR models have been estimated to evaluate the relationship between the partial productivity indices and these popular performance indicators to establish the extent to which any of the top ten indicators are indeed meaningful measures for establishing an improvement in cost efficiency (Table 5). There is substantial collinearity between indicators 1 and 2 (partial correlation of 0.8), indicators 3 and 5 (partial correlation of 0.5) and indicators 5 and 7 (partial correlation of 0.94). The final results have taken into account the presence of multicollinearity as well as acceptable hypotheses on causal links between each performance indicator and each partial productivity index.

Table 5. The Relationship Between PPI's and The Top Ten Univariate Performance Indicators

Explanatory Variable	Acronym	Parameter Estimate	t-value
PPIL: Partial Productivity of Labour (single eqn r^2=.11)			
Revenue vehicle hours per operating expense	RVHPOE1	2.4353	2.08
Revenue vehicle capacity kms per total cost	CE5	0.00231	3.71
Constant		1.0201	17.1
PPIF: Partial Productivity of Fuel (r^2=.21)			
Vehicle kms per operating expense	TVKPTC7	0.01797	2.08
Vehicle hours per peak vehicle requirements	VHRPTV9	-0.6039-05	-1.71
Constant		0.28339	26.9
PPIM: Partial Productivity of Maintainance (r^2=.54)			
Revenue vehicle hours per operating expense	RVHPOE1	2.0097	4.70

Constant	0.1482	11.9	
PPIK: Partial Productivity of Capital			
(r^2=.16)			
Vehicle kilometres per active vehicle	TVKPVEH3	0.4768-05	3.64
Vehicle hours per peak vehicle requirements	VHRPTV9	-0.1174-03	-2.09
Constant		0.4434	5.2

The evidence in Table 5 supports the view that there is a systematic relationship between a number of the best and alternative marker indicators and the input productivity indices; but that the mapping is far from comprehensive. Simple regressions of the statistically significant marker indicators in Table 5 against the contextual and operating variables in Table 3 produces explanations of variation of 80 percent, but since the contextual and operating variables only explain between 28 and 50 percent of the variation in the PPI's, the application of all the univariate indicators is only a partial measure of the overall productivity of each firm.

THE CAPITAL COST OF BUSES

The treatment of capital assets, in particular bus capital has traditionally been a very superficial exercise in nearly all public bus operations in Australia. The appropriate cost of an asset to be charged against operations during any given period is the opportunity cost of using it during that period. This is referred to as the user cost of capital for that period. When evaluating the opportunity cost of a bus, the relevant cost to be considered is the entire capital cost, to be regarded as an outlay in the period the bus is acquired minus its residual value on sale (scrapping), to be regarded as a cash receipt at the time the bus is disposed. Depreciation should not be charged against the revenue produced by service provision for this is implicit in the procedure of comparing the discounted benefit and cost streams.

The relevant variables for operations planning are cash flows and opportunity costs (both central to the idea of user cost), rather than costs determined on the basis of arbitrary accounting allocations. In the majority of bus costing studies the capital costs are determined as the sum of depreciation and interest, the former usually calculated on a straight-line basis. A theoretically superior (and easy to implement) means of determining capital costs is to use capital recovery factors to determine the annual outlay which would be equivalent, in terms of net present value, to future cash outlays resulting from an investment decision.

In proposing the user cost approach to bus capital costing, the issue of the temporal distribution of costs and its treatment requires consideration, especially the treatment of the peak versus the off-peak . The capital costs of route-service provision have traditionally been treated as a cost item allocated in full to peak services on the argument that fleet size is determined by peak vehicle requirements. If the off-peak services were eliminated, the capital cost would remain unchanged. Some analysts (e.g. Kerin 1989) however have suggested that if the peak was eliminated, positive capital costs would be incurred in the provision of off-peak services.

Off-peak service contributes to capital costs in two ways. First, while they do not increase the fleet size required at any point in time, they do increase the number of buses required in the long run. Running more buses in the off-peak increases average annual bus kilometres and thus reduces average bus life in terms of years and hence increases vehicle replacement frequency. Secondly, the annualised capital costs are no longer directly proportional to peak vehicle requirements. This is because the capital costs of peak and off-peak services are now *interdependent*. Thus total capital costs are a function of fleet size and the ratio of peak to off-peak vehicle requirements. In our model we assume that the economic life of a bus is a function of vehicle utilisation and elapsed time, with each influencing dimension weighted to reflect its contribution. The weights which sum to unity can be varied to test the sensitivity of the overall average capital cost of a bus.

A formula can be defined for the average capital cost per annum (AKC) for a bus according to capital recovery theory. AKC is defined as:

$$AKC = A + (P - S*(1+r)^{-n})*CRF$$

where

CRF = cost recovery factor = $r/(1-(1+r)^{-n})$
P = bus real purchase price
S = bus real scrap or residual value after L kilometres
r = real rate of interest
A = the average annual outlays of bus insurance (bus registration charges excluded)
* = the multiplication notation
n = average vehicle life, endogenously determined by the model.

The riskless cost of borrowing in Australia stood at 17.03% at the end of 1989. A corporate borrowing premium of 1% brings this to 18%. The riskless rate of 17.03% plus the general risk premium of 7% is the cost of equity. If we were to equate the rate of return on a bus firm's stock to the rate of return on the market portfolio (i.e. a beta coefficient of 1.0), then the risk-adjusted nominal cost of borrowing would be 25.03%. If a bus firm has government protection and we treat it as a riskless entity, then the nominal rate of return would be 17.03%, approximately equivalent to an 8% real rate of interest.

To obtain an estimate of the residual value, we have sampled a number of market prices obtained for vehicles disposed in 1988 in the private bus sector. The prices have been averaged to ensure a uniform change in relative prices between years. The prices are then converted to constant dollars by calculating the compound rate of increase of a new bus over a 15 year period (approximately 13%) and applying it to the nominal bus prices. The decline in value per annum is then calculated, and the value projected to a constant 15 year life. We have selected 15 years in order to be consistent with the mean life assumed by the private bus sector. The ratio of the value projected in constant dollars to a constant 15 year life over the historical cost can be expressed as the average percentage residual or scrap value of a 15 year old bus. The suggested working percentage is 15%.

The average bus life depends on the average number of annual kilometres run per bus, K, and the elapsed time, T, where

$$K = [s_p*WD*BP*HP + s_o*WD*BO*HO + s_o*WE*BO*HZ]/1.1*BP \quad (4)$$

and

$$T = \ln(S/P)/(1-d)$$

where

s_p = average vehicle speed (kph) in the peak period
s_o = average vehicle speed (kph) in the off-peak period
WD = number of annual weekdays
WE = number of annual non-weekdays
BP = number of peak buses run
BO = number of off-peak buses run
HP = number of peak hours per weekday
HO = number of off-peak hours per weekday
HZ = number of off-peak hours per non-weekday
d = nominal rate of depreciation
1.1 = allowance for 10% spare bus requirement

A little amount of algebra applied to equation (4) will demonstrate that the average annual vehicle kilometres per bus are a function of the ratio of off-peak to peak buses run:

$$K = s_p*WD*HP/1.1 + s_o(WD*HO + WE*HZ)*(BO/1.1*BP)$$

T is based on the accounting formula for the diminishing value rate for an n-year bus life. In order to identify the independent contribution of bus utilisation and elapsed time to the economic life of a bus we assume a simple linear additive function with weights reflecting the relative contribution of each dimension:

$$n = a(L/K) + bT; \; a+b = 1$$

The weights (a, b) can be obtained by ordinary least squares regression of current bus market value as a function of total odometers since new and the age of each bus. The data to parameterise this equation can be obtained from a sample of buses, suitably selected to contain vehicles of different vintages. We had some difficulty in obtaining suitable data for the regression equation because of the lack of a sufficiently large second-hand bus market in Australia for buses usually used on urban scheduled route services. The used bus market for coaches is much greater although it is also currently quite surpressed. These reasons prevented us from finding enough buses for sale of sufficient variability in use and vintage to be able to estimate the regression equation. Discussions with a number of operators and bus dealers suggested that a reasonable starting point for the weights is a=0.05 and b=0.95. We have recently embarked on a new survey to obtain the required data from a sample of private and public bus operators in Australia.

Assuming a spare bus capacity of 10%, total capital cost (TKC) is defined as the product of AKC and 1.1*BP:

$$TKC = 1.1*BP*\{A + [P-S/(1+r)^{-n}]*r/(1-(1+r)^{-n})\}$$

The application of the user cost approach suggests that the average capital cost per bus per annum is approximately $23,000. Note that for operatots with more than one depot, because many bus firms currently move their buses between depots, it is preferable to use a weighted average bus price based on the entire fleet. When buses are dedicated to particular depots, it will be possible to use depot-specific bus prices. It is interesting to observe that when this procedure is applied to the State Transit Authority (NSW) fleet, the total annual average capital cost of buses is approximately $9.65 million, considerably higher than the estimate of approximately $4.85 million budgetted for 1990/91. Changes in the peak-to-base bus ratio can have sizeable implications for total capital costs, even if fleet size is fixed.

The full set of calculations incorporated are summarised in Table 6 for an illustrative operator. The unit cost of a bus expressed in dollars per vehicle operating hour as used in the estimation of the cost model can be readily calculated.

Table 6. Illustrative Inputs and outputs of Average Capital Costs of Buses

INPUTS TO CAPITAL COST:	
insur+tax per peak bus (A)	2850.88
Annual weekdays (WD)	250
Annual non-weekdays (WE)	115
No. of peak buses run (BP)	109
No. of off-peak buses run (BO)	30
No. of peak hrs per weekday (HP)	6
No. of off-peak hrs per weekday (HO)	10
Off-peak hrs per non-weekday (HZ)	17
Nominal Rate of depreciation (d)	0.12
Ave speed in peak periods (s_p)	17
Ave. speed in off-peak periods (s_o)	18
Average annual VKM per bus (K)	43246
Bus resid value $89-90 after L kms (S)	29236
Ave bus purchase price $89-90 (P)	194912
Utilisation Weight (a)	0.05
Elapsed time weight (b)	0.95
Elapsed time effect (T)	14.84
Average bus life (n)	15.02
Bus life in kilometres (L)	800000
Real rate of interest (r)	0.07
Cost Recovery Factor (CRF)	0.1096
Ave.cap cost per period (AKC) (per peak bus)	**23071**
Total capital cost per period (TKC)	2514772
L/K: use only determined age	18.498

CONCLUSION: AN ASSESSMENT OF RELEVANT MEASURES

This paper continues a theme which has steadily evolved since performance indicators have been recognised as a useful source of information for measuring the success or failure of corporate change at the strategic level as well as at the operations' level. The most important message is the need to establish a reference benchmark index of productivity to represent the cost efficiency dimension of performance, which is designed to serve as a mechanism for establishing a plethora of **truly relevant measures.** The set of offered marker indicators originally established by Fielding and his colleagues have a partial correspondence with our preferred benchmark index, giving plenty of scope for an improved set of measures.

Although our primary focus is on the framework for performance measurement and translation into sources of variation which have an operationally-identifiable set of decision making capabilities, the need to recognise the inadequacies of data throughout the transit industry is paramount in any future efforts to establish more appropriate indicators of performance. There remains the unproven overiding concern that a significant element of the "mismatch" between our preferred reference benchmark index and the preferred marker indicators is attributable to inadequate data, and especially the limitation of reliance on top-down data. Until such data are available which permit appropriate weighting to allow for heterogeneity from the bottom-up as we aggregate outputs, inputs and other dimensions of information, the current inconclusiveness will remain.

We are at a crucial threshold in the debate on productivity measurement. The set of techniques for reasonably measuring performance are essentially in place. Although analytical refinements will continue, the returns on this activity will be marginal in contrast to the rewards from a very serious bottom-up data information strategy within all firms in the bus and coach industry. To be effective, we will require such data from a representative sample of private and publicly owned operators receiving varying degrees of subsidy support (including no such support), and who vary on important dimensions such as physical size, location, market structure, patronage opportunities, activity composition, network configuration and management structure. These empirical dimensions are not random examples, they are the essence of sources of variation in performance.

REFERENCES

Benjamin, J. and Obeng, K. (1990) The Effect of Policy and Background Variables on Total Factor Productivity for Public Transit, **Transportation Research**, 24B(1), 1-14.

Caves, D.W., Christensen, L.R. and Diewert, W.E. (1982) Multilateral Comparisons of Output, Input, and Productivity using Superlative Index Numbers, **The Economic Journal,** 92, 73-86.

Domberger, S, and Hensher, D.A. (1991) On the Performance of Competitively Tendered Public Sector Contracts, Graduate School of Management and Public Policy, **The University of Sydney** (mimeo).

Fielding, G.J., Babitsky, T.T. and Brennan, M.E. (1985) Performance Evaluation for Bus Transit, **Transportation Research,** 19A(1), 73-82.

Forsund, F.R., Lovell, C.A.K. and Schmidt, P. (1980) A Survey of Frontier Production Functions and their Relationship to Efficiency Measurement, **Journal of Econometrics**, 13, 5-25.

Gillen, D.W., Oum, T.H. and Tretheway, M.W. (1985) **Airline Cost and Performance: Implications for Public and Industry Policies,** Centre for Transportation Studies, University of British Columbia.

Hensher, D.A. (1989) Total Factor Productivity Growth of Public Transit Services: Australia 1980-1987, **Proceedings of the Fifth World Conference on Transport Research,** Yokohama, Japan, 17-29.

Hensher, D.A. (1990) **The Productivity and Performance of Public and Private Transit**, Institute of Transport Studies, manuscript (mimeo).

Hensher, D.A. (1991) Sources of Variation in the Performance of Private Bus and Coach Operations in Australia 1987-88, Special Issue of **Transportation Research** on The Measurement of Performance and Productivity in the Transport Sector (guest edited by D.A. Hensher), (forthcoming)

Hensher, D.A., Milthorpe, F.W., Smith, N.C., Young, J. and Battellino, H.C. (1991) **A Route Service Revenue and Cost Model System: Identification of Commercial and**

Non-Commercial Bus Services, Report prepared by the Institute of Transport Studies for the State Transit Authority (South and West Division), October.

Kerin, P. D. (1989) On the Marginal Capital Costs of Peak and Off-Peak Transit Services, **Journal of the Transportation Research Forum,** XXIX (2), 349-355.

Lee, D. (1989) Transit Cost and Performance Measurement, **Transport Reviews**, 9(2), 147-170.

Lyons, W.M. (1987) Analysis of Nine European Public Transit Databases: Insights for the Urban Mass Transportation Administration Section 15 Program, **Transportation Research Record 1144,** 24-33.

Mackie, P. and Nash, C. (1982) Efficiency and Performance Indicators: the case of the Bus Industry, **Public Money**, December, 41-44.

Obeng, K., Assar, N. and Benjamin, J.(1991) Total Factor Productivity in Transit Systems, Dept of Economics, **North Carolina A&T State University** (mimeo).

Talvitie, A. and Obeng, K. (1990) Productivity Measurement: A Workshop Report, in Proceedings of the First International Conference on Competition and Ownership of Bus and Coach Services, **Special Issue of Transportation Planning and Technology** (guest edited by D.A. Hensher).

Windle, R.J. (1988) Transit Policy and the Cost Structure of Urban Bus Transportation, in Dodgson, J. (ed.) **Bus Deregulation and Privatisation: An International Perspective**, Gower, London.

Witham, M. (1989) Comparative Performance Indicators: Discussion Paper on Data Definitions, **Australian and New Zealand City Transit Association**, mimeo

This paper is concerned with identifying the appropriate level of detail required for data collection in order to be able to make performance-based decisions *within* a passenger transport enterprise. There has been a preoccupation in the published literature with industry-wide measurement and reporting of performance using data which is often of limited value due to its level of aggregation (despite the sample points being individual firms). We are of the strong belief that even for non-operating organisations responsible for the development of advice at the strategic level on the role and structure of passenger transport operations, that the industry-wide approach can often be quite misleading because of the inability to adequately represent the substantial differences between operators in both the private and public sectors. The industry-wide approach does not have to be of limited value to a particular enterprise provided that the data is sufficiently rich to adequately reflect the substantive differences. What is needed is a balanced approach which begins with the assumption that useful data must be able to generate firm-specific advice on directions of change which will enhance performance. The presentation of the information must also ensure that the performance measures are intuitive to practictioners in operating firms otherwise the exercise is in the main of academic value only.

(ii) No allowance for the Heterogeneity of output and labour inputs.

Explanatory Variable	Acronym	Parameter Estimate	t-value
Constant		13.8513	53.97
Ln (output)	LQ	1.1477	1.23
$(\text{Ln(output)})^2$	LQSQ	0.3553	1.64
Ln(price of labour)	LPL	0.4585	26.2
$(\text{Ln(price of labour)})^2$	LPLSQ	0.02708	2.77
Ln(price of fuel)	LPF	0.11271	20.03
$(\text{Ln(price of fuel)})_2$	LPFSQ	-0.0065	-1.19
Ln(price of maintenance)	LPM	0.0785	10.89
$(\text{Ln(price of maintenance)})_2$	LPMSQ	0.01674	3.21
Ln(price of capital)	LPK	0.1787	16.43
$(\text{Ln(price of capital)})_2$	LPKSQ	0.07838	22.07
LQ*LPL	LQLPL	-0.02759	-0.98
LQ*LPF	LQLPF	-0.0014	-0.2
LQ*LPM	LQLPM	0.01014	0.87
LQ*LPK	LQLPK	0.0099	0.57

Log-Likelihood at Convergence = -28.51