WORKING PAPER
ITS-WP-02-16

Performance-Based Quality Contracts for the Bus Sector: Delivering Social and Commercial Value for Money

By

David A Hensher and Erne Houghton

September, 2002

ISSN 1440-3501

INSTITUTE OF TRANSPORT STUDIES
The Australian Key Centre in Transport Management

The University of Sydney and Monash University

Established under the Australian Research Council's Key Centre Program.

NUMBER: Working Paper ITS-WP-02-16

TITLE: Performance-Based Quality Contracts for the Bus Sector: Delivering Social and Commercial Value for Money

ABSTRACT: Reform of the bus sector has been occurring in many countries. One matter central to these reform initiatives is the establishment of a value for money (VM) regime to ensure that operators deliver to the market the best possible service levels consistent with stakeholder needs and especially the objectives of government. A key underlying feature of 'value for money' (VM) is identifying the benefit to society associated with each dollar of subsidy support from government. This paper reviews the elements of a VM regime within the setting of an incentive-based performance contract and develops a formal framework for establishing optimum subsidy based on system-wide maximisation of social surplus. The maximisation of social surplus is subject to a number of constraints including the commercial imperative of the operator, minimum service levels under community service obligations and a fare and subsidy budget cap. An important feature of the performance-based contract (PBC) regime is a passenger trip-based incentive payment scheme linked to user and environmental externality benefits incorporating a subsidy per additional passenger trip above the patronage delivered under minimum service and fare levels. In this way, rewards to operators are revealed through the fare box, through increased consumer surplus and through reductions in negative externalities associated with car use. PBCs can be designed to accommodate both transition from an existing regime and post-transition growth strategies. The implementation of performance-based contracts is illustrated using data from private operators in the Sydney Metropolitan Area.

KEY WORDS: Contracts, Bus Reform, Value for Money, Performance, Optimum Subsidy and Multiple Objectives.

AUTHORS: David A Hensher and Erne Houghton

CONTACT: Institute of Transport Studies (Sydney & Monash)
The Australian Key Centre in Transport Management, C37
The University of Sydney NSW 2006, Australia

Telephone:	+61 9351 0071
Facsimile:	+61 9351 0088
Email:	itsinfo@its.usyd.edu.au
Internet:	http://www.its.usyd.edu.au

DATE: September 2002

1. Introduction

Over the recent period of significant change in the way that bus services are supplied in many countries, a key focus has been the delivery of cost efficient services (through mixtures of privatisation, economic deregulation and competitive tendering) and finding ways to grow patronage (Hensher 2002a). Despite all the developments to improve the cost and service efficiency of operations, something has often been shown to be lacking – the global picture which recognises that public transport is, above all, provided through a supply chain in which different objectives apply such as commercial and social obligations. This broad and more holistic approach presented in Hensher and Macario (2002) recognises that no institution is able to act without affecting the other agents in the system. Social surplus maximisation (SSM) principles applied to transport tend to suffer when the focus is narrowed to the detail of cost efficient operations (the dominating focus in recent years of competitive tendering), losing to a growing extent the SSM aim associated with an overall mobility system. A big challenge is to re-focus on the integration of SSM and commercial objectives in a way that delivers much improved service levels as part of what might be generically termed *a value for money objective function*. The holistic vision is to pursue social planning with a commitment to commercial objectives and opportunities at the operational level under a cost *and* service efficiency regime, thereby recognising the real meaning of optimum subsidy. This theoretical approach is not new and was articulated in the public transport context over 18 years ago by Jansson (1984), and more recently by Jansson (2001)[1].

As part of the many reviews of the contracting regimes that bus businesses operate within, it has been recognised that the relationship between commercial and social objectives has not been investigated in a systematic manner. To what extent are existing subsidy support levels optimal? What exactly does this mean? One issue of interest to many governments is growing bus patronage that in particular switches from the car and hence reduces the negative environmental impacts of transport (Hensher 2002a). Thus an important task in the review of a service delivery regime is the establishment of an optimum *system-wide* subsidy system for the provision of bus services such that a profit maximisation level of passenger trip activity on the part of the operator will coincide with social surplus maximisation objectives. Economists when integrating these two maximisation objectives refer to social surplus (SS) maximisation as the sum of producer surplus (PS) (maximisation) and consumer surplus (CS) (maximisation). The former is equivalent (under a cost-efficiency regime) to profit maximisation for private bus operators. In most cost-benefit analyses undertaken by the public sector, there has been an almost total focus on consumer surplus maximisation, defining net benefit as the difference between consumer surplus in the presence and absence of a policy

[1] Jan Owen Jansson in his plenary paper at the *7th International Conference on Competition and Ownership of Land Passenger Transport* (Jansson 2001) states:

> "Two main possibilities for improvement [in cost efficiency] are to stimulate competition, and to enhance the motivation and creativity of operators by introducing the profit motive into a traditional 'public service'. The question is, if the present allocative inefficiency in transport markets will be improved in the process, it is argued that these changes will not be brought about by the increased reliance on market forces. On the contrary, better planning of public transport systems, and, I dare say, continued or increased subsidization are two necessary conditions for realizing the potential improvement of the resource allocation. A complementary, significant point is, however, that there is no inevitable conflict between the ambition to increase cost efficiency in public transport, and a transport policy towards an efficient modal split."

instrument (typically measured by changes in generalised cost). Yet it is the sum of PS and CS that represents the overall benefit to society. Thus failure to take into account the operator's objective function is a failure to recognise social optimality.

One of the most innovative payment schemes designed to secure socially optimum behavioural responses from transport operators has been developed in Norway for application in Hordaland County[2]. The local government makes payments to the bus operators through an incentive scheme that "pays for results rather than shares the costs of inputs" (Carlquist 2001)[3]. The approach identifies a set of 'external' effects that are typically not taken into account by the individual traveller when choosing a transport mode.[4] Hensher and Stanley (2002) provide more details on this scheme as well as other approaches to the establishment of performance-based contracts.

When a traveller chooses to go by car, the decision-maker ignores the external costs imposed on others (eg. the costs of congestion, accident risk and pollution) – assuming (as usual) that the institutional context does not allow the deployment of (first-best) car-user charges to reflect these costs. Conversely, an extra traveller who goes by bus (or other public transport) helps to create a *positive* external effect – often called the Mohring effect: as patronage increases on a route (or in a particular area), the (socially) optimum service frequency also increases. This benefits the new travellers (whose patronage has led to the service improvement), and also reduces trip time for those others who continue to use the service.

In the absence of practicable price discrimination, the operator is not able to extract the increase in consumer surplus that is enjoyed by the continuing users as a result of the increase in frequency – because a fare increase for all passengers would preclude some or all of the extra travel that justifies and requires the extra frequency. To achieve the optimum service level, a government-funded incentive payment is needed. To the extent that the incentive payments result in lower fares and/or improved service levels, there can be social benefit from increased travel (that is, generated trips) as well as from the reduction in car travel. This too should be recognised in establishing the incentive payments.

The apparent conflict between the operator's objective function and that of SS maximisation is primarily related to the absence of the use of benchmarked best practice costing and the presence of externalities linked to environmental (eg congestion, pollution) and social (eg equity) impacts that are not internalised in the operator's profit and loss account. If SS maximisation imposes a substantial financial loss on the operator it would be unacceptable to the operator. If however a positive change in CS (based on private user benefits) and non-internalised environmental externality benefits (EB)[5] would increase revenue (and conversely decrease revenue for a negative change in CS and EB), the operator would have the necessary incentive to act as a social surplus maximiser. The question then becomes one of identifying how this incentive can

[2] An area that includes the city of Bergen as well as some surrounding rural areas.
[3] Competitive tendering as implemented, in contrast, has mainly focussed on sharing the costs of inputs.
[4] Although the principal modal choice in the Hordaland context is between bus and car, the competition can be generalised to include rail, ferry etc.
[5] Strictly, consumer surplus (CS) is the sum of private user benefits (UB) and (internalised) environmental benefits (EB), but herein we treat them as separate benefit sources, referring to private user benefits as consumer surplus.

be provided in practice. The implementation 'solution' appears to lie in changes to the pricing (ie fare) and/or supply regulations in a way that opens up opportunities for the operator and the regulator (the latter acting on behalf of the government) to seek out incentive-based mechanisms that reflect the challenge to internalise CS and EB[6]. This should hopefully provide the necessary freedom and (positive) incentives for the operator to pro-actively participate in pricing policy and service design to increase cost efficiency as well as allocative efficiency. The benchmark for progress however is internalisation of CS and EB, achieved by the mix of internalised cost recovery and externalised funding by the provision of an optimum subsidy (or incentive-payment).

What formula will work in practice that is acceptable to both the operator and the regulator? One thing is almost certain - there will need to be a transparent level of external subsidy[7]. If a scheme is to work, however, it must prevent cost inefficiency (which can be a product of subsidy support, as indeed can poor service delivery). An effective monitoring and benchmarking program is critical[8] to ensure that cost inefficiency does not occur as the subsidy is introduced to support initiatives that deliver consumer surplus, and that external funding delivers the best value for money. Periodically reviewed benchmark best cost practice associated with specific geographical settings should be the basis of subsidy determination.

The following sections of the paper review the elements of a VM regime within the setting of an incentive-based performance contract and develops a formal (economic) framework for establishing an optimum subsidy based on maximisation of social surplus. The maximisation of social surplus is subject to a number of constraints including the commercial imperative of the operator, minimum service levels and a fare and subsidy budget cap. An important feature of the performance-based quality contract regime is a passenger-based incentive payment scheme incorporating a subsidy per additional passenger trip above that patronage delivered under minimum service and fare levels. In this way, rewards to operators are revealed through the fare box, through increased consumer surplus and through reductions in negative externalities associated with car use. The implementation of performance-based contracts is illustrated using data collected in 2002 from private operators in the Sydney Metropolitan Area. Appendix A summarises the main elements of a PBS transitional scheme for Sydney. PBCs can be designed to accommodate both transition from an existing regime and post-transition growth strategies.

---

[6] It must also be recognised that the delivery of positive CS under a subsidy-scheme recognises the presence of under-pricing of competing modes such as the car. Subsidies to public transport are designed to bring its operation into line with social considerations. In particular, when car users are not charged for the negative externalities that arise from their car use, subsidies for bus services can help to encourage travellers to make appropriate choices between travel modes. Yet, when privatisation and contracting-out of bus services came into vogue in the mid-1980s, the principal aims were simply to reduce subsidies and to increase cost efficiency. In recent years, the focus has turned to the shaping of payment instruments to try to secure behavioural responses that support the specific policy purposes of the government instrumentality that pays the subsidy.

[7] This is separate from any operator commitment to internal cross-subsidy between various activities that is consistent with efficiency objectives provided that avoidable costs are covered on each (well-defined) activity.

[8] We recognise that monitoring of performance cannot be precise and must be dependent on trust and quality reporting (Carlquist 2001). Such a monitoring program should focus on the three dimensions of overall performance: cost efficiency, cost effectiveness and service effectiveness. The role of constructs such as a Service Quality Index (SQI) developed by Hensher and his colleagues (eg Prioni and Hensher 2000, Hensher and Prioni 2002, Hensher et al 2002) offers one way of tracking the last dimension.

2. Incentive-Based Performance Contracts

Before setting out the formal economic framework for a proposed performance-based contract regime (for Australia), we will take a closer look at a recent initiative in Norway that promotes the PBC regime over competitive tendering[9]. New performance contracts were established, in early 2000, for the three bus operators in the Hordaland county. One of these serves the urban area; the other two operate in rural areas and on the main corridors into Bergen. There is little or no on-the-road competition.

The design of the Hordaland payment mechanism is innovative. Larsen and his colleagues (Larsen 2001, Johansen et al 2001) develop a two stage procedure where the first stage determines fare levels, bus revenue-km and bus capacities to maximise a social welfare function (essentially SS maximisation). The second stage calculates rates for fare subsidies, and for revenue-km subsidies (applicable in the peak and/or periods), *that will induce a profit-maximising operator to choose the (socially) optimum levels for revenue-km and for bus capacities*. This statement in italics is the essence of the approach providing the link between commercial and social objectives. The operator does not set fare levels but complies with maximum fare levels set by the authority. The per-passenger remuneration received by the operator is the sum of the fare level (determined in the first-stage welfare-maximising calculation) and the subsidy level (determined in the second-stage calculation).

In this approach, a per-passenger subsidy, or fare subsidy 'pays for results' and the revenue-km payment reimburses some of the costs. The operator also receives the fare revenue and both kinds of revenue together provide the operator with sufficient income to balance the operating costs. In other words, the revenue-km subsidy will not encourage an operator to run empty vehicles. It does encourage service frequency and the extent of the induced increase in frequency depends on how vigorously (and successfully) the operator pursues profits. What we have here is an incentive-based performance contract where the subsidy is set to match the sum of the avoided external costs of car use *and* the benefits of increased service frequency.

The welfare outcomes depend on the details of the implementation. The implementation of the Hordaland model is described in Carlquist (2001)[10]. Each operator has a separately calibrated contract. As in earlier contracts, these are on a net-cost basis; but unlike the Larsen (2001) model, each operator may determine the fare levels. In the

[9] The evidence is drawn from Carlquist (2001), Larsen (2001), Johansen et al (2001), Mills and Gale (2002). Hensher and Stanley (2002) provide further details of the Norwegian model and the arguments for PBC compared to Competitive Tendering.

[10] As an example of the subsidy calculation, using vehicle kilometres (VKM) as the performance criterion and \$/vkm as the cost rate (RATE), with the subsidy subject to a maximum predetermined level, the subsidy in year t = ($RATE*VKM_t$) minus a fixed deduction as explained in Larsen (2001). Profits are co-determined by different performance-based items – ticket revenues (I), subsidies (S), and costs (C). Ticket revenue is equal to fare (F) multiplied by demand (D), and demand is a function of VKM, fares and other service attributes. That is: profits=I+S-C, C=f(VKM), I=F*X and X=g(VKM,F,…). Given the right incentive (ie RATE) the operator will decide on a fare level and VKM at a level that maximises profits and maximises social welfare given the budgetary limits for subsidy support. The budgetary limit is often associated with a constrained social welfare maximisation rule (or Ramsey rule) that implicitly imposes a marginal cost of government funds on the calculation (ie the amount that government is willing and possibly able to contribute to the social welfare objective).

event, the implemented contracts do not include any per-passenger subsidy, in part because the (global) budget constraint limited the amounts of subsidy that could be paid[11]. The Larsen modelling had suggested such subsidy should be paid, but only where the fare was significantly less than the marginal cost – as for peak-period rural services. The revenue-km subsidy has been implemented through two components – one subsidy rate per vehicle-km and another per vehicle-hour, to accommodate differences between congested urban conditions and non-congested rural operation.

The subsidy rates are calculated to secure optimum *marginal* conditions. In principle, there is no certainty that the total amount of subsidy will be such as to enable the operator to receive as much as, and no more than, a reasonable return on investment. Numerical calculations prepared by Larsen show that the urban operator (in particular) would be likely to receive a substantial level of excess profit. This arises because the marginal cost of the peak services is very much higher than the cost of the other ('basic') services, which are a substantial part of the total offering. Accordingly, a 'fixed deduction' was suggested. Being fixed in total amount, this has no effect on the (marginal) incentive structure. Carlquist reports that the fixed-deduction principle *was* incorporated in the implemented contracts.

In the first year (2001) of the deployment of the new performance contracts, there has been little change (especially in regard to route networks) – in part because the budget constraint was tight enough to limit the scope for change, and in part (perhaps) because of inertia, including political resistance to change. Nevertheless Carlquist (2001) reported that experience with the new contracts is generally well regarded.

The Hordaland model has provided the starting position for the authors' proposal for a PBC framework for Australia. The data used to illustrate the implementation of a PBC regime has been obtained from a major private operator who is widely regarded as operating at best practice with respect to cost efficiency and effectiveness. Thus the approach detailed below is indicative of the outcomes one might anticipate under a PBC regime for an outer urban area bus operator in a major city in Australia. We focus on a PBC scheme under a transition from the existing contract regime but show that once the transition is complete, the very same PBC scheme can be used to promote growth in passenger trips through improved service levels supported by incentive payments (Hensher and Houghton (in progress)).

3. The Australian PBC Proposition

The proposed PBC framework is based upon a model system that recognises the obligations of government, as well as the need to provide appropriate incentives to operators to service the market in line with value for money under a tight subsidy regime. In addition, we recognise the constraints under which the regulator charged with implementing and monitoring a contract regime operates. In NSW, for example, a

[11] The global budget constraint is a very important parameter for the NSW government because it is at the heart of the Bus Reform agenda. The intent appears to be clear – to provide increased value for money within a system-wide pre-determined maximum budget. As detailed herein PBC's can be developed for transition (holding existing subsidy levels fixed) and then later allow the subsidy level to vary as the reward for growing patronage.

paramount requirement is for a minimum[12] administrative burden based on suitable reliable data provided by bus operators.

The PBC framework is assumed to be implemented *system-wide* over a pre-defined geographical area (but can also be implemented for a single operator). We distinguish between metropolitan and non-metropolitan settings and focus herein on the metropolitan model. Furthermore we recognise intra-metropolitan differences in the operating environment, especially due to patronage catchment, traffic congestion and time of day. These differences are accommodated (to a large extent) by distinguishing between inner and outer metropolitan areas as well as peak and off-peak periods. Where minimum service levels (MSLs) are required, they will be set exogenously for each region and period based on a grading system determined (outside of the PBC structure) by a number of criteria including population, population density and incidence of school children[13]. All costs used will be assumed to be benchmarked best practice for the specific context. The use of benchmarked costs ensures that optimum subsidies are based on cost efficient service levels[14].

3.1 Defining Annual Passenger Demand

The demand for bus travel (Y) is defined as one-way annual passenger trips[15] per contract period, and is assumed to be influenced by fares (q) and service levels (X), where the latter is proxied by revenue vehicle kilometres (ie total vehicle kilometres minus dead running kilometres). Since the categories of bus passengers have differing degrees of behavioural responsiveness to changes in fares and service levels, separate passenger demand models are required for each segment. Within each geographical context, we initially propose separate demand models for peak and off-peak travel for two broad classes of travellers: (i) adults, (fare paying) children and concession travellers (ACC) and (ii) school children (S). Further segmentation can be introduced as required. There are many specifications available to represent travel demand. We have chosen equation form (1) for class (i) travellers and a separate equation form (2) for class (ii) travellers, where the latter applies when school children do not pay a fare. Before the implementation of the proposed scheme (base case B), demand levels, Y^B, are based on *existing* fares and service levels. After the implementation of the proposed scheme (Application case A), predicted demand, Y^A, is a function of a base demand (Y^B); the direct fare elasticity of demand and the direct revenue vehicle kilometre elasticity of demand; and operator responses to the scheme through changes to fares and revenue

[12] And certainly no increase over existing regulatory resource commitments.
[13] Although we specify MSL in terms of a minimum amount of revenue vehicle kilometres, the regulator may wish to impose some very specific conditions on where and when these RVKM are to be provided within the contract area. This is not an issue of concern to establishing the appropriate level of incentive payment given a system-wide subsidy budget since all we need to know is the minimum RVKM for each of the peak and of-peak periods for each contract area. We have doubts about the benefit of imposing too rigid a service specification as is currently the situation in NSW because it results in many services with very little patronage and substantial cost-burdens that do not provide real benefits to society. Spreading thin resources thinly is not a virtue that we should promote. Larsen (2001, page 2) promotes a view that "…the design of a route system is best left to an operator familiar with the area to be served". There are sensible reasons for moving from the tactical to operator level the fare structure, fare level, route networks and timetables within the parameters of the incentive-driven quality contract.
[14] If there is a case for differences in cost efficient rates (for whatever reason, such as an equity-adjustment), this can be included.
[15] A passenger trip is defined as a single one-way trip from an origin to a destination. If a transfer between buses is required this is not two passenger trips.

vehicle kilometres. The elasticities used in equation (1) for each of peak and off-peak activity are weighted averages across the classes of travellers within the separate demand categories.

$$Y_{ACC}^{A} = Y_{ACC}^{B} * \exp[\frac{\varepsilon_{Y(ACC)}^{q}}{q^{B}}(q^{A} - q^{B}) + \frac{\varepsilon_{Y(ACC)}^{X}}{X^{B}}(X^{A} - X^{B})] \quad (1)$$

$$Y_{S}^{A} = Y_{S}^{B} * \exp[\frac{\varepsilon_{Y(S)}^{X}}{X^{B}}(X^{A} - X^{B})] \quad (2)$$

We initially assume a static representation with the annual patronage response assumed to occur at the specified rate over the period of a contract. For class (i) travellers, the set of fare elasticities is respectively -.20 and -.45 for the peak and off-peak periods, and the service (RVKM) elasticities are 0.33 and 0.63. For class (ii) travellers, the service elasticities are assumed to be the same as class (i), on the assumption that the parent traveller decides on the school child's modal activity.

The PBC system requires a base prediction of patronage associated with minimum service levels[16]. To obtain this patronage we use the level of RVKM associated with MSL and impose a fare level unchanged from case *B*. The resulting MSL patronage for class (i) travellers is Y^B in (3).

$$Y_{ACC}^{MSL} = Y_{ACC}^{B} * \exp[\frac{\varepsilon_{Y(ACC)}^{X}}{X^{B}}(X^{MSL} - X^{B})] \quad (3)$$

In what follows Y^A, Y^B, Y^{MSL} will be used in place of $(Y_{ACC}^{A} + Y_{S}^{A})$.

3.2 Defining Annual Total Cost

Benchmark cost efficiency is formalised by a set of total annual cost equations (4) for each period and region. Total predicted cost (C) is defined as a function of benchmarked base cost (calculated from best practice total cost per kilometre); predicted responses in total vehicle kilometres (VKM) (including dead running kilometres), predicted changes in total passenger demand (from equations 1 and 2), predicted responses in total seat capacity per revenue vehicle kilometre; and the respective set of cost elasticities for VKM, patronage and bus capacity. VKM is the sum of revenue and dead running kilometres with the default value in our empirical example for dead running VKM set equal to12.5% of VKM for both peak and off-peak activity (That is, VKM = 1.1258RVKM). Bus capacity (defined by seating and standing capacity per bus multiplied by the number of buses) impacts on passenger demand through revenue vehicle kilometres through a service *quality* constraint that indicates how much bus capacity must be provided to satisfy passenger trip demand. This then translates into vehicle kilometres which impacts on total annual cost, and takes into account the annualised cost of bus capital. The starting passenger trip-demand elasticities of cost are respectively -0.32 and -0.20 for the peak and off-peak periods. The equivalent service

[16] An MSL is not a necessary input into the determination of a PBC but we include it as a specific input given that the regulator may require its inclusion. In section 4 we will show what the implications are for determining the maximum social surplus solution when there is no MSL.

(RVKM) elasticities are 0.76 and 1.20; and the equivalent fleet size elasticity, which is derived from increased capital charges and applies only to peak periods, is 0.19. The separate cost equation for peak and off-peak periods, for each region and period, has the form of (4).

$$C^A = C^B * \exp[\frac{\varepsilon_C^X}{VKM^B}(VKM^A - VKM^B) + \frac{\varepsilon_C^{Y(ACC)}}{Y_{ACC}^B}(Y_{ACC}^A - Y_{ACC}^B) + \frac{\varepsilon_C^{Y(S)}}{Y_S^B}(Y_S^A - Y_S^B) + \frac{\varepsilon_C^{\#bus}}{\#bus^B}(\#bus^A - \#bus^B)] \quad (4)$$

3.3 Defining the Constraints

There are a number of constraints that enable us to represent the environment in which the delivery of services satisfies all stakeholders. The key constraints are shown below.

3.3.1 Fare Cap

A fare cap (5) over the contract period for each peak/off-peak period and region is a political reality in most jurisdictions and in Australia (maximum) fares typically may not increase by more than the consumer price index. The introduction of performance-based contracts must comply with this condition, set as a 5% maximum increase per annum. This can be adjusted to suit the political setting.

$$q^A - 1.05q^B \leq 0 \quad (5)$$

3.3.2 Vehicle Kilometres (VKM)

A condition of public transport service delivery often included in contracts is that there is a minimum level of service that must be provided under community service obligations (CSO) at cost efficient levels. These service levels are determined by external criteria set by government such as a requirement to provide a minimum amount of vehicle kilometres depending on the socio-economic and demographic profile of the region to be served. This profile must be defined by an agreed set of criteria such as total resident population, population density (1000's of people per square kilometre), the percentage of total population that are school children and availability of other modes (eg a train service) (see Ton and Hensher 1997). On the basis of a weighted system for each criterion, a minimum amount of RVKM is required for each period and region. The precise geographical allocation of this MSL is a detail of specific contract compliance and has no impact on the determination of the optimal social solution. This minimum RVKM would ideally be an absolute amount; but for the present application we define it as 67% of current service VKM's[17]. Condition (6) defines the minimum level of service (MSL). A total cost per kilometre can be introduced to convert this MSL to a dollar commitment from government. We assume *$VKM* = $2.60 in the peak and $2.30 in the off-peak (based on 2002 best practice costs in the private bus sector in Sydney in a setting where the operator retains all fare revenue).

The proportion of the total subsidy budget (TB) allocated to performance-based contracts in the regulator's scheme is denoted by R, which permits variations in the

[17] This percentage is derived from the percentage of RVKM complying with MSL's for the illustrative operating context from which the data is extracted.

structure of the subsidy scheme between MSL and above-MSL (or PBC) components. Since *TB* is the pure-MSL subsidy requirement as determined by CSO, the MSL of a given scheme is defined by the associated *R* value as CSO*(1-R)[18]. The inclusion of *R* is very important since it enables us to assess the implications of various mixes of MSL and PBC service levels.

$$X^{MSL} = (0.67)\text{VKM}\ (1\text{-R})\ X^{A} \geq X^{MSL} \qquad (6)$$

In addition to the fare cap and MSL constraints, government typically has a limited budget to allocate to subsidy support for bus transport. This subsidy cap is assumed to be *a system-wide constraint* within the metropolitan area and applies to all inner and outer metropolitan bus operators[19]. The subsidy cap is exogenously given but adjustable by government decree and has to fund the CSO payments as well as payments directly linked to incentives for growing patronage. The passenger-based incentive payment scheme at the heart of PBC's is made up of gains in consumer surplus and externality benefits, where the latter are primarily linked to reductions in traffic congestion due to reductions in car VKMs (see section 3.5.2). For every additional passenger trip above predicted patronage based on $RVKM^{MSL}$ and associated fares, the operator has the opportunity to secure revenue from three sources: (i) the fare box (ii) the change in consumer surplus as a measure of user benefit and (iii) the change in externality cost from reduced car VKM. The last two revenue streams are referred to as incentive payments (above fare revenue) and are part of the total budget commitment to the system as a whole by government. After committing CSO payments the balance of the total subsidy budget is available for such incentive payments (constraint (6)). While this residual amount is fixed, the estimate of its dollar value per passenger trip of the consumer surplus benefit will be determined by the maximisation of the social surplus function subject to the set of constraints. The dollar unit values of reductions in car VKM are exogenously supplied based on studies of the environmental cost of car use (see Bus Industry Confederation 2001 and Sansom et al 2002). If additional passenger trip growth over the predicted amount per contract period is exceeded it cannot be funded out of the available incentive payments unless government revises its total subsidy budget. Nonetheless, all additional fare revenue will be accrued by the operators.

3.3.3 Traffic and capacity

In peak and off peak periods the road traffic in which buses operate is vastly different, and to achieve a given RVKM in dense traffic requires the deployment of more buses compared to light traffic conditions. A direct measure of bus-utilisation (ie traffic) intensity in the period is given by $Z^B = \frac{(pers.\#bus)^B}{X^B}$. *Z* defines capacity required per RVKM as determined from the RVKM achieved by the number of buses (# *buses)* allocated to the period in the base case. An increase in base traffic results in a reduction

[18] Specifically, R controls the structure of the contract scheme. Defining %PBC= (1-R), $CSO*(1-R) gives the MSL component of the subsidy; and hence the subsidy applied to the performance incentive is TB-CSO*(1-R); and the RVKM required to meet the (reduced) CSO is VKM*.67*(1-R).

[19] This cap can be applied to specific locations if that is more politically palatable. For Example, in the Sydney metropolitan area the government may choose to treat the government operator (the inner area supplier) differently to the private (outer area) operators. In addition, government may wish to pre-assign a cap to each operator (which we would recommend in the transition phase but not in post-transition growth phase).

in X^B and an increase in Z, which has the effect of increasing the capacity required, X^AZ^B, for a given solution X^A. Z is not a control parameter but simply reflects the traffic of the period in the base case.

Imposing equivalent traffic conditions in equivalent periods (peak, off-peak) to the base case requires

$$Z^A = Z^B \text{ , or,}$$
$$X^A = \frac{(pers.\#bus)^A}{Z^B} \tag{7}$$

where

\# *bus* = the number of buses assigned to the period/region and is assumed to reflect the demand levels of the base period and may be changed with corresponding cost implications. The capital cost of extra buses is fixed to # bus unless included with Z

Pers = bus capacity (seating + standing) assumed to be single-valued and unchanging

From (7) the capacity required for a given solution X^A is given by X^AZ^B.

The number of buses may be increased or decreased to provide an upper bound to X^A that is fixed by the number of buses assigned to the period, i.e.

$$X^A \leq \frac{(pers.\#bus)^A}{Z^B} \tag{8}$$

For a given *#bus* value, the bound may be loosened by deteriorating service quality, as discussed above. Again, the environment provided by the single stage solution is consistent with a profitable operator strategy to achieve the maximum social surplus, although it does not guarantee the optimum solution will be achieved.

3.3.4 Service quality

Service quality is maintained through the service quality constraint, which in its fundamental form requires

$$Y^A/X^A \leq Y^B/X^B. \tag{9}$$

This becomes very restrictive for low X solutions, since with X^A decreasing from X^B towards X^{MSL}, Y^A declines towards Y^{MSL}, given by $Y^{MSL} = Y^B * \exp[\frac{\varepsilon_Y^X}{X^B}(X^A - X^B)]$, more slowly than X^A is declining. At low service levels, however, it is realistic to allow a decline in service *quality* to reflect an interaction between the declining returns and declining price elasticity of demand as the volume of business declines. In general, it is important to loosen the form of (9) through a control variable, κ; which relates to how full the buses are allowed to be on average given normal operating practices. κ is a measure of service quality with respect to loading and allows the service level to slip. The less restrictive form of (9) is given in (10)

$$Y^A \leq \kappa Z^A X^A \tag{10}$$

The starting value of κ is $\kappa = \dfrac{Y^B}{X^B Z^B}$ which measures the base trip-rate per unit carrying capacity allocated. κ can be adjusted up or down to control an increase or decrease in acceptable bus crowding levels, thereby providing decreased or increased service quality (loading). Where increased κ is not associated with a reduced volume of business it should result in increased costs to reflect a loss of goodwill. Solutions incorporating increased values of κ will define an environment within which operators may make normal profits whilst providing high social surplus solutions. As in the previous section, optimum operator strategies may take the industry in different directions.

3.3.5 System Wide Constraints

There are two system-wide constraints associated with all regional activity.

3.3.5.1 Subsidy cap

First we have the total subsidy cap (11) in which the amount of subsidy available for passenger incentive payments is less than or equal to the total allocated subsidy budget minus commitments to CSO payments.

$$\sum_{\text{region, period}}^{4} P\left(CS + EB\right) \leq TB - \sum_{\text{region, period}}^{4} \$CSO(1-R) \text{ for (CS+EB)>0} \tag{11}$$

Constraint (11) states that the patronage incentive must be less than or equal to the subsidy budget above CSO payments for all operators for (CS+EB)>0. Performance-based contracts allow subsidy payments to be earned whenever (*CS*+*EB*) are positive. Negative payments are not part of the performance-based system and are excluded in the modelling. Since both CS and EB are measured from the MSL position, payments are excluded when (*CS*+*EB*)<0. Although the total CS + EB is realised *to the benefit of the community*, the regulator can exercise the option to pay all of the benefit to the operator or only a proportion. P is the payout rate defining the proportion of external benefits accrued by bus companies on achieved (CS+EB). This is an important issue since the incentive payment focus does not suggest that 100% of the benefit must be paid to the operator. Indeed distribution of the full social benefit to the operator may not be equitable and/or financially feasible. What is critical however is that the payment distribution ensures sufficient incentive for the operator to improve service levels in order to grow patronage.

3.3.5.2 Commercial requirements

Total cost (including an acceptable return on investment) to all operators delivering bus services must be covered by all sources of revenue (12). The commercial constraint (equation 12) requiring that operator costs do not exceed revenues may be implemented when only commercially viable solutions are considered.

$$\sum_{\text{region, period}}^{4} \left[C^A - \left(qY_{ACC}^A + P(CS+EB)\right)\right] \leq \sum_{\text{region, period}}^{4} \$CSO(1-R) \text{ … for (CS+EB)>0} \tag{12}$$

3.4 Defining the Objective Function

The demand and cost models together with the constraint set condition the maximum value of the social surplus objective function, given in (13)[20].

Max:

$$\sum_{\text{region, period}}^{4}\left[(1+P)(CS+EB)+qY_{ACC}^{A}-C^{A}+\$CSO(1-R)-(\$CSO(1-R)+P(CS+EB))\right]$$

$$\ldots \text{ for (CS+EB)>0} \qquad (13)$$

CS is the consumer surplus and EB is the environmental benefit, where both of these are calculated from and above Y_{MSL}; all other variables are as defined previously. The measure of consumer surplus is relatively complex and influenced by changes in demand.

3.5 Defining the Benefit Sources

3.5.1 Consumer surplus

The minimum service level, *MSL*, corresponds to the *CSO*, and is defined by a minimum RVKM, (X^{MSL}) and maximum fare charged under MSL (typically the maximum permissible fare). The corresponding patronage level, Y^{MSL}, is established from (1). Y^{MSL} establishes the base patronage *above which* consumer surplus is generated given the current subsidy scheme. We let *CS* denote the level of consumer surplus associated with patronage determined by X^{MSL} and maximum fares.

A composite demand variable, *G*, is a function of both fare level and RVKM. G^{MSL} is determined equivalently to Y^{MSL}**.** Quantity demanded is related to bus travel attributes, some of which are desirable to the consumer, like RVKM, and others which are undesirable, like price. These attributes may be combined in a composite attribute measure, *G*, where

$$G^{MSL}=kq^{MSL}+\lambda X^{MSL}; \qquad G^{A}=kq^{A}+\lambda X^{A};$$

$$G^{MSL}-G^{A}=k\left(q^{MSL}-q^{A}\right)+\lambda\left(X^{MSL}-X^{A}\right). \qquad (14)$$

and k = -1

λ = Community preparedness-to-pay for 1 km increase in X.

Deriving lambda is a challenge given the absence of empirical studies. However additional service levels can be approximated by improved service frequency. The TRESIS project (Hensher 2002) provides a willingness to pay for improvements in service frequency of $2.66 per passenger trip hour. Given an average speed in the peak period of 24 kph and an off-peak average speed of 30 kph, we can convert the frequency valuation into $0.11 per RVKM in the peak and $0.0886 per RVKM in the off-peak for class (i) travelers. For class (ii) travellers the rates are halved.

A corresponding composite demand function gives Y^{A} as a function of G^{A} etc., and consumer surplus is then measured as (15).

[20] Eqn (13) adds P(CS+EB) and $CSO(1-R) to the social surplus expression as they constitute part of the producers surplus, and then they are both subtracted since they sum to the scheme cost.

$$CS = 0.5 * ABS(Y_{ACC}^{A} + Y_{S}^{A} - Y_{ACC}^{MSL} - Y_{S}^{MSL})(G^{MSL} - G^{A}) * if[(Y_{ACC}^{A} + Y_{S}^{A}) < (Y_{ACC}^{MSL} + Y_{S}^{MSL}), -1, 1] \quad (15)$$

(CS between Y^{MSL}, Y^{A})

$$+ if[(Y_{ACC}^{A} + Y_{S}^{A} - Y_{ACC}^{MSL} - Y_{S}^{MSL}) * (G^{A} - G^{MSL}) < 0,$$
$$(Y_{ACC}^{MSL} + Y_{S}^{MSL})(G^{MSL} - G^{A}) * if[(Y_{ACC}^{A} + Y_{S}^{A}) < (Y_{ACC}^{MSL} + Y_{S}^{MSL}), -1, 1], 0]$$

(CS to axis if negative slope)

Given that increases in fares reduce CS and increases in RVKM increase CS, we have to be careful how we treat the two impacts in the determination of changes in consumer surplus. Effective demand results from a balance between q and X. For given parameter values, k and λ, the slope of the composite demand function will be positive or negative depending on solution values, q^{A} and X^{A}. When the slope is negative, as shown in **Figure A**, a consumer surplus, $G^{A}ABG^{MSL}$, is derived from a reduction in the composite trip attribute from G^{MSL} to G^{A}. But, when the slope is positive, as shown in **Figure B**, a consumer surplus, ABC, is derived from an increase in the composite trip attribute from G^{MSL} to G^{A}.

FIGURE A: Composite demand function – negative slope

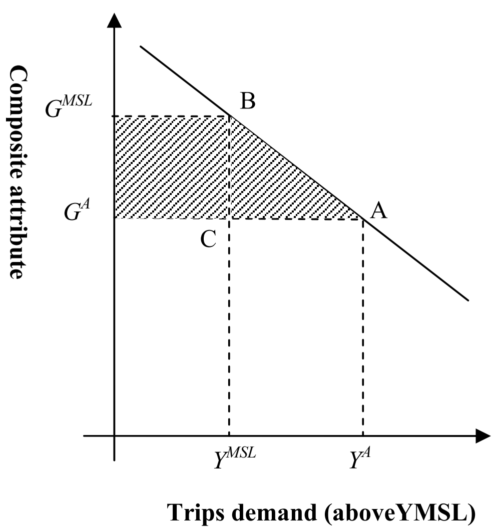
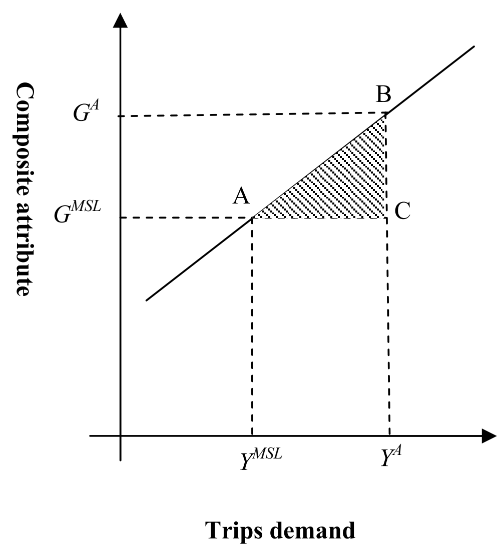


FIGURE B: Composite demand function – positive slope



In both **Figures A and B**, consumer surplus derives from ABC, but this is supplemented by the addition of $(G^{MSL}$-$G^{A})(Y^{MSL})$ in **Figure A**. When Y^{MSL} is high and $(Y^{A}$-$Y^{MSL}) = 0$, the supplement will induce the optimization to choose a marginal difference between Y^{A} and Y^{MSL} in order to achieve a negative slope and accrue the supplement. In the programming, therefore, the supplement is accrued only for $(Y^{A}$-$Y^{MSL})$ significantly different from zero.

3.5.2 Environmental Externality Benefit

The change in environmental benefits associated with car use is defined by equation (16). We assume initially that on average every car trip switched to a bus trip reduces car use by 10 kilometres and that 40% (20%) of all switched trips by adults (by school, children) are from car[21]. Any transfer of car trips to bus trips reduces road traffic congestion and creates an environmental benefit which also contributes to social surplus. *EB* denotes the environmental benefit generated by solution trips above Y^{MSL} and is directly comparable to *CS*.

EB = \$/(↓car user)*(↑passengers from car) … for each region, period

$= (\$/VKM^{car})*(av\ VKM^{car})*(\uparrow passengers\ from\ car)$

$$= (\$/VKM^{car})*(10\text{KM})*\left(Y_{ACC}^{A} + Y_{S}^{A} - Y_{ACC}^{MSL} - Y_{S}^{MSL}\right)*(\text{shift factor car-bus})$$

$$= (\$/VKM^{car})*(10\text{KM})*\left(Y_{ACC}^{A} + Y_{S}^{A} - Y_{ACC}^{MSL} - Y_{S}^{MSL}\right)*0.4 \qquad (16)$$

The unit rate of environmental benefit per VKM travelled by class (i) travellers, is a composite sum of six externalities, summarised in Table 1 for peak and off-peak and inner and outer metropolitan contexts. The evidence is drawn from the Bus Industry Confederation (2001) submission to the Commonwealth fuel tax inquiry. It is broadly consistent with the UK evidence reported in Sansom et al (2002).

TABLE 1 Environmental Externality Costs per VKM

Peak Period	***Inner***	***Outer***
Road damage	0.2	0.2
Congestion	90	60
Air pollution	1	0.5
Climate change	1.3	0.9
Noise	0.4	0.3
Accidents	0.8	0.8
Total	*93.7*	*62.7*
Off-Peak Period	***Inner***	***Outer***
Road damage	0.2	0.2
Congestion	16	16
Air pollution	0.5	0.2
Climate change	0.9	0.6
Noise	0.3	0.1
Accidents	0.8	0.8
Total	*18.7*	*17.7*

The patronage incentive is the sum of CS and EB (in dollars)[22]. Importantly, although school children travel for free in most jurisdictions and the operators are compensated through CSO payments, additional trips by children will attract an incentive payment through increased consumer surplus, and for car switchers, through increased externality benefit. On the latter calculation we may have to impose an additional assumption as to whether the school child's bus use results in a reduction in car VKM or not, since some trips may continue.

[21] This assumption can be refined by an assessment of source of switchers in the first monitoring period of if other evidence is available.
[22] EB may be negative if passenger trips fall and they switch to car, although we are not proposing to tax the operator.

4. A Case Study for the Outer Metropolitan Area of Sydney

The formal economic optimisation framework presented in section 3 has been tested on operators in the outer areas of the Sydney metropolitan area. Drawing on data collected in 2002 by the Institute of Transport Studies (ITS), in cooperation with 12 private bus operators[23], we have extracted the relevant data for the model system. Importantly, the amount of data required from operators is relatively small and manageable for the regulatory task. Benchmark costs are those of the most cost efficient operator in the set (who is also the best operator on cost efficiency in the ongoing benchmarking program of ITS).

Exogenous indicators such as elasticities, unit externality cost rates, willingness to pay parameters, minimum service level VKM etc are provided from non-operator sources and can be modified as new information becomes available. We have selected what are regarded as best-knowledge estimates in this case study to illustrate the feasibility and appeal of the analytical relationships used to establish appropriate incentive payments for performance-based contracts under a social surplus maximisation (or value for money) subsidy scheme. In the current paper we focus on the transition-phase of introducing PBCs and set the 'optimal' subsidy budget to the existing operator-specific level. In a follow-up paper, Hensher and Houghton (in progress) generalise the approach to optimise the total subsidy budget under a 'growth after transition' schema.

The X^{MSL} level is determined exogenously to accommodate the demographics of the region and availability of other modes. For this case study, X^{MSL} is set for illustrative purposes to $X^{MSL} = 0.67$ of VKM . The value of the pure MSL subsidy, \$CSO, is based on \$2.60/VKM (peak) and \$2.30 (off-peak), which gives \$CSO= \$9,884,429. The subsidy budget of the illustrative cost-efficient operator is set to \$CSO for the pure-MSL strategy. The approach permits the entire range of contracts, from a pure-MSL to a pure-PBC and all mixes between. If the MSL component of the regulator's subsidy scheme is reduced by R% of \$CSO, then X^{MSL} is reduced by R% of 0.67VKM and the subsidy budget allocated to PBC is the difference between TB and R% of \$CSO. A subsidy scheme incorporating a mix of MSL and performance-based contracts, with a relatively large MSL component and a relatively small PB component, is likely to be a politically acceptable first step into a PB contract regime, and is a specific interest of this paper. In particular we consider optimizing the structure of the scheme (starting with the existing 0.67VKM base and R=0) to establish what mix of MSL and above-MSL (ie performance based) service levels deliver a better value for money outcome than the baseline (ie current) MSL situation. An initial parity is established between alternative scheme mixes by holding RVKM, average fare, number of buses, patronage and costs fixed at the case B levels under what we refer to as the 'calibration for parity' (Section 4.1). We then allow RVKM, fares, fleet size, patronage and costs to change in the search for an improved solution (Section 4.2).

[23] We used the data from 12 operators to confirm benchmark best cost practice and then used other data from this operator as if they were the system-wide provider. This paper does not assume anything about the optimum number of contract areas or operators. This issue is detailed in Hensher (2002b).

The seven model parameters are shown in **Table 2**. Four parameters are available to the regulator to define the subsidy scheme; and the operators as a group have four parameters to establish operator strategy within the environment of the defined scheme.

Table 2: Model parameters

Parameter type	**Parameter**
Regulator parameters	P, R, $RVKM$(MSL), fare cap
Operator parameters	q, $RVKM$, κ, $\#bus$

4.1. Calibration for Parity

Under a mixed scheme, the difference between TB and R% of $CSO is available to distribute a return to the operators for the consumer benefits generated by $Y>Y^{MSL}$. For a given total subsidy budget the pure-PBC scheme may be calibrated to achieve parity with the pure-MSL scheme, in the sense that a payout rate on (CS+EB) exhausts the subsidy and the optimum "standard" operator strategy is the base case B, where standard strategies preclude changes to #bus, service quality and fares. The pure-MSL outcome is given in **Table 3**. No calibration is required for the pure-MSL scheme which is defined by current regulator rates.

Table 3: Model outcome for the pure-MSL scheme

Model soln	X	q	#bus used	C	Y (ACC+S)	CS (ACC+S)	EB (ACC+S)	Y(MSL) (ACC+S)	X(MSL)		Funding		Retn on cost
P-O	1,986,429	1.44	70	2,916,035	4,083,932	4,289,576	532,368	3,781,614	1,523,475		TB	**9,884,429**	
change	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**2.10%**	**0.00%**	**0.00%**	**0.00%**		CS+EB PAY	0	
OP-O	3,358,000	1.52	36	13,048,221	2,794,325	2,253,562	259,467	2,412,741	2,575,389		FARES	6,291,216	
change	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**13.44%**	**0.00%**	**0.00%**	**0.00%**		CSO	9,884,429	
TOTAL	5,344,429	1.51	70	15,964,256	6,878,257	6,543,138	791,835	6,194,356	4,098,864		*less op COST*	15,964,256	
change	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**5.74%**	**0.00%**	**0.00%**	**0.00%**		prod surp	211,389	1.32%
TB	9,884,429										CS+EB	7,334,972	
					Y (S)	CS (S)	EB (S)	Y(MSL) (S)			SS	7,546,361	
		P			2,432,928	1,819,764	225,846	2,252,828			*less SS Cost*	9,884,429	
		0.000000%			**0.00%**	**0.00%**	**0.00%**	**0.00%**			net SS	-2,338,067	-23.65%
					221,220	92,881	10,694	191,011			TB undist	0	
		0.000000%			**0.00%**	**0.00%**	**0.00%**	**0.00%**	CB	PS	%PS	SS	%SS
					2,654,148	1,912,645	236,540	2,443,839	7,334,972	211,389	1.32%	7,546,361	-23.65%
					0.00%	**0.00%**	**0.00%**	**0.00%**	**5.09%**	**0.00%**	**0.00%**	**4.94%**	**-13.18%**
					Y (ACC)	CS (ACC)	EB (ACC)	Y(MSL) (ACC)					
					1,651,004	2,469,812	306,522	1,528,786					
					0.00%	**3.70%**	**0.00%**	**0.00%**					
					2,573,105	2,160,680	248,773	2,221,731					
					0.00%	**14.09%**	**0.00%**	**0.00%**					
					4,224,109	4,630,493	555,295	3,750,517					
					0.00%	**8.31%**	**0.00%**	**0.00%**					

For a patronage level corresponding to the optimum standard RVKM under the pure-PBC scheme, **Table 4 shows that** ($CS+EB$) exceeds the total budget by a substantial financial sum and cannot be paid in total to the operator. However, we can apply a non-negative payout rate, $P<1$, to ($CS+EB$) to distribute the reduced sum to the operator and ensure there is no subsidy blowout. P will vary with the proportionate PBC component (R) in the scheme. A payout rate of P=9.334436% gives the case B outcome for the pure PBC scheme, as shown in Table 4.

But there are many mixed regulator strategies between Pure-MSL and pure-PBC. The 5%-PBC regulator strategy includes a payout rate of P=5.086524%, and the model outcome is shown in **Table 5**. **Tables 4** and **5** show that all aspects of peak and off peak operator strategies are unchanged for the optimum outcomes under the pure-and-mixed PBC regulator strategy. It is clear that a mixed PBC scheme can always be found that provides an environment within which current best practice will lead to operator outcomes equivalent to the pure-MSL scheme, as summarised in **Table 6,** which shows the totals/averages of the optimum standard strategy. The case B operational strategies (X, q) and associated outcomes (Y, C) are optimum for the case B fleet size (#bus) and service quality level, fare increases below 5%, and the specified (R, P) values.

Table 4: Model outcome for the pure-PBC scheme

Model soln	X	q	#bus used	C	Y (ACC+S)	CS (ACC+S)	EB (ACC+S)	Y(MSL) (ACC+S)	X(MSL)
P-O	1,986,429	1.44	70	2,916,035	4,083,932	69,885,636	2,021,391	2,936,036	0
change	0.00%	0.00%	0.00%	0.00%	0.00%	1563.38%	279.70%	-22.36%	-100.00%
OP-O	3,358,000	1.52	36	13,048,221	2,794,325	33,096,947	888,108	1,488,235	0
change	0.00%	0.00%	0.00%	0.00%	0.00%	1565.98%	242.28%	-38.32%	-100.00%
TOTAL	5,344,429	1.51	70	15,964,256	6,878,257	102,982,583	2,909,499	4,424,270	0
change	0.00%	0.00%	0.00%	0.00%	0.00%	1564.22%	267.44%	-28.58%	-100.00%
TB	9,884,429								

Funding		Retn on cost
TB	9,884,429	
CS+EB PAY	9,884,429	
FARES	6,291,216	
CSO	0	
less op COST	15,964,256	
prod surp	211,389	1.32%
CS+EB	105,892,082	
SS	106,103,472	
less SS Cost	9,884,429	
net SS	96,219,043	973.44%
TB undist	0	

P	Y (S)	CS (S)	EB (S)	Y(MSL) (S)	CB	PS	%PS	SS	%SS
	2,432,928	29,647,536	857,533	1,749,090					
9.334436%	0.00%	1529.20%	279.70%	-22.36%					
	221,220	1,364,099	36,604	117,820					
9.334436%	0.00%	1368.65%	242.28%	-38.32%					
	2,654,148	31,011,635	894,137	1,866,910	105,892,082	211,389	1.32%	106,103,472	973.44%
	0.00%	1521.40%	278.01%	-23.61%	1417.10%	0.00%	0.00%	1375.45%	-3672.73%

Y (ACC)	CS (ACC)	EB (ACC)	Y(MSL) (ACC)
1,651,004	40,238,100	1,163,858	1,186,946
0.00%	1589.50%	279.70%	-22.36%
2,573,105	31,732,848	851,505	1,370,415
0.00%	1575.65%	242.28%	-38.32%
4,224,109	71,970,948	2,015,362	2,557,361
0.00%	1583.37%	262.94%	-31.81%

Table 5: Model outcome for the 5%-PBC scheme

Model soln	X	q	#bus used	C	Y (ACC+S)	CS (ACC+S)	EB (ACC+S)	Y(MSL) (ACC+S)	X(MSL)
P-O	1,986,429	1.44	70	2,916,035	4,083,932	5,781,122	616,106	3,734,061	1,447,301
change	0.00%	0.00%	0.00%	0.00%	0.00%	37.60%	15.73%	-1.26%	-5.00%
OP-O	3,358,000	1.52	36	13,048,221	2,794,325	3,020,438	298,627	2,355,151	2,446,620
change	0.00%	0.00%	0.00%	0.00%	0.00%	52.04%	15.09%	-2.39%	-5.00%
TOTAL	5,344,429	1.51	70	15,964,256	6,878,257	8,801,560	914,733	6,089,212	3,893,921
change	0.00%	0.00%	0.00%	0.00%	0.00%	42.23%	15.52%	-1.70%	-5.00%
TB	9,884,429								

Funding		Retn on cost
TB	9,884,429	
CS+EB PAY	494,222	
FARES	6,291,216	
CSO	9,390,207	
less op COST	15,964,256	
prod surp	211,389	1.32%
CS+EB	9,716,293	
SS	9,927,682	
less SS Cost	9,884,429	
net SS	43,253	0.44%
TB undist	0	

P	Y (S)	CS (S)	EB (S)	Y(MSL) (S)	CB	PS	%PS	SS	%SS
	2,432,928	2,452,522	261,370	2,224,499					
5.086524%	0.00%	34.77%	15.73%	-1.26%					
	221,220	124,488	12,308	186,452					
5.086524%	0.00%	34.03%	15.09%	-2.39%					
	2,654,148	2,577,010	273,678	2,410,950	9,716,293	211,389	1.32%	9,927,682	0.44%
	0.00%	34.74%	15.70%	-1.35%	39.20%	0.00%	0.00%	38.05%	-101.61%

Y (ACC)	CS (ACC)	EB (ACC)	Y(MSL) (ACC)
1,651,004	3,328,601	354,736	1,509,562
0.00%	39.76%	15.73%	-1.26%
2,573,105	2,895,950	286,319	2,168,700
0.00%	52.92%	15.09%	-2.39%
4,224,109	6,224,550	641,055	3,678,262
0.00%	45.59%	15.44%	-1.93%

Table 6: Optimum "standard" operator strategy for mixed PBC schemes

X	q	#bus	C	Y (ACC+S)
5,344,429	1.51	70	15,964,256	6,878,257

The summary scheme results for the pure schemes and mixed schemes up to 30%-PBC are shown in **Table 7**, where outcomes are totalled/averaged across periods. Outcomes for each regulator strategy specified by (R, P) pairs are shown in each row of the table, where the R value is clear from the first column and the P value is shown in the second column. The declining Y^{MSL} values from which consumer surplus and external benefits are computed for the specified schemes, are shown in column 4. Consumer surplus and external benefits, both of which generate operator income under PBC schemes, are shown in columns 5 and 6 as a proportion of patronage above Y^{MSL}. As such, they show the unit incentive payment per passenger trip (above MSL patronage) from consumer surplus and external benefits respectively. These payments increase as the PBC component of the scheme increases, reflecting the decreasing value of Y^{MSL} (note that the EB unit rate is averaged across all patronage above MSL even though it is applicable only to car switchers). The producer surplus (PS) rate is equal to the case B rate of return (1.32%), referred to as the normal rate of return, and CB shows the total consumer benefit. Column 6 shows the SS level improving with CB, but these are not comparable across schemes due to varying Y^{MSL}. (This will be addressed later)

Table 7: Scheme results for mixed PBC schemes

Scheme	X(MSL)	P	PS	CB	SS	%PS	%SS	CS*P /(Y-YMSL) (ACC+S)	EB*P /(Y-YMSL) (ACC+S)	Y(MSL) (ACC+S)
Pure MSL	4,098,864	0.000000%	211,389	7,334,972	7,546,362	1.32%	-23.65%	0.00	0.00	6,194,356
1%-PBC	4,057,875	1.269504%	211,389	7,786,067	7,997,457	1.32%	-19.09%	0.13	0.01	6,173,167
5%-PBC	3,893,921	5.086524%	211,389	9,716,293	9,927,682	1.32%	0.44%	0.57	0.06	6,089,212
10%-PBC	3,688,977	7.966483%	211,389	12,407,521	12,618,911	1.32%	27.66%	1.02	0.09	5,986,042
20%-PBC	3,279,091	10.577781%	211,389	18,689,043	18,900,432	1.32%	91.21%	1.69	0.12	5,785,458
30%-PBC	2,869,205	11.352685%	211,389	26,120,066	26,331,456	1.32%	166.39%	2.17	0.13	5,592,292
Pure PBC	0	9.334436%	211,389	105,892,082	106,103,472	1.32%	973.44%	3.92	0.11	4,424,270

Through optimising SS, the model provides an environment, as specified by the regulator parameters, consistent with the resulting maximum returns for both the operators and the regulator. **Table 7** has shown that, changing the proportion (R) of PBC in the subsidy scheme will always allow current best operator practice, with a given fleet size and service quality, to lead to operator outcomes equivalent to the pure-MSL scheme, as given by the case B outcome. In this paper, service quality is controlled through constraint (10), which requires extra buses if the service level measured by RVKM is to be increased. In the next section, fleet size is added to the standard operator strategy parameters to assess the potential for market growth.

4.2. Operator strategy

To maintain community service obligations while pursuing the case B outcomes, the operator strategies (X,q) used above restricted fare changes to ≤5%, and precluded optimisation over fleet size and service quality (κ). In the above environment, reductions to *RVKM* are restricted by the MSL, and the maximum fare increase, and increases are restricted by the fleet size and minimum service quality levels. In this section, the service quality level is maintained and *#bus* is added to the operator strategy parameters to allow market expansion. In this way we establish the gains for a benchmark operator by increasing the service level. The impact of unrestricted fare increases is also analysed. These operator strategies are analysed in the context of varying regulator parameter settings.

4.2.1. Operator strategy: fleet size

To assess the effectiveness of PBC schemes in providing an environment within which patronage may be commercially expanded, the operator strategy parameter *dbus*, which gives the increase in fleetsize, is applied to both peak and off-peak bus deployment. For each scheme ranging from 0%- to 100%-PBC we start from the calibrated scheme, with *dbus*=0, and establish the sensitivity of outcomes to increasing *dbus*.

The optimum *standard* outcome for the 5%-PBC scheme is shown in **Table 5**. Under 5%-PBC the return to the operator (PS) varies with increasing fleet size reaching a maximum of 6.7% when 3 buses are added to the fleet. This approximates the maximum return under all other PBC-schemes.

A feature of the operator strategies for the 5%-PBC scheme is that increasing RVKM is associated with decreasing total patronage. This is explained by contrasting operator strategies between the peak and off-peak periods outcome, which is apparent from **Table 8**. *In the peak period*, the service level increases with increasing *dbus* up to *dbus*=3 and is stable thereafter. Fares increase by 5% when *dbus*=1 and are stable thereafter, Costs increase steadily over the range of increasing fleet size[24]. *In the off-peak period*, the service level, patronage and costs decrease with increasing dbus up to *dbus=3* and these are stable thereafter. Fares increase to the maximum when dbus=2 and are stable at that level thereafter. The result of the different strategies for peak and off-peak periods is that as the fleet size increases over the range of 0≤*dbus*≤3, total RVKM, and patronage decrease and are stable thereafter; costs decrease over the same range and increase slowly thereafter. The reason for the diversity of strategies is that the limited TB is more profitably secured from the peak market until *dbus*=3, after which the peak and off-peak markets are both stable.

Table 8: Peak and off-peak operator strategies: R=5%

dbus	X(P)	X(OP)	X(TOT)	q(P)	q(OP)	q(TOT)	C(P)	C(OP)	C(TOT)	Y(P)	Y(OP)	Y(TOT)	%PS	%SS
0	1,986,429	3,358,000	5,344,429	1.44	1.52	1.51	2,916,035	13,048,221	15,964,256	4,083,932	2,794,325	6,878,257	1.32%	0.44%
1	2,014,806	3,274,865	5,289,671	1.51	1.55	1.55	2,959,395	12,681,966	15,641,361	4,086,454	2,725,145	6,811,599	3.99%	4.61%
2	2,043,184	3,174,066	5,217,250	1.51	1.60	1.58	2,999,640	12,253,681	15,253,321	4,104,961	2,638,954	6,743,915	6.55%	8.41%
3	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,010,246	12,216,677	15,226,923	4,106,293	2,634,320	6,740,613	6.70%	8.62%
4	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,018,515	12,216,677	15,235,193	4,106,293	2,634,320	6,740,613	6.64%	8.53%
5	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,026,808	12,216,677	15,243,485	4,106,293	2,634,320	6,740,613	6.58%	8.45%
6	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,035,123	12,216,677	15,251,800	4,106,293	2,634,320	6,740,613	6.52%	8.37%
7	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,043,461	12,216,677	15,260,139	4,106,293	2,634,320	6,740,613	6.47%	8.28%
8	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,051,822	12,216,677	15,268,500	4,106,293	2,634,320	6,740,613	6.41%	8.20%
9	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,060,206	12,216,677	15,276,884	4,106,293	2,634,320	6,740,613	6.35%	8.11%
10	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,068,613	12,216,677	15,285,291	4,106,293	2,634,320	6,740,613	6.29%	8.03%
11	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,077,044	12,216,677	15,293,721	4,106,293	2,634,320	6,740,613	6.23%	7.94%
12	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,085,497	12,216,677	15,302,174	4,106,293	2,634,320	6,740,613	6.17%	7.86%

[24] Total cost in Table 8 is initially greater at dbus=0 then decreases before increasing beyond 3 buses. The reason for the initial decrease in C(TOT) as dbus increases is that X(OP) is decreasing fairly rapidly at that time and the cost function has (XA-XB) in the exponent. This is required to implement the trade-off of Y(OP) for Y(P) through a trade-off of the corresponding X's. Also, the X(OP)/X(P) rate of exchange is very high due to the relatively low kappa (OP) compared to kappa (P), where kappa measures average bus loading rates.

Funds available for the PBC component of the 5%-PBC scheme are $494,222, and this is realised by bus operators as *P*(CS+EB) where P* is around 5.1%. Based on the optimisations, the PBC payments are shown in **Table 9** to reach a maximum, on average, of 68 cents per passenger trip.

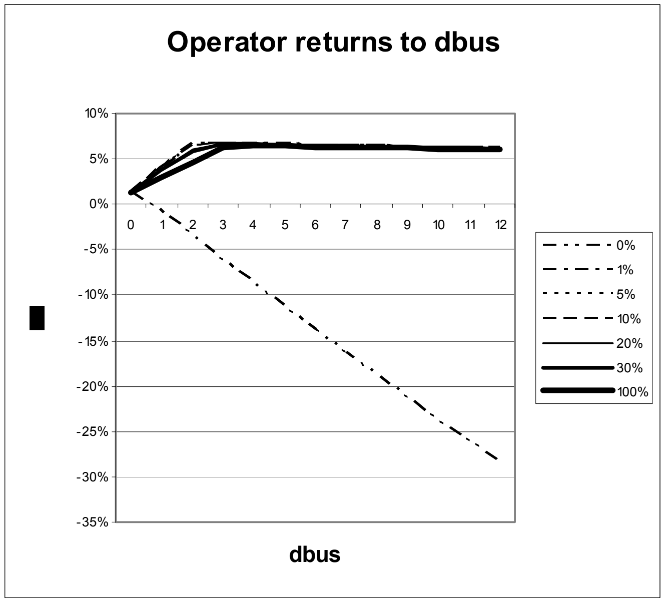
Table 9: Incentive payments
per trip: R=5%.

dbus	CS*P /(Y-YMSL) (ACC+S)	EB*P /(Y-YMSL) (ACC+S)
0	0.57	0.06
1	0.59	0.06
2	0.61	0.06
3	0.62	0.06
4	0.62	0.06
5	0.62	0.06
6	0.62	0.06
7	0.62	0.06
8	0.62	0.06
9	0.62	0.06
10	0.62	0.06
11	0.62	0.06
12	0.62	0.06

Similar analyses apply to operator strategies for other regulator schemes. In all cases the maximum achievable return to operators is around 6.7%.

Figure C shows that under 0%-PBC, SS is optimised by the operator maximising patronage in both peak and off-peak markets, by maximising RVKM and lowering fares to fill the buses available. This socially optimum strategy, with growing negative operator returns associated with increasing social surplus, is not practicable – the optimum social surplus will never be achieved. The dominant feature of **Figure C** is that the producer surplus rate functions for the various mixed-PBC schemes are similar, showing very little sensitivity to scheme parameters. The PS functions differ primarily for *dbus* up to 3, where they are in reverse order of R, indicating an operator preference for 1%-PBC.

Figure C: Operator Returns to Dbus for varying R (%PBC)



The contrasting behaviour between the pure-MSL and mixed-PBC schemes is the more interesting when related to the regulator surplus rate, as in **Figures D-F**. The model objective is to maximise the social surplus resulting from the regulator's scheme and the social surplus moves monotonously with the regulators surplus rate. **Figure D** shows that the interests of the operator are not consistent with those of the regulator for the pure-MSL scheme, but in Figures **E and F** these interests are seen to be aligned under PBC schemes. The important conclusion is that if the operator were to optimise performance under a given PBC scheme, the outcome will approximate that of the model. Indeed, the optimum operator strategy under all PBC schemes is *dbus*=3 and the other strategy components *X*, and *q* are as in the optimum social surplus outcome for the dbus=3 case. The significant conclusion, therefore, is that a mixed PBC scheme brings together the operator and regulator objectives, to provide approximately optimum social surplus outcomes.

Figure D: Operator and Societal Returns to Dbus for 0%PBC

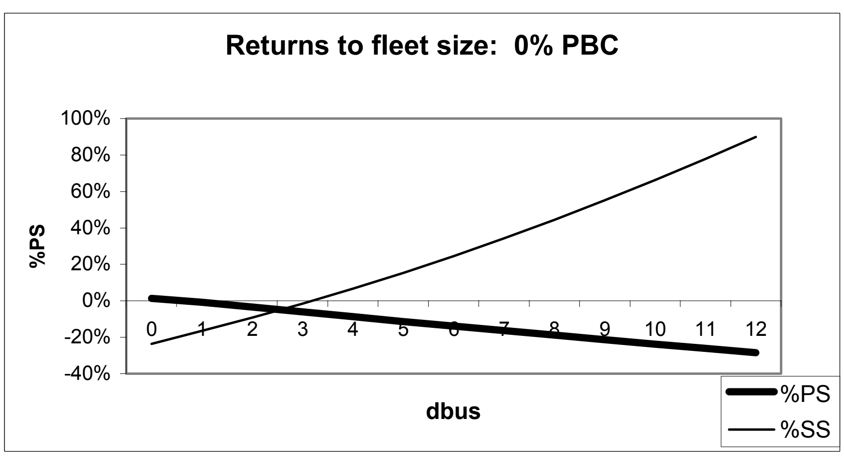


Figure E: Operator and Societal Returns to Dbus for 1%PBC

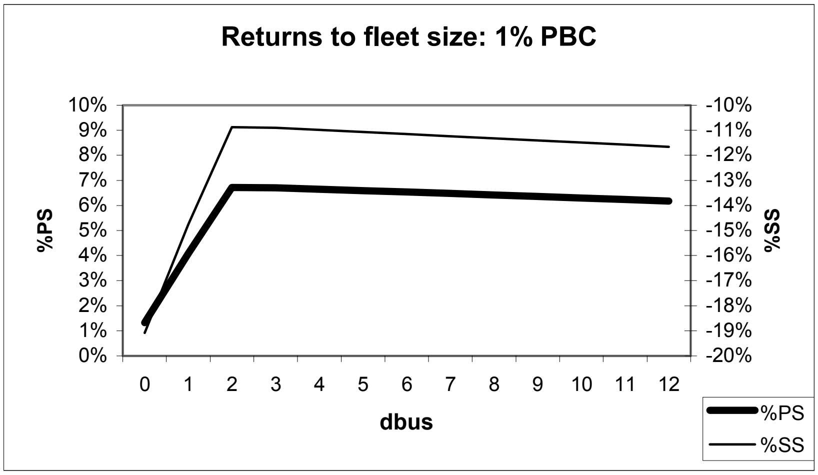
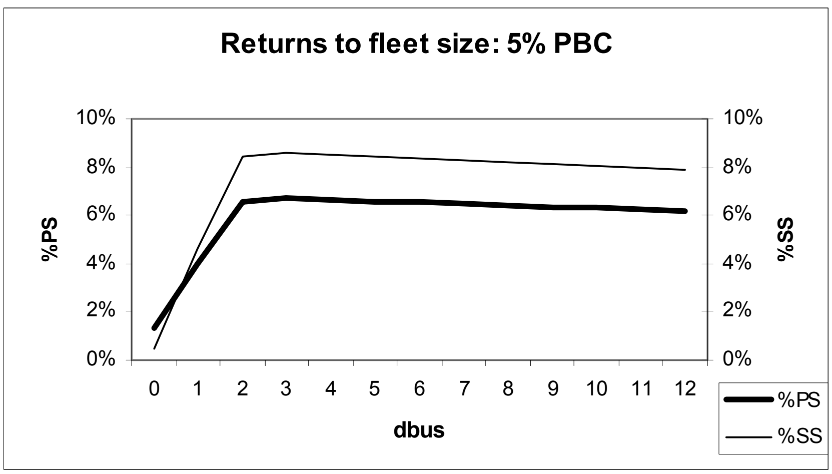


Figure : Operator and Societal Returns to Dbus for 5%PBC



Outcomes for social surplus are greatly influenced by the different Y^{MSL} points[25] for the alternative schemes and hence SS is not comparable across schemes. The schemes may be brought to comparability by adding to SS for each scheme, a single valued estimate of the consumer surplus *below* Y^{MSL}. These CS estimates are shown in **Table 10**. The result is to order the schemes' SS performance in reverse order of R. Given that R=0% has no practical value, best outcomes are indicated by 1%-PBC. Given the PS function as shown in **Figure E**, the optimum operator strategy is to increase the fleet size by two and implement the corresponding strategy as shown in **Table 11**. Incentive payments for 1%-PBC are shown in **Table 12**.

[25] As we change the value of R (or 1-R), the baseline patronage changes and makes all patronage above it eligible for an incentive payment (through the determination of CS + EB).

Table 10: CS below Y^{MSL} Estimates

R	0%	1%	5%	10%	20%	30%	100%
CS Below Y(MSL)	213,311,719	210,286,631	198,400,981	184,016,746	156,761,490	131,418,594	1,580,438

Table 11: Peak and off-peak operator strategies: R=1%

dbus	X(P)	X(OP)	X(TOT)	q(P)	q(OP)	q(TOT)	C(P)	C(OP)	C(TOT)	Y(P)	Y(OP)	Y(TOT)	%PS	%SS
0	1,986,429	3,358,000	5,344,429	1.44	1.52	1.51	2,916,035	13,048,221	15,964,256	4,083,932	2,794,325	6,878,257	1.32%	-19.09%
1	2,014,806	3,277,713	5,292,519	1.51	1.60	1.58	2,959,395	12,723,770	15,683,165	4,086,454	2,695,163	6,781,617	4.09%	-14.74%
2	2,043,184	3,167,667	5,210,851	1.51	1.60	1.58	2,999,640	12,225,303	15,224,943	4,104,961	2,635,403	6,740,364	6.72%	-10.88%
3	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,008,409	12,216,677	15,225,087	4,105,259	2,634,320	6,739,579	6.71%	-10.90%
4	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,016,674	12,216,677	15,233,351	4,105,259	2,634,320	6,739,579	6.65%	-10.98%
5	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,024,962	12,216,677	15,241,639	4,105,259	2,634,320	6,739,579	6.59%	-11.06%
6	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,033,272	12,216,677	15,249,949	4,105,259	2,634,320	6,739,579	6.53%	-11.15%
7	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,041,605	12,216,677	15,258,282	4,105,259	2,634,320	6,739,579	6.48%	-11.23%
8	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,049,961	12,216,677	15,266,638	4,105,259	2,634,320	6,739,579	6.42%	-11.32%
9	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,058,340	12,216,677	15,275,017	4,105,259	2,634,320	6,739,579	6.36%	-11.40%
10	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,066,742	12,216,677	15,283,419	4,105,259	2,634,320	6,739,579	6.30%	-11.49%
11	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,075,167	12,216,677	15,291,844	4,105,259	2,634,320	6,739,579	6.24%	-11.57%
12	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,083,615	12,216,677	15,300,292	4,105,259	2,634,320	6,739,579	6.18%	-11.66%

Table 12: Incentive payments per trip: R=1%

dbus	CS*P /(Y-YMSL) (ACC+S)	EB*P /(Y-YMSL) (ACC+S)
0	0.13	0.01
1	0.13	0.02
2	0.14	0.02
3	0.14	0.02
4	0.14	0.02
5	0.14	0.02
6	0.14	0.02
7	0.14	0.02
8	0.14	0.02
9	0.14	0.02
10	0.14	0.02
11	0.14	0.02
12	0.14	0.02

4.3. Operator strategy: fare bounds

In the above analysis, fares have been free of a lower bound, but an upper bound of 5% increase has been in place as described in the introduction to Section 2. An upper fare bound to 10% with schemes calibrated as in the 5% example gives very similar results, but the returns to operators are higher. Again, the operator return functions are similar across schemes and the preferred scheme is 1%-PBC. The operator strategies and incentive payments for 1%-PBC are shown in **Table 13** and **Table 14** respectively. The returns to fleet size, shown in **Figure G**, indicate a fleet size increase of 4, and the associated optimum strategy is shown in the corresponding row of **Table 13**.

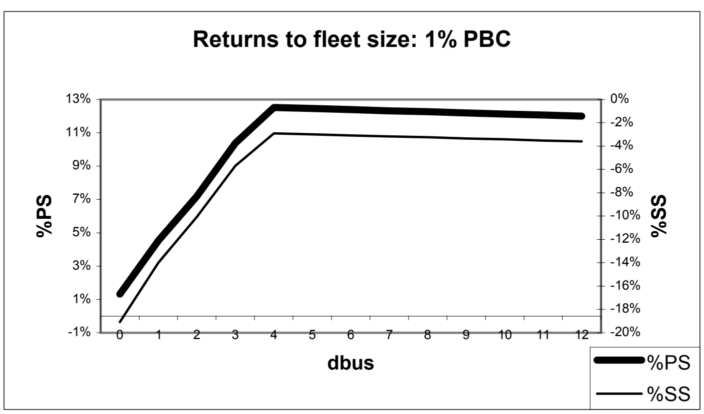
Table 13: Peak and off-peak operator strategies: R=1%, q(UB)=10%

dbus	X(P)	X(OP)	X(TOT)	q(P)	q(OP)	q(TOT)	C(P)	C(OP)	C(TOT)	Y(P)	Y(OP)	Y(TOT)	%PS	%SS
0	1,986,429	3,358,000	5,344,429	1.44	1.52	1.51	2,916,035	13,048,221	15,964,256	4,083,932	2,794,325	6,878,257	1.32%	-19.09%
1	2,014,806	3,292,858	5,307,664	1.59	1.67	1.66	2,963,186	12,844,858	15,808,044	4,070,113	2,647,894	6,718,007	4.53%	-13.98%
2	2,043,184	3,182,920	5,226,104	1.59	1.67	1.66	3,003,501	12,340,729	15,344,230	4,088,547	2,589,783	6,678,330	7.19%	-10.07%
3	2,071,562	3,051,104	5,122,665	1.59	1.67	1.66	3,044,465	11,765,347	14,809,812	4,106,556	2,516,475	6,623,031	10.37%	-5.68%
4	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,071,521	11,389,015	14,460,536	4,116,526	2,463,860	6,580,385	12.53%	-2.90%
5	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,079,959	11,389,015	14,468,974	4,116,526	2,463,860	6,580,385	12.46%	-2.99%
6	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,088,420	11,389,015	14,477,435	4,116,526	2,463,860	6,580,385	12.40%	-3.07%
7	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,096,905	11,389,015	14,485,920	4,116,526	2,463,860	6,580,385	12.33%	-3.16%
8	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,105,413	11,389,015	14,494,428	4,116,526	2,463,860	6,580,385	12.26%	-3.25%
9	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,113,944	11,389,015	14,502,959	4,116,526	2,463,860	6,580,385	12.20%	-3.33%
10	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,122,499	11,389,015	14,511,514	4,116,526	2,463,860	6,580,385	12.13%	-3.42%
11	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,131,077	11,389,015	14,520,092	4,116,526	2,463,860	6,580,385	12.07%	-3.51%
12	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,139,679	11,389,015	14,528,694	4,116,526	2,463,860	6,580,385	12.00%	-3.59%

Table 14: Incentive payments per trip: R=1%, q(UB)=10%

dbus	CS*P /(Y-YMSL) (ACC+S)	EB*P /(Y-YMSL) (ACC+S)
0	0.13	0.01
1	0.13	0.02
2	0.14	0.02
3	0.15	0.02
4	0.16	0.02
5	0.16	0.02
6	0.16	0.02
7	0.16	0.02
8	0.16	0.02
9	0.16	0.02
10	0.16	0.02
11	0.16	0.02
12	0.16	0.02

Figure G: Returns to fleet size and social surplus: R=1%, q(UB)=10%



The approach taken in this paper has been to define a set of regulator schemes (R, P) where P calibrates the "standard" operator strategy under R, and to allow operators to optimise their strategy within that scheme. The advantage of the proposed approach is that it aligns the interests of operator and regulator for all non-standard strategies, so that the operator left to optimise corporate performance will be working in the social interest. It is possible to calibrate other strategies, but this alignment-of-interests property is then lost.

4.4 The Preferred Transition Position for Reform in the Outer Metropolitan Area of Sydney

The previous sections present a large number of potential 'solutions'. Although we have discussed the range of outcomes based on specific assumptions such as the mix of MSL and PBC components and resulting user and environmental externality benefits together with the rates of return to the operator and the subsidy allocation, it is appropriate to conclude with what might appear to be a good starting set of condition for the introduction of performance-based contracts. A practitioner's guide to the recommended transition strategy is summarised in point form in Appendix A.

Assuming that the regulator will require an MSL component to the delivery of services, we recommend that the CSO payment for MSL delivery should be based on $2.60 in the peak and $2.30 in the off-peak per vehicle kilometre. The establishment of the incentive payment rates is determined externally for the environmental benefits (respectively for outer urban operators of $0.627/car vkm for peak travel and $0.177/car vkm for off-peak travel). The rate for user benefit (ie consumer surplus) per bus passenger trip is determined by the optimisation procedure, conditional on the proportion of the CSO to be implemented (1-R) and the incentive *payout rate* to the operators (P). Given a subsidy scheme defined as 1%-PBC with a payout rate of P=1.269504% and a total subsidy budget of TB=$9,884,429, if fares are bounded above by a 5% increase, the benchmark operator may be expected to increase fleet size by two buses for a return on operator investment (PS) of 6.7%, and the average user benefit per passenger incentive payment may be expected to be $0.14. This is additional to an average fare of $1.51 (peak) and $1.60 (off-peak). If fares are bounded above by a 10% increase, the benchmark operator may be expected to increase the fleet size by 4 for a return on operator investment (PS) of 12.53%, and the average user benefit per passenger incentive payment may be expected to be $0.18. This is additional to an average fare of $1.59 (peak) and $1.67 (off-peak). The unit rate of incentive payment has been derived by averaging across all passenger trips above MSL even though the EB unit rate only applies to converted car VKM. The adoption of an average incentive payment per passenger trip above Y^{MSL} makes for a very simple administrative formula.

5. Conclusions

Performance-based contracts (PBCs) have emerged as a practical contracting regime with many virtues. Under a transparent partnership between the regulator and the service provider, a PBC offers a most effective way of delivering transport services, ensuring over time that the allocation of subsidy is determined optimally *from a system-wide perspective*, not on an individual contract by individual contract basis (as would be required under other contracting regimes)[26]. In achieving system-wide optimisation, all

[26] There is growing concern in England that concessionary fare subsidies are not matched by appropriate 'deliverable and measurable outputs' (DLTR 2002). The Director-General of the Greater Manchester Passenger Transport Executive stated in a submission to the House of Commons Transport Select Committee's inquiry on the bus industry that "We would like to reach a point where all the money paid to the bus industry is linked in some way to outputs'. The most interesting feature of the reform proposal is, over a 3-5 year period, to transfer some or all of the concessionary fares budget into a central pot. Operators would then be asked to come forward with proposals for delivering a network of commercial and supported services determined by the central authority and 10 metropolitan governments. This has been described as 'voluntary quality contracts' that push at the limits of quality partnerships but which is

parties should share the risks and rewards that quality partnerships can deliver (in contrast competitive tendering[27] suggests a principal-agent relationship which is not as partnership compatible).

The proposed system of subsidy which makes profit maximisation on the part of operators and social surplus maximisation coincide appears to offer a very attractive contract regime. Nash and Jansson (2002) in reviewing alternative reform schemes introduced over the last 15 years, conclude that "the regulatory phase could be better managed this time round, with an emphasis on 'light touch' regulation, perhaps combined with the appropriate use of subsidies per passenger kilometre and infrastructure charges to incentivise the franchisee to provide the socially optimum fares/service combination'. This is the intent of PBCs both in transition and post-transition.

The method developed and implemented in this paper is sufficiently flexible to be applicable under a large number of regulatory and operating regimes. For example, it is feasible to consider alternative fare increase caps, different aggregate subsidy budget levels (be they increments of decrements on existing levels), variations in minimum-service levels and incentive payment rates for environmental benefits, and acceptable commercial returns. The ability to recognise the full extent of consumer (ie user) surplus benefits to society and to determine the amount that might reasonable be paid to operators to ensure that the returns are incentive-compatible, without delivering unacceptable high rates of return on investment from the provision of public funds, is a very appealing feature of the approach.

Looking ahead, it is important to keep in mind that the model developed herein is a model for the benchmark (in terms of cost efficiency) operator who begins from an optimum position. The model performance reflects this. Hence it is an appealing transition model. With the existing #bus the case B solution is optimum; and, as the fleet is expanded, improved "non-standard" strategies are found. These are, however, trade-off positions, typically involving an expansion in the peak period and a cut back in the off-peak period. The trade-off is required by the total subsidy budget and is consistent with PBC funding being essential for a benchmark operator's expansion.

The approach of optimising within a given R, and calibrating to the "standard" strategy is fundamental to the specific PBC implementation strategy. First, SS comparisons across R are not made within the model (nor should they be); and second, calibrating to other strategies departs from the assumption of a benchmark operator, and also provides

necessary to improve the increasingly poor quality of service levels of bus provision (which has evolved out of economic deregulation and competitive tendering of non-commercial services).

[27] Although competitive tendering of PBC's is possible it must be based on a selection system that involves quality criteria rather than the conventional tendering processes (is the 'lowest price wins'). Telemark County in southern Norway has recently adopted this model, although it is too early to see how it compares with PBC's per se. The ability to optimise system-wide social surplus still remains a challenge however. In a recent review of competitive tendering in Adelaide and Perth, Bray (2002) in commenting on Hensher and Stanley (2002) statement 'performance based contracts should deliver better long-term value for money to governments and consumers than the competitive tendering (CT) of bus contracts' concludes that 'they may well be correct'. He then asks a question: "If the CT process was run again in Perth and Adelaide would any further meaningful savings be achieved particularly when considering the enormous cost of the tendering process for regulators and operators?".

schemes with competing operator-regulator interests. An unrestricted optimisation across R, P, X, q, and dbus will give the nonsense outcome: R=100%, P is calibrated to 100% and %PS is large and negative.

Hensher and Houghton (in progress) recognise that the PBC framework developed herein can be extended beyond the transition stage, to encourage growth from transition, and to establish the social surplus maximisation solution under an unconstrained total subsidy budget. This stage of growth after transition will consolidate the fuller extent of value for money under a PBC regime. The transition stage however is crucial in an environment where established operators have demonstrated (to varying degrees) the ability to deliver service quality. The transition to an incentive-compatible contract scheme should ensure greater gains to society in the future which may have been denied by the existing contract regime[28]. Future research will develop decision rules for applying the scheme in new regions.

Acknowledgements

The comments of Erik Carlquist, Odd Larsen, Nils Fearnley, Darryl Mellish and John Stanley are very much appreciated as is the feedback from numerous bus operators and regulators in Australia. We are indebted to Stephen Rowe and Busways for providing the data required to illustrate the implementation of the PBC system. The opportunity to discuss our ideas with John Rogan and Johanna Quilty of Transport NSW is gratefully appreciated (especially in the development of the transition scheme).

References

Bray, A. (2002) Competitive performance, *Australasian Bus and Coach*, 14 (10), June, 22-29.

Bus Industry Confederation (2001) Getting the Prices Right: Policy for More Sustainable Fuel Taxation for Road Transport in Australia, Submission to the Commonwealth Fuel Tax Inquiry, October.

Carlquist, Erik (2001) Incentive contracts in Norwegian local public transport: the Hordaland model, paper presented at the *7th International Conference on Competition and Ownership of Land Passenger Transport*, Molde, Norway, June.

de Weger, T.H.D. and de Jong, L. (2001) PT infrastructure for bus systems in the Netherlands, paper presented at the *7th International Conference on Competition and Ownership of Land Passenger Transport*, Molde, Norway, June.

[28] Benchmark operators (as we have analysed in the case study) claim all of the subsidy budget by moving to their existing (developed) position. But lesser operators will be more seriously influenced by the percentage of PBC in the scheme. At 1%PBC, 1%TB is spread over service levels from 99%MSL to MSL+ development potential, and the lesser operator is unlikely to be much influenced to change. Consider, therefore, an increasing %PBC, where the increase is staged in a way that allows adequate time for operators to progressively improve efficiency as the scheme moves increasingly further away from the status quo. The final position would be 100%-PBC over the range 0% MSL to the full development potential. Hensher and Houghton (in progress) present this range of opportunities.

Department of Transport, Local Government and Regions (DTLR) (2002) *Transport Statistics Bulletin Survey of Concessionary Bus Fare Schemes in England 2001*, DTLR, London.

Fearnley, N. and Carlquist, E. (2001) A tale of seven cities: subsidy reductions in Norwegian public transport, paper presented at the *7th International Conference on Competition and Ownership of Land Passenger Transport*, Molde, Norway, June.

Hensher, D.A. (2002) A systematic assessment of the environmental impacts of transport policy: an end use perspective, Invitational paper for a Special Issue of *Environmental and Resource Economics* on 'Tools of the Trade for Environmental Economists' guest edited by Richard Carson, 22, 185-217.

Hensher, D.A. (2002a) *Urban public transport delivery in Australia: issues and challenges in retaining and growing patronage*, Institute of Transport Studies, The University of Sydney, May.

Hensher, D.A. (2002b) *Contract areas and integrated fares for public transit provision: some thoughts,*, Institute of Transport Studies, The University of Sydney, July.

Hensher, D.A. and Houghton, E. (in progress) *Growth after transition under performance-based contracts,*, Institute of Transport Studies, The University of Sydney.

Hensher, D. and Macario, R. (2002) Organisation and ownership of public transport services, *Transport Reviews*

Hensher, D.A, and Prioni, P. (2002) A service quality index for area-wide contract performance assessment regime, *Journal of Transport Economics and Policy*

Hensher, D.A. and Stanley, J. K. (2002) Performance-based quality contracts, Institute of Transport Studies, University of Sydney, June (version 2.7a).

Hensher, D.A., Stopher, P.R. and Bullock, P. (2002) Benchmarking and service quality at a market segment level, (presented at the 2002 *Annual Transportation Research Board Conference*, Washington DC.) *Transportation Research A*.

Jansson, J.O. (1984) *Transport System Optimization and Pricing*, Wiley, New York.

Jansson, J.O. (2001) Efficient modal split, paper presented at the *7th International Conference on Competition and Ownership of Land Passenger Transport*, Molde, Norway, June.

Johansen, K.W., Larsen, O. and Norheim, B. (2001), Towards economic efficiency in public transport, *Journal of Transport Economics and Policy*, 35 (3), 491-511.

Larsen, O I. (1996) Efficient public transit subsidies. In Hensher, D.A., King, J. and Oum, T. A. (eds): *Proceedings of the 7th World Conference on Transport Research*, Pergamon Press, Oxford, Vol 3, 225-236.

Larsen, O. I. (2001) Designing incentive schemes for public transport operators in Hordaland County, Norway, paper presented at the 7th *International Conference on Competition and Ownership of Land Passenger Transport*, Molde, Norway, June

Mills, G. and Gale, J. (2002) Funding of public transport and infrastructure: Theme D, workshop report 7th *International Conference on Competition and Ownership of Land Passenger Transport*, Transport Reviews.

Nash, C.A. and Jansson, K. (2002) Competition and regulation in public transport: Theme B, workshop report 7th *International Conference on Competition and Ownership of Land Passenger Transport*, Transport Reviews.

Prioni, P. and Hensher, D.A.(2000) Measuring service quality in scheduled bus services, *Journal of Public Transport*, 3 (2), 51-74.

Sansom, T., Nash, C., Mackie, P., Shires, J. and Watkiss, P. (2002) *Surface Transport Costs and Charges: Great Britain 1998*, Institute for Transport Studies, University of Leeds.

Ton, T. and Hensher, D.A. (1997) RouteInfo - A GIS based bus planning program for route planning and establishing minimum service levels *Proceedings of the 21st Australasian Transport Research Forum*, 21 (Part 2), 869-884.

Appendix A: A Summary of the Main Features of a Practical PBC Transitional Scheme for Sydney

1. This appendix sets out the main elements of a PBC system introduced in a transition phase before moving to a fuller PBC scheme. In the transition phase we commit the government to the exact same level of financial support as currently received under each contract. The majority of this support is from the school subsidy transport scheme (SSTS) and concessional reimbursements.

2. We call this total support TB (total subsidy budget). It will be imposed in the transition phase as an upper limit. The method developed in the body of the paper enables us to vary the TB upwards (or downwards) which will be desirable in the post-transition phase as government seeks out the best value for money solution.

3. Maintaining the notion of a minimum service level (MSL), the first step is to identify the community service obligation ($CSO) payment in order to see what will be left over from TSB as an incentive payment (provided patronage is grown). (An important aside: any concern about an operator's ability to survive without high CSO payments does not become an issue since the PBC scheme in the transition phase will support existing financial arrangements).

4. Calculation of $CSO requires determination of the appropriate MSL. We will base it on existing levels as defined by RVKM (revenue vehicle kilometres). Given RVKM associated with MSL and average fare (as well as the existing ratio of seating capacity and RVKM (a proxy for service quality)), the PBC method uses a simple demand model to establish patronage levels associated

with MSL (see Section 3). We distinguish 'adults, children and concession' (ACC) from 'school children' (S), since the fare level does not apply in the latter's demand model.

5. The resulting patronage is called Y^{MSL}. This patronage has a fare associated with it (if ACC) which is collected and kept by the operator in addition to the \$CSO, the latter based on \$/VKM multiplied by $RVKM^{MSL}$. We are using benchmarked best practice costs (\$2.60 for peak and \$2.30 for off-peak) for private operators in Sydney. These unit costs could be varied if there is evidence to support an equity-adjusted cost efficient benchmark. (SSTS and all concessions reimbursements are no longer paid, which is a huge administration gain).

6. The total revenue associated with \$CSO plus Y^{MSL} patronage fares can be built on by attracting additional patronage (above Y^{MSL}).

7. Given that we want to ensure that society gets value for money in the spending of TB, we need a way of calculating the maximum achievable social surplus. This involves recognising that the social surplus may well exceed TB and hence the operator should get only part of this social surplus.

8. Because of different capabilities of operators to attract patronage (because of different operating environments) we need a way of ensuring some equity in establishing the incentive payment available. We do this by taking each operating area and running the social surplus (SS) maximisation model in which we hold \$CSO fixed but allow VKM(RVKM) to increase above $VKM(RVKM)^{MSL}$, fares to vary up or down with a 5% cap on fare increases, and fleet size to increase but holding service quality fixed (the latter defined by ratio of seating capacity and patronage, must not decline).

9. This SS maximisation model (developed and detailed in the body of the paper) will enable us to identify the most likely achievable patronage growth (ie patronage above MSL level), some of which operators already have by providing better than MSL services.

10. The additional patronage will pay fares (if ACC) or travel for free if they are school children (our model makes this distinction). Together with \$CSO and fare revenue for MSL-level patronage, we can calculate the total fare and CSO payment revenue. The difference between TB and (\$CSO plus all fare revenue) is the amount available as incentive payments to be paid out for the additional patronage. (Note: this is determined by our fixed TB).

11. Under the fixed TB, all incentive payments would actually be distributed because they are achievable (ie passenger trips above Y^{MSL} are already being undertaken). However if TB were further increased, that money would not be automatically provided without additional patronage growth.(This latter growth is linked with what we refer to as '*growth after transition'*) But now we have an appropriate framework to ensure that each additional subsidy dollar delivers value for money.

12. When we compare all income sources to the total annual costs of running the business including an acceptable return on investment we should have operator balance.

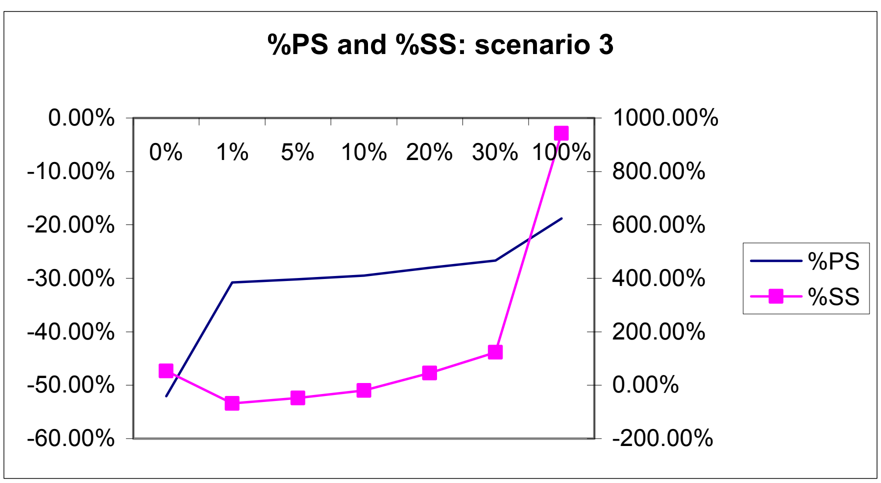
13. What we have is a contract system that has led to the removal of SSTS and concessional reimbursements and re-focused on incentives to grow patronage. Although the case study in the body of the paper imposes a budget limit based on the existing TB level, it is now possible for the government to increase TB but only return the increase to the operator if they grow patronage. We now have an incentive-compatible contract scheme for the first time.

Appendix B: Partial withholding of fare revenue

The model may be used to test a variety of scenarios, in the manner of the 10% fare cap in the text. In this appendix we consider an alternative scenario to assess the effect of a partial withholding of fare revenue. Here, the regulator withdraws from the operator, fare revenue generated by $Y<Y^{MSL}$. The motivation is the belief that operators are already paid at benchmark cost rates for $X \leq X^{MSL}$ and fare revenue would repeat the payment. However, the fares are currently a part of the operator's revenue, and the total subsidy budget (*TB*) has replaced the SSTS subsidy. On this basis, the benchmark operator has expanded the service level to its current level which exceeds X^{MSL} by 50%. Clearly, if the service level is to be maintained, withdrawing the fare revenue as proposed will convert the current 1.32% rate of return into a serious loss.

Outcomes are shown in **Figure Z**, where optimum rates of return across R for both the operator and the regulator are seen to be negative. Clearly, the scenario is impracticable.

Figure Z: OPTIMUM %PS AND %SS FOR SCENARIO 3



1. Introduction

Over the recent period of significant change in the way that bus services are supplied in many countries, a key focus has been the delivery of cost efficient services (through mixtures of privatisation, economic deregulation and competitive tendering) and finding ways to grow patronage (Hensher 2002a). Despite all the developments to improve the cost and service efficiency of operations, something has often been shown to be lacking – the global picture which recognises that public transport is, above all, provided through a supply chain in which different objectives apply such as commercial and social obligations. This broad and more holistic approach presented in Hensher and Macario (2002) recognises that no institution is able to act without affecting the other agents in the system. Social surplus maximisation (SSM) principles applied to transport tend to suffer when the focus is narrowed to the detail of cost efficient operations (the dominating focus in recent years of competitive tendering), losing to a growing extent the SSM aim associated with an overall mobility system. A big challenge is to re-focus on the integration of SSM and commercial objectives in a way that delivers much improved service levels as part of what might be generically termed *a value for money objective function*. The holistic vision is to pursue social planning with a commitment to commercial objectives and opportunities at the operational level under a cost *and* service efficiency regime, thereby recognising the real meaning of optimum subsidy. This theoretical approach is not new and was articulated in the public transport context over 18 years ago by Jansson (1984), and more recently by Jansson (2001)[1].

As part of the many reviews of the contracting regimes that bus businesses operate within, it has been recognised that the relationship between commercial and social objectives has not been investigated in a systematic manner. To what extent are existing subsidy support levels optimal? What exactly does this mean? One issue of interest to many governments is growing bus patronage that in particular switches from the car and hence reduces the negative environmental impacts of transport (Hensher 2002a). Thus an important task in the review of a service delivery regime is the establishment of an optimum *system-wide* subsidy system for the provision of bus services such that a profit maximisation level of passenger trip activity on the part of the operator will coincide with social surplus maximisation objectives. Economists when integrating these two maximisation objectives refer to social surplus (SS) maximisation as the sum of producer surplus (PS) (maximisation) and consumer surplus (CS) (maximisation). The former is equivalent (under a cost-efficiency regime) to profit maximisation for private bus operators. In most cost-benefit analyses undertaken by the public sector, there has been an almost total focus on consumer surplus maximisation, defining net benefit as the difference between consumer surplus in the presence and absence of a policy

[1] Jan Owen Jansson in his plenary paper at the 7^{th} *International Conference on Competition and Ownership of Land Passenger Transport* (Jansson 2001) states:

> "Two main possibilities for improvement [in cost efficiency] are to stimulate competition, and to enhance the motivation and creativity of operators by introducing the profit motive into a traditional 'public service'. The question is, if the present allocative inefficiency in transport markets will be improved in the process, it is argued that these changes will not be brought about by the increased reliance on market forces. On the contrary, better planning of public transport systems, and, I dare say, continued or increased subsidization are two necessary conditions for realizing the potential improvement of the resource allocation. A complementary, significant point is, however, that there is no inevitable conflict between the ambition to increase cost efficiency in public transport, and a transport policy towards an efficient modal split."

instrument (typically measured by changes in generalised cost). Yet it is the sum of PS and CS that represents the overall benefit to society. Thus failure to take into account the operator's objective function is a failure to recognise social optimality.

One of the most innovative payment schemes designed to secure socially optimum behavioural responses from transport operators has been developed in Norway for application in Hordaland County[2]. The local government makes payments to the bus operators through an incentive scheme that "pays for results rather than shares the costs of inputs" (Carlquist 2001)[3]. The approach identifies a set of 'external' effects that are typically not taken into account by the individual traveller when choosing a transport mode.[4] Hensher and Stanley (2002) provide more details on this scheme as well as other approaches to the establishment of performance-based contracts.

When a traveller chooses to go by car, the decision-maker ignores the external costs imposed on others (eg. the costs of congestion, accident risk and pollution) – assuming (as usual) that the institutional context does not allow the deployment of (first-best) car-user charges to reflect these costs. Conversely, an extra traveller who goes by bus (or other public transport) helps to create a *positive* external effect – often called the Mohring effect: as patronage increases on a route (or in a particular area), the (socially) optimum service frequency also increases. This benefits the new travellers (whose patronage has led to the service improvement), and also reduces trip time for those others who continue to use the service.

In the absence of practicable price discrimination, the operator is not able to extract the increase in consumer surplus that is enjoyed by the continuing users as a result of the increase in frequency – because a fare increase for all passengers would preclude some or all of the extra travel that justifies and requires the extra frequency. To achieve the optimum service level, a government-funded incentive payment is needed. To the extent that the incentive payments result in lower fares and/or improved service levels, there can be social benefit from increased travel (that is, generated trips) as well as from the reduction in car travel. This too should be recognised in establishing the incentive payments.

The apparent conflict between the operator's objective function and that of SS maximisation is primarily related to the absence of the use of benchmarked best practice costing and the presence of externalities linked to environmental (eg congestion, pollution) and social (eg equity) impacts that are not internalised in the operator's profit and loss account. If SS maximisation imposes a substantial financial loss on the operator it would be unacceptable to the operator. If however a positive change in CS (based on private user benefits) and non-internalised environmental externality benefits (EB)[5] would increase revenue (and conversely decrease revenue for a negative change in CS and EB), the operator would have the necessary incentive to act as a social surplus maximiser. The question then becomes one of identifying how this incentive can

[2] An area that includes the city of Bergen as well as some surrounding rural areas.
[3] Competitive tendering as implemented, in contrast, has mainly focussed on sharing the costs of inputs.
[4] Although the principal modal choice in the Hordaland context is between bus and car, the competition can be generalised to include rail, ferry etc.
[5] Strictly, consumer surplus (CS) is the sum of private user benefits (UB) and (internalised) environmental benefits (EB), but herein we treat them as separate benefit sources, referring to private user benefits as consumer surplus.

be provided in practice. The implementation 'solution' appears to lie in changes to the pricing (ie fare) and/or supply regulations in a way that opens up opportunities for the operator and the regulator (the latter acting on behalf of the government) to seek out incentive-based mechanisms that reflect the challenge to internalise CS and EB[6]. This should hopefully provide the necessary freedom and (positive) incentives for the operator to pro-actively participate in pricing policy and service design to increase cost efficiency as well as allocative efficiency. The benchmark for progress however is internalisation of CS and EB, achieved by the mix of internalised cost recovery and externalised funding by the provision of an optimum subsidy (or incentive-payment).

What formula will work in practice that is acceptable to both the operator and the regulator? One thing is almost certain - there will need to be a transparent level of external subsidy[7]. If a scheme is to work, however, it must prevent cost inefficiency (which can be a product of subsidy support, as indeed can poor service delivery). An effective monitoring and benchmarking program is critical[8] to ensure that cost inefficiency does not occur as the subsidy is introduced to support initiatives that deliver consumer surplus, and that external funding delivers the best value for money. Periodically reviewed benchmark best cost practice associated with specific geographical settings should be the basis of subsidy determination.

The following sections of the paper review the elements of a VM regime within the setting of an incentive-based performance contract and develops a formal (economic) framework for establishing an optimum subsidy based on maximisation of social surplus. The maximisation of social surplus is subject to a number of constraints including the commercial imperative of the operator, minimum service levels and a fare and subsidy budget cap. An important feature of the performance-based quality contract regime is a passenger-based incentive payment scheme incorporating a subsidy per additional passenger trip above that patronage delivered under minimum service and fare levels. In this way, rewards to operators are revealed through the fare box, through increased consumer surplus and through reductions in negative externalities associated with car use. The implementation of performance-based contracts is illustrated using data collected in 2002 from private operators in the Sydney Metropolitan Area. Appendix A summarises the main elements of a PBS transitional scheme for Sydney. PBCs can be designed to accommodate both transition from an existing regime and post-transition growth strategies.

---

[6] It must also be recognised that the delivery of positive CS under a subsidy-scheme recognises the presence of under-pricing of competing modes such as the car. Subsidies to public transport are designed to bring its operation into line with social considerations. In particular, when car users are not charged for the negative externalities that arise from their car use, subsidies for bus services can help to encourage travellers to make appropriate choices between travel modes. Yet, when privatisation and contracting-out of bus services came into vogue in the mid-1980s, the principal aims were simply to reduce subsidies and to increase cost efficiency. In recent years, the focus has turned to the shaping of payment instruments to try to secure behavioural responses that support the specific policy purposes of the government instrumentality that pays the subsidy.

[7] This is separate from any operator commitment to internal cross-subsidy between various activities that is consistent with efficiency objectives provided that avoidable costs are covered on each (well-defined) activity.

[8] We recognise that monitoring of performance cannot be precise and must be dependent on trust and quality reporting (Carlquist 2001). Such a monitoring program should focus on the three dimensions of overall performance: cost efficiency, cost effectiveness and service effectiveness. The role of constructs such as a Service Quality Index (SQI) developed by Hensher and his colleagues (eg Prioni and Hensher 2000, Hensher and Prioni 2002, Hensher et al 2002) offers one way of tracking the last dimension.

2. Incentive-Based Performance Contracts

Before setting out the formal economic framework for a proposed performance-based contract regime (for Australia), we will take a closer look at a recent initiative in Norway that promotes the PBC regime over competitive tendering[9]. New performance contracts were established, in early 2000, for the three bus operators in the Hordaland county. One of these serves the urban area; the other two operate in rural areas and on the main corridors into Bergen. There is little or no on-the-road competition.

The design of the Hordaland payment mechanism is innovative. Larsen and his colleagues (Larsen 2001, Johansen et al 2001) develop a two stage procedure where the first stage determines fare levels, bus revenue-km and bus capacities to maximise a social welfare function (essentially SS maximisation). The second stage calculates rates for fare subsidies, and for revenue-km subsidies (applicable in the peak and/or periods), *that will induce a profit-maximising operator to choose the (socially) optimum levels for revenue-km and for bus capacities*. This statement in italics is the essence of the approach providing the link between commercial and social objectives. The operator does not set fare levels but complies with maximum fare levels set by the authority. The per-passenger remuneration received by the operator is the sum of the fare level (determined in the first-stage welfare-maximising calculation) and the subsidy level (determined in the second-stage calculation).

In this approach, a per-passenger subsidy, or fare subsidy 'pays for results' and the revenue-km payment reimburses some of the costs. The operator also receives the fare revenue and both kinds of revenue together provide the operator with sufficient income to balance the operating costs. In other words, the revenue-km subsidy will not encourage an operator to run empty vehicles. It does encourage service frequency and the extent of the induced increase in frequency depends on how vigorously (and successfully) the operator pursues profits. What we have here is an incentive-based performance contract where the subsidy is set to match the sum of the avoided external costs of car use *and* the benefits of increased service frequency.

The welfare outcomes depend on the details of the implementation. The implementation of the Hordaland model is described in Carlquist (2001)[10]. Each operator has a separately calibrated contract. As in earlier contracts, these are on a net-cost basis; but unlike the Larsen (2001) model, each operator may determine the fare levels. In the

[9] The evidence is drawn from Carlquist (2001), Larsen (2001), Johansen et al (2001), Mills and Gale (2002). Hensher and Stanley (2002) provide further details of the Norwegian model and the arguments for PBC compared to Competitive Tendering.

[10] As an example of the subsidy calculation, using vehicle kilometres (VKM) as the performance criterion and \$/vkm as the cost rate (RATE), with the subsidy subject to a maximum predetermined level, the subsidy in year t = (RATE*VKM_t) minus a fixed deduction as explained in Larsen (2001). Profits are co-determined by different performance-based items – ticket revenues (I), subsidies (S), and costs (C). Ticket revenue is equal to fare (F) multiplied by demand (D), and demand is a function of VKM, fares and other service attributes. That is: profits=I+S-C, C=f(VKM), I=F*X and X=g(VKM,F,…). Given the right incentive (ie RATE) the operator will decide on a fare level and VKM at a level that maximises profits and maximises social welfare given the budgetary limits for subsidy support. The budgetary limit is often associated with a constrained social welfare maximisation rule (or Ramsey rule) that implicitly imposes a marginal cost of government funds on the calculation (ie the amount that government is willing and possibly able to contribute to the social welfare objective).

event, the implemented contracts do not include any per-passenger subsidy, in part because the (global) budget constraint limited the amounts of subsidy that could be paid[11]. The Larsen modelling had suggested such subsidy should be paid, but only where the fare was significantly less than the marginal cost – as for peak-period rural services. The revenue-km subsidy has been implemented through two components – one subsidy rate per vehicle-km and another per vehicle-hour, to accommodate differences between congested urban conditions and non-congested rural operation.

The subsidy rates are calculated to secure optimum *marginal* conditions. In principle, there is no certainty that the total amount of subsidy will be such as to enable the operator to receive as much as, and no more than, a reasonable return on investment. Numerical calculations prepared by Larsen show that the urban operator (in particular) would be likely to receive a substantial level of excess profit. This arises because the marginal cost of the peak services is very much higher than the cost of the other ('basic') services, which are a substantial part of the total offering. Accordingly, a 'fixed deduction' was suggested. Being fixed in total amount, this has no effect on the (marginal) incentive structure. Carlquist reports that the fixed-deduction principle *was* incorporated in the implemented contracts.

In the first year (2001) of the deployment of the new performance contracts, there has been little change (especially in regard to route networks) – in part because the budget constraint was tight enough to limit the scope for change, and in part (perhaps) because of inertia, including political resistance to change. Nevertheless Carlquist (2001) reported that experience with the new contracts is generally well regarded.

The Hordaland model has provided the starting position for the authors' proposal for a PBC framework for Australia. The data used to illustrate the implementation of a PBC regime has been obtained from a major private operator who is widely regarded as operating at best practice with respect to cost efficiency and effectiveness. Thus the approach detailed below is indicative of the outcomes one might anticipate under a PBC regime for an outer urban area bus operator in a major city in Australia. We focus on a PBC scheme under a transition from the existing contract regime but show that once the transition is complete, the very same PBC scheme can be used to promote growth in passenger trips through improved service levels supported by incentive payments (Hensher and Houghton (in progress)).

3. The Australian PBC Proposition

The proposed PBC framework is based upon a model system that recognises the obligations of government, as well as the need to provide appropriate incentives to operators to service the market in line with value for money under a tight subsidy regime. In addition, we recognise the constraints under which the regulator charged with implementing and monitoring a contract regime operates. In NSW, for example, a

[11] The global budget constraint is a very important parameter for the NSW government because it is at the heart of the Bus Reform agenda. The intent appears to be clear – to provide increased value for money within a system-wide pre-determined maximum budget. As detailed herein PBC's can be developed for transition (holding existing subsidy levels fixed) and then later allow the subsidy level to vary as the reward for growing patronage.

paramount requirement is for a minimum[12] administrative burden based on suitable reliable data provided by bus operators.

The PBC framework is assumed to be implemented *system-wide* over a pre-defined geographical area (but can also be implemented for a single operator). We distinguish between metropolitan and non-metropolitan settings and focus herein on the metropolitan model. Furthermore we recognise intra-metropolitan differences in the operating environment, especially due to patronage catchment, traffic congestion and time of day. These differences are accommodated (to a large extent) by distinguishing between inner and outer metropolitan areas as well as peak and off-peak periods. Where minimum service levels (MSLs) are required, they will be set exogenously for each region and period based on a grading system determined (outside of the PBC structure) by a number of criteria including population, population density and incidence of school children[13]. All costs used will be assumed to be benchmarked best practice for the specific context. The use of benchmarked costs ensures that optimum subsidies are based on cost efficient service levels[14].

3.1 Defining Annual Passenger Demand

The demand for bus travel (Y) is defined as one-way annual passenger trips[15] per contract period, and is assumed to be influenced by fares (q) and service levels (X), where the latter is proxied by revenue vehicle kilometres (ie total vehicle kilometres minus dead running kilometres). Since the categories of bus passengers have differing degrees of behavioural responsiveness to changes in fares and service levels, separate passenger demand models are required for each segment. Within each geographical context, we initially propose separate demand models for peak and off-peak travel for two broad classes of travellers: (i) adults, (fare paying) children and concession travellers (ACC) and (ii) school children (S). Further segmentation can be introduced as required. There are many specifications available to represent travel demand. We have chosen equation form (1) for class (i) travellers and a separate equation form (2) for class (ii) travellers, where the latter applies when school children do not pay a fare. Before the implementation of the proposed scheme (base case B), demand levels, Y^B, are based on *existing* fares and service levels. After the implementation of the proposed scheme (Application case A), predicted demand, Y^A, is a function of a base demand (Y^B); the direct fare elasticity of demand and the direct revenue vehicle kilometre elasticity of demand; and operator responses to the scheme through changes to fares and revenue

[12] And certainly no increase over existing regulatory resource commitments.

[13] Although we specify MSL in terms of a minimum amount of revenue vehicle kilometres, the regulator may wish to impose some very specific conditions on where and when these RVKM are to be provided within the contract area. This is not an issue of concern to establishing the appropriate level of incentive payment given a system-wide subsidy budget since all we need to know is the minimum RVKM for each of the peak and of-peak periods for each contract area. We have doubts about the benefit of imposing too rigid a service specification as is currently the situation in NSW because it results in many services with very little patronage and substantial cost-burdens that do not provide real benefits to society. Spreading thin resources thinly is not a virtue that we should promote. Larsen (2001, page 2) promotes a view that "…the design of a route system is best left to an operator familiar with the area to be served". There are sensible reasons for moving from the tactical to operator level the fare structure, fare level, route networks and timetables within the parameters of the incentive-driven quality contract.

[14] If there is a case for differences in cost efficient rates (for whatever reason, such as an equity-adjustment), this can be included.

[15] A passenger trip is defined as a single one-way trip from an origin to a destination. If a transfer between buses is required this is not two passenger trips.

vehicle kilometres. The elasticities used in equation (1) for each of peak and off-peak activity are weighted averages across the classes of travellers within the separate demand categories.

$$Y_{ACC}^{A} = Y_{ACC}^{B} * \exp[\frac{\varepsilon_{Y(ACC)}^{q}}{q^{B}}(q^{A} - q^{B}) + \frac{\varepsilon_{Y(ACC)}^{X}}{X^{B}}(X^{A} - X^{B})] \tag{1}$$

$$Y_{S}^{A} = Y_{S}^{B} * \exp[\frac{\varepsilon_{Y(S)}^{X}}{X^{B}}(X^{A} - X^{B})] \tag{2}$$

We initially assume a static representation with the annual patronage response assumed to occur at the specified rate over the period of a contract. For class (i) travellers, the set of fare elasticities is respectively -.20 and -.45 for the peak and off-peak periods, and the service (RVKM) elasticities are 0.33 and 0.63. For class (ii) travellers, the service elasticities are assumed to be the same as class (i), on the assumption that the parent traveller decides on the school child's modal activity.

The PBC system requires a base prediction of patronage associated with minimum service levels[16]. To obtain this patronage we use the level of RVKM associated with MSL and impose a fare level unchanged from case *B*. The resulting MSL patronage for class (i) travellers is Y^{B} in (3).

$$Y_{ACC}^{MSL} = Y_{ACC}^{B} * \exp[\frac{\varepsilon_{Y(ACC)}^{X}}{X^{B}}(X^{MSL} - X^{B})] \tag{3}$$

In what follows Y^{A}, Y^{B}, Y^{MSL} will be used in place of $(Y_{ACC}^{A} + Y_{S}^{A})$.

3.2 Defining Annual Total Cost

Benchmark cost efficiency is formalised by a set of total annual cost equations (4) for each period and region. Total predicted cost (C) is defined as a function of benchmarked base cost (calculated from best practice total cost per kilometre); predicted responses in total vehicle kilometres (VKM) (including dead running kilometres), predicted changes in total passenger demand (from equations 1 and 2), predicted responses in total seat capacity per revenue vehicle kilometre; and the respective set of cost elasticities for VKM, patronage and bus capacity. VKM is the sum of revenue and dead running kilometres with the default value in our empirical example for dead running VKM set equal to12.5% of VKM for both peak and off-peak activity (That is, VKM = 1.1258RVKM). Bus capacity (defined by seating and standing capacity per bus multiplied by the number of buses) impacts on passenger demand through revenue vehicle kilometres through a service *quality* constraint that indicates how much bus capacity must be provided to satisfy passenger trip demand. This then translates into vehicle kilometres which impacts on total annual cost, and takes into account the annualised cost of bus capital. The starting passenger trip-demand elasticities of cost are respectively -0.32 and -0.20 for the peak and off-peak periods. The equivalent service

[16] An MSL is not a necessary input into the determination of a PBC but we include it as a specific input given that the regulator may require its inclusion. In section 4 we will show what the implications are for determining the maximum social surplus solution when there is no MSL.

(RVKM) elasticities are 0.76 and 1.20; and the equivalent fleet size elasticity, which is derived from increased capital charges and applies only to peak periods, is 0.19. The separate cost equation for peak and off-peak periods, for each region and period, has the form of (4).

$$C^A = C^B * \exp[\frac{\varepsilon_C^X}{VKM^B}(VKM^A - VKM^B) + \frac{\varepsilon_C^{Y(ACC)}}{Y_{ACC}^B}(Y_{ACC}^A - Y_{ACC}^B) + \frac{\varepsilon_C^{Y(S)}}{Y_S^B}(Y_S^A - Y_S^B) + \frac{\varepsilon_C^{\#bus}}{\#bus^B}(\#bus^A - \#bus^B)] \quad (4)$$

3.3 Defining the Constraints

There are a number of constraints that enable us to represent the environment in which the delivery of services satisfies all stakeholders. The key constraints are shown below.

3.3.1 Fare Cap

A fare cap (5) over the contract period for each peak/off-peak period and region is a political reality in most jurisdictions and in Australia (maximum) fares typically may not increase by more than the consumer price index. The introduction of performance-based contracts must comply with this condition, set as a 5% maximum increase per annum. This can be adjusted to suit the political setting.

$$q^A - 1.05q^B \leq 0 \quad (5)$$

3.3.2 Vehicle Kilometres (VKM)

A condition of public transport service delivery often included in contracts is that there is a minimum level of service that must be provided under community service obligations (CSO) at cost efficient levels. These service levels are determined by external criteria set by government such as a requirement to provide a minimum amount of vehicle kilometres depending on the socio-economic and demographic profile of the region to be served. This profile must be defined by an agreed set of criteria such as total resident population, population density (1000's of people per square kilometre), the percentage of total population that are school children and availability of other modes (eg a train service) (see Ton and Hensher 1997). On the basis of a weighted system for each criterion, a minimum amount of RVKM is required for each period and region. The precise geographical allocation of this MSL is a detail of specific contract compliance and has no impact on the determination of the optimal social solution. This minimum RVKM would ideally be an absolute amount; but for the present application we define it as 67% of current service VKM's[17]. Condition (6) defines the minimum level of service (MSL). A total cost per kilometre can be introduced to convert this MSL to a dollar commitment from government. We assume *$VKM* = $2.60 in the peak and $2.30 in the off-peak (based on 2002 best practice costs in the private bus sector in Sydney in a setting where the operator retains all fare revenue).

The proportion of the total subsidy budget (TB) allocated to performance-based contracts in the regulator's scheme is denoted by R, which permits variations in the

[17] This percentage is derived from the percentage of RVKM complying with MSL's for the illustrative operating context from which the data is extracted.

structure of the subsidy scheme between MSL and above-MSL (or PBC) components. Since *TB* is the pure-MSL subsidy requirement as determined by CSO, the MSL of a given scheme is defined by the associated *R* value as CSO*(1-R)[18]. The inclusion of *R* is very important since it enables us to assess the implications of various mixes of MSL and PBC service levels.

$$X^{MSL} = (0.67)\text{VKM}\ (1\text{-R})\ X^{A} \geq X^{MSL} \tag{6}$$

In addition to the fare cap and MSL constraints, government typically has a limited budget to allocate to subsidy support for bus transport. This subsidy cap is assumed to be *a system-wide constraint* within the metropolitan area and applies to all inner and outer metropolitan bus operators[19]. The subsidy cap is exogenously given but adjustable by government decree and has to fund the CSO payments as well as payments directly linked to incentives for growing patronage. The passenger-based incentive payment scheme at the heart of PBC's is made up of gains in consumer surplus and externality benefits, where the latter are primarily linked to reductions in traffic congestion due to reductions in car VKMs (see section 3.5.2). For every additional passenger trip above predicted patronage based on $RVKM^{MSL}$ and associated fares, the operator has the opportunity to secure revenue from three sources: (i) the fare box (ii) the change in consumer surplus as a measure of user benefit and (iii) the change in externality cost from reduced car VKM. The last two revenue streams are referred to as incentive payments (above fare revenue) and are part of the total budget commitment to the system as a whole by government. After committing CSO payments the balance of the total subsidy budget is available for such incentive payments (constraint (6)). While this residual amount is fixed, the estimate of its dollar value per passenger trip of the consumer surplus benefit will be determined by the maximisation of the social surplus function subject to the set of constraints. The dollar unit values of reductions in car VKM are exogenously supplied based on studies of the environmental cost of car use (see Bus Industry Confederation 2001 and Sansom et al 2002). If additional passenger trip growth over the predicted amount per contract period is exceeded it cannot be funded out of the available incentive payments unless government revises its total subsidy budget. Nonetheless, all additional fare revenue will be accrued by the operators.

3.3.3 Traffic and capacity

In peak and off peak periods the road traffic in which buses operate is vastly different, and to achieve a given RVKM in dense traffic requires the deployment of more buses compared to light traffic conditions. A direct measure of bus-utilisation (ie traffic) intensity in the period is given by $Z^{B} = \dfrac{(pers.\#bus)^{B}}{X^{B}}$. Z defines capacity required per RVKM as determined from the RVKM achieved by the number of buses (# *buses)* allocated to the period in the base case. An increase in base traffic results in a reduction

---

[18] Specifically, R controls the structure of the contract scheme. Defining %PBC= (1-R), $CSO*(1-R) gives the MSL component of the subsidy; and hence the subsidy applied to the performance incentive is TB-CSO*(1-R); and the RVKM required to meet the (reduced) CSO is VKM*.67*(1-R).

[19] This cap can be applied to specific locations if that is more politically palatable. For Example, in the Sydney metropolitan area the government may choose to treat the government operator (the inner area supplier) differently to the private (outer area) operators. In addition, government may wish to pre-assign a cap to each operator (which we would recommend in the transition phase but not in post-transition growth phase).

in X^B and an increase in Z, which has the effect of increasing the capacity required, $X^A Z^B$, for a given solution X^A. Z is not a control parameter but simply reflects the traffic of the period in the base case.

Imposing equivalent traffic conditions in equivalent periods (peak, off-peak) to the base case requires

$$Z^A = Z^B \text{ , or,}$$
$$X^A = \frac{(pers.\#bus)^A}{Z^B} \tag{7}$$

where

$\# \ bus$ = the number of buses assigned to the period/region and is assumed to reflect the demand levels of the base period and may be changed with corresponding cost implications. The capital cost of extra buses is fixed to # bus unless included with Z

Pers = bus capacity (seating + standing) assumed to be single-valued and unchanging

From (7) the capacity required for a given solution X^A is given by $X^A Z^B$.

The number of buses may be increased or decreased to provide an upper bound to X^A that is fixed by the number of buses assigned to the period, i.e.

$$X^A \leq \frac{(pers.\#bus)^A}{Z^B} \tag{8}$$

For a given *#bus* value, the bound may be loosened by deteriorating service quality, as discussed above. Again, the environment provided by the single stage solution is consistent with a profitable operator strategy to achieve the maximum social surplus, although it does not guarantee the optimum solution will be achieved.

3.3.4 Service quality

Service quality is maintained through the service quality constraint, which in its fundamental form requires

$$Y^A/X^A \leq Y^B/X^B. \tag{9}$$

This becomes very restrictive for low X solutions, since with X^A decreasing from X^B towards X^{MSL}, Y^A declines towards Y^{MSL}, given by $Y^{MSL} = Y^B * \exp[\frac{\varepsilon_Y^X}{X^B}(X^A - X^B)]$, more slowly than X^A is declining. At low service levels, however, it is realistic to allow a decline in service *quality* to reflect an interaction between the declining returns and declining price elasticity of demand as the volume of business declines. In general, it is important to loosen the form of (9) through a control variable, κ; which relates to how full the buses are allowed to be on average given normal operating practices. κ is a measure of service quality with respect to loading and allows the service level to slip. The less restrictive form of (9) is given in (10)

$$Y^A \leq \kappa Z^A X^A \tag{10}$$

The starting value of κ is $\kappa = \frac{Y^B}{X^B Z^B}$ which measures the base trip-rate per unit carrying capacity allocated. κ can be adjusted up or down to control an increase or decrease in acceptable bus crowding levels, thereby providing decreased or increased service quality (loading). Where increased κ is not associated with a reduced volume of business it should result in increased costs to reflect a loss of goodwill. Solutions incorporating increased values of κ will define an environment within which operators may make normal profits whilst providing high social surplus solutions. As in the previous section, optimum operator strategies may take the industry in different directions.

3.3.5 System Wide Constraints

There are two system-wide constraints associated with all regional activity.

3.3.5.1 Subsidy cap

First we have the total subsidy cap (11) in which the amount of subsidy available for passenger incentive payments is less than or equal to the total allocated subsidy budget minus commitments to CSO payments.

$$\sum_{\text{region, period}}^{4} P\left(CS + EB\right) \leq TB - \sum_{\text{region, period}}^{4} \$CSO(1 - R) \text{ for (CS+EB)>0} \tag{11}$$

Constraint (11) states that the patronage incentive must be less than or equal to the subsidy budget above CSO payments for all operators for (CS+EB)>0. Performance-based contracts allow subsidy payments to be earned whenever (*CS*+*EB*) are positive. Negative payments are not part of the performance-based system and are excluded in the modelling. Since both CS and EB are measured from the MSL position, payments are excluded when (*CS*+*EB*)<0. Although the total CS + EB is realised *to the benefit of the community*, the regulator can exercise the option to pay all of the benefit to the operator or only a proportion. P is the payout rate defining the proportion of external benefits accrued by bus companies on achieved (CS+EB). This is an important issue since the incentive payment focus does not suggest that 100% of the benefit must be paid to the operator. Indeed distribution of the full social benefit to the operator may not be equitable and/or financially feasible. What is critical however is that the payment distribution ensures sufficient incentive for the operator to improve service levels in order to grow patronage.

3.3.5.2 Commercial requirements

Total cost (including an acceptable return on investment) to all operators delivering bus services must be covered by all sources of revenue (12). The commercial constraint (equation 12) requiring that operator costs do not exceed revenues may be implemented when only commercially viable solutions are considered.

$$\sum_{\text{region, period}}^{4} \left[C^A - \left(qY_{ACC}^A + P(CS + EB)\right)\right] \leq \sum_{\text{region, period}}^{4} \$CSO(1 - R) \text{ … for (CS+EB)>0} \tag{12}$$

3.4 Defining the Objective Function

The demand and cost models together with the constraint set condition the maximum value of the social surplus objective function, given in (13)[20].

Max:

$$\sum_{\text{region, period}}^{4} \left[(1+P)(CS+EB) + qY_{ACC}^{A} - C^{A} + \$CSO(1-R) - (\$CSO(1-R) + P(CS+EB)) \right]$$

$$\ldots \text{ for } (CS+EB)>0 \qquad (13)$$

CS is the consumer surplus and EB is the environmental benefit, where both of these are calculated from and above Y_{MSL}; all other variables are as defined previously. The measure of consumer surplus is relatively complex and influenced by changes in demand.

3.5 Defining the Benefit Sources

3.5.1 Consumer surplus

The minimum service level, *MSL*, corresponds to the *CSO*, and is defined by a minimum RVKM, (X^{MSL}) and maximum fare charged under MSL (typically the maximum permissible fare). The corresponding patronage level, Y^{MSL}, is established from (1). Y^{MSL} establishes the base patronage *above which* consumer surplus is generated given the current subsidy scheme. We let *CS* denote the level of consumer surplus associated with patronage determined by X^{MSL} and maximum fares.

A composite demand variable, *G*, is a function of both fare level and RVKM. G^{MSL} is determined equivalently to Y^{MSL}**.** Quantity demanded is related to bus travel attributes, some of which are desirable to the consumer, like RVKM, and others which are undesirable, like price. These attributes may be combined in a composite attribute measure, *G*, where

$$G^{MSL} = kq^{MSL} + \lambda X^{MSL}; \qquad G^{A} = kq^{A} + \lambda X^{A};$$

$$G^{MSL} - G^{A} = k\left(q^{MSL} - q^{A}\right) + \lambda\left(X^{MSL} - X^{A}\right). \qquad (14)$$

and $k = -1$

λ = Community preparedness-to-pay for 1 km increase in X.

Deriving lambda is a challenge given the absence of empirical studies. However additional service levels can be approximated by improved service frequency. The TRESIS project (Hensher 2002) provides a willingness to pay for improvements in service frequency of $2.66 per passenger trip hour. Given an average speed in the peak period of 24 kph and an off-peak average speed of 30 kph, we can convert the frequency valuation into $0.11 per RVKM in the peak and $0.0886 per RVKM in the off-peak for class (i) travelers. For class (ii) travellers the rates are halved.

A corresponding composite demand function gives Y^{A} as a function of G^{A} etc., and consumer surplus is then measured as (15).

[20] Eqn (13) adds P(CS+EB) and $CSO(1-R) to the social surplus expression as they constitute part of the producers surplus, and then they are both subtracted since they sum to the scheme cost.

$$CS = 0.5 * ABS(Y^{A}_{ACC} + Y^{A}_{S} - Y^{MSL}_{ACC} - Y^{MSL}_{S})(G^{MSL} - G^{A}) * if[(Y^{A}_{ACC} + Y^{A}_{S}) < (Y^{MSL}_{ACC} + Y^{MSL}_{S}), -1, 1] \quad (15)$$

(CS between Y^{MSL}, Y^{A})

$$+if[(Y^{A}_{ACC} + Y^{A}_{S} - Y^{MSL}_{ACC} - Y^{MSL}_{S}) * (G^{A} - G^{MSL}) < 0,$$
$$(Y^{MSL}_{ACC} + Y^{MSL}_{S})(G^{MSL} - G^{A}) * if[(Y^{A}_{ACC} + Y^{A}_{S}) < (Y^{MSL}_{ACC} + Y^{MSL}_{S}), -1, 1], 0]$$

(CS to axis if negative slope)

Given that increases in fares reduce CS and increases in RVKM increase CS, we have to be careful how we treat the two impacts in the determination of changes in consumer surplus. Effective demand results from a balance between q and X. For given parameter values, k and λ, the slope of the composite demand function will be positive or negative depending on solution values, q^{A} and X^{A}. When the slope is negative, as shown in **Figure A**, a consumer surplus, $G^{A}ABG^{MSL}$, is derived from a reduction in the composite trip attribute from G^{MSL} to G^{A}. But, when the slope is positive, as shown in **Figure B**, a consumer surplus, ABC, is derived from an increase in the composite trip attribute from G^{MSL} to G^{A}.

FIGURE A: Composite demand function – negative slope

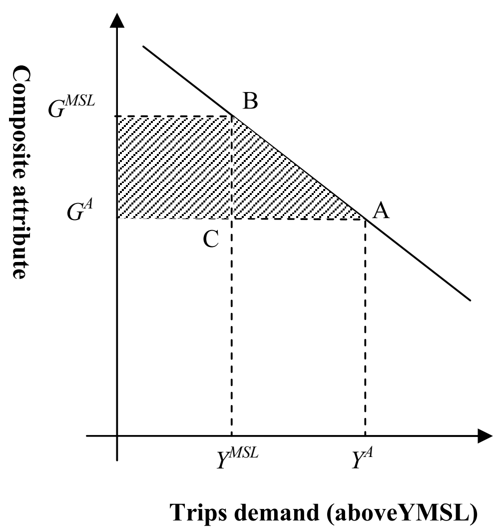
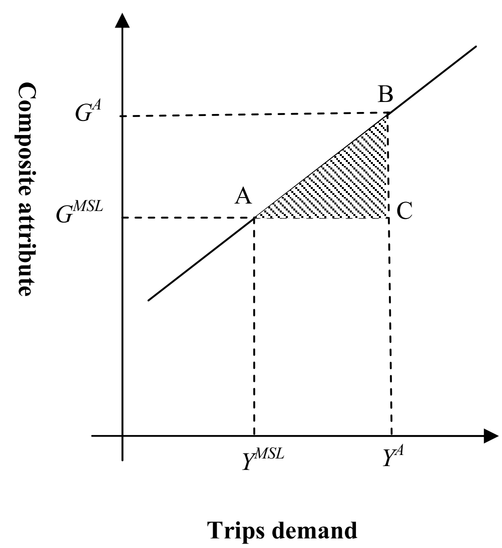


FIGURE B: Composite demand function – positive slope



In both **Figures A and B**, consumer surplus derives from ABC, but this is supplemented by the addition of (G^{MSL}-G^{A})(Y^{MSL}) in **Figure A**. When Y^{MSL} is high and (Y^{A}-Y^{MSL}) = 0, the supplement will induce the optimization to choose a marginal difference between Y^{A} and Y^{MSL} in order to achieve a negative slope and accrue the supplement. In the programming, therefore, the supplement is accrued only for (Y^{A}-Y^{MSL}) significantly different from zero.

3.5.2 Environmental Externality Benefit

The change in environmental benefits associated with car use is defined by equation (16). We assume initially that on average every car trip switched to a bus trip reduces car use by 10 kilometres and that 40% (20%) of all switched trips by adults (by school, children) are from car[21]. Any transfer of car trips to bus trips reduces road traffic congestion and creates an environmental benefit which also contributes to social surplus. *EB* denotes the environmental benefit generated by solution trips above Y^{MSL} and is directly comparable to *CS*.

EB = \$/(↓car user)*(↑passengers from car) … for each region, period

$$= (\$/VKM^{car})*(av\ VKM^{car})*(\uparrow passengers\ from\ car)$$

$$= (\$/VKM^{car})*(10\text{KM})*\left(Y^{A}_{ACC} + Y^{A}_{S} - Y^{MSL}_{ACC} - Y^{MSL}_{S}\right)*(\text{shift factor car-bus})$$

$$= (\$/VKM^{car})*(10\text{KM})*\left(Y^{A}_{ACC} + Y^{A}_{S} - Y^{MSL}_{ACC} - Y^{MSL}_{S}\right)*0.4 \qquad (16)$$

The unit rate of environmental benefit per VKM travelled by class (i) travellers, is a composite sum of six externalities, summarised in Table 1 for peak and off-peak and inner and outer metropolitan contexts. The evidence is drawn from the Bus Industry Confederation (2001) submission to the Commonwealth fuel tax inquiry. It is broadly consistent with the UK evidence reported in Sansom et al (2002).

TABLE 1 Environmental Externality Costs per VKM

Peak Period	***Inner***	***Outer***
Road damage	0.2	0.2
Congestion	90	60
Air pollution	1	0.5
Climate change	1.3	0.9
Noise	0.4	0.3
Accidents	0.8	0.8
Total	*93.7*	*62.7*
Off-Peak Period	***Inner***	***Outer***
Road damage	0.2	0.2
Congestion	16	16
Air pollution	0.5	0.2
Climate change	0.9	0.6
Noise	0.3	0.1
Accidents	0.8	0.8
Total	*18.7*	*17.7*

The patronage incentive is the sum of CS and EB (in dollars)[22]. Importantly, although school children travel for free in most jurisdictions and the operators are compensated through CSO payments, additional trips by children will attract an incentive payment through increased consumer surplus, and for car switchers, through increased externality benefit. On the latter calculation we may have to impose an additional assumption as to whether the school child's bus use results in a reduction in car VKM or not, since some trips may continue.

[21] This assumption can be refined by an assessment of source of switchers in the first monitoring period of if other evidence is available.

[22] EB may be negative if passenger trips fall and they switch to car, although we are not proposing to tax the operator.

4. A Case Study for the Outer Metropolitan Area of Sydney

The formal economic optimisation framework presented in section 3 has been tested on operators in the outer areas of the Sydney metropolitan area. Drawing on data collected in 2002 by the Institute of Transport Studies (ITS), in cooperation with 12 private bus operators[23], we have extracted the relevant data for the model system. Importantly, the amount of data required from operators is relatively small and manageable for the regulatory task. Benchmark costs are those of the most cost efficient operator in the set (who is also the best operator on cost efficiency in the ongoing benchmarking program of ITS).

Exogenous indicators such as elasticities, unit externality cost rates, willingness to pay parameters, minimum service level VKM etc are provided from non-operator sources and can be modified as new information becomes available. We have selected what are regarded as best-knowledge estimates in this case study to illustrate the feasibility and appeal of the analytical relationships used to establish appropriate incentive payments for performance-based contracts under a social surplus maximisation (or value for money) subsidy scheme. In the current paper we focus on the transition-phase of introducing PBCs and set the ‘optimal’ subsidy budget to the existing operator-specific level. In a follow-up paper, Hensher and Houghton (in progress) generalise the approach to optimise the total subsidy budget under a ‘growth after transition’ schema.

The X^{MSL} level is determined exogenously to accommodate the demographics of the region and availability of other modes. For this case study, X^{MSL} is set for illustrative purposes to X^{MSL} = 0.67 of VKM . The value of the pure MSL subsidy, \$CSO, is based on \$2.60/VKM (peak) and \$2.30 (off-peak), which gives \$CSO= \$9,884,429. The subsidy budget of the illustrative cost-efficient operator is set to \$CSO for the pure-MSL strategy. The approach permits the entire range of contracts, from a pure-MSL to a pure-PBC and all mixes between. If the MSL component of the regulator’s subsidy scheme is reduced by *R*% of \$CSO, then X^{MSL} is reduced by *R*% of 0.67VKM and the subsidy budget allocated to PBC is the difference between TB and R% of \$CSO. A subsidy scheme incorporating a mix of MSL and performance-based contracts, with a relatively large MSL component and a relatively small PB component, is likely to be a politically acceptable first step into a PB contract regime, and is a specific interest of this paper. In particular we consider optimizing the structure of the scheme (starting with the existing 0.67VKM base and R=0) to establish what mix of MSL and above-MSL (ie performance based) service levels deliver a better value for money outcome than the baseline (ie current) MSL situation. An initial parity is established between alternative scheme mixes by holding RVKM, average fare, number of buses, patronage and costs fixed at the case B levels under what we refer to as the ‘calibration for parity’ (Section 4.1). We then allow RVKM, fares, fleet size, patronage and costs to change in the search for an improved solution (Section 4.2).

[23] We used the data from 12 operators to confirm benchmark best cost practice and then used other data from this operator as if they were the system-wide provider. This paper does not assume anything about the optimum number of contract areas or operators. This issue is detailed in Hensher (2002b).

The seven model parameters are shown in **Table 2**. Four parameters are available to the regulator to define the subsidy scheme; and the operators as a group have four parameters to establish operator strategy within the environment of the defined scheme.

Table 2: Model parameters

Parameter type	Parameter
Regulator parameters	*P*, *R*, *RVKM*(MSL), fare cap
Operator parameters	*q*, *RVKM*, κ, *#bus*

4.1. Calibration for Parity

Under a mixed scheme, the difference between TB and R% of $CSO is available to distribute a return to the operators for the consumer benefits generated by $Y>Y^{MSL}$. For a given total subsidy budget the pure-PBC scheme may be calibrated to achieve parity with the pure-MSL scheme, in the sense that a payout rate on (CS+EB) exhausts the subsidy and the optimum "standard" operator strategy is the base case B, where standard strategies preclude changes to #bus, service quality and fares. The pure-MSL outcome is given in **Table 3**. No calibration is required for the pure-MSL scheme which is defined by current regulator rates.

Table 3: Model outcome for the pure-MSL scheme

Model soln	X	q	#bus used	C	Y (ACC+S)	CS (ACC+S)	EB (ACC+S)	Y(MSL) (ACC+S)	X(MSL)		Funding		Retn on cost
P-O	1,986,429	1.44	70	2,916,035	4,083,932	4,289,576	532,368	3,781,614	1,523,475		TB	**9,884,429**	
change	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**2.10%**	**0.00%**	**0.00%**	**0.00%**		CS+EB PAY	0	
OP-O	3,358,000	1.52	36	13,048,221	2,794,325	2,253,562	259,467	2,412,741	2,575,389		FARES	6,291,216	
change	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**13.44%**	**0.00%**	**0.00%**	**0.00%**		CSO	9,884,429	
TOTAL	5,344,429	1.51	70	15,964,256	6,878,257	6,543,138	791,835	6,194,356	4,098,864		*less op COST*	15,964,256	
change	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**5.74%**	**0.00%**	**0.00%**	**0.00%**		prod surp	211,389	1.32%
TB	9,884,429										CS+EB	7,334,972	
					Y (S)	CS (S)	EB (S)	Y(MSL) (S)			SS	7,546,361	
		P			2,432,928	1,819,764	225,846	2,252,828			*less SS Cost*	9,884,429	
		0.000000%			**0.00%**	**0.00%**	**0.00%**	**0.00%**			net SS	-2,338,067	-23.65%
					221,220	92,881	10,694	191,011			TB undist	0	
		0.000000%			**0.00%**	**0.00%**	**0.00%**	**0.00%**	CB	PS	%PS	SS	%SS
					2,654,148	1,912,645	236,540	2,443,839	7,334,972	211,389	1.32%	7,546,361	-23.65%
					0.00%	**0.00%**	**0.00%**	**0.00%**	**5.09%**	**0.00%**	**0.00%**	**4.94%**	**-13.18%**
					Y (ACC)	CS (ACC)	EB (ACC)	Y(MSL) (ACC)					
					1,651,004	2,469,812	306,522	1,528,786					
					0.00%	**3.70%**	**0.00%**	**0.00%**					
					2,573,105	2,160,680	248,773	2,221,731					
					0.00%	**14.09%**	**0.00%**	**0.00%**					
					4,224,109	4,630,493	555,295	3,750,517					
					0.00%	**8.31%**	**0.00%**	**0.00%**					

For a patronage level corresponding to the optimum standard RVKM under the pure-PBC scheme, **Table 4 shows that** (*CS*+*EB*) exceeds the total budget by a substantial financial sum and cannot be paid in total to the operator. However, we can apply a non-negative payout rate, *P*<1, to (*CS*+*EB*) to distribute the reduced sum to the operator and ensure there is no subsidy blowout. P will vary with the proportionate PBC component (R) in the scheme. A payout rate of *P*=9.334436% gives the case B outcome for the pure PBC scheme, as shown in Table 4.

But there are many mixed regulator strategies between Pure-MSL and pure-PBC. The 5%-PBC regulator strategy includes a payout rate of P=5.086524%, and the model outcome is shown in **Table 5**. **Tables 4** and **5** show that all aspects of peak and off peak operator strategies are unchanged for the optimum outcomes under the pure-and-mixed PBC regulator strategy. It is clear that a mixed PBC scheme can always be found that provides an environment within which current best practice will lead to operator outcomes equivalent to the pure-MSL scheme, as summarised in **Table 6,** which shows the totals/averages of the optimum standard strategy. The case B operational strategies (X, q) and associated outcomes (Y, C) are optimum for the case B fleet size (#bus) and service quality level, fare increases below 5%, and the specified (R, P) values.

Table 4: Model outcome for the pure-PBC scheme

Model soln	X	q	#bus used	C	Y (ACC+S)	CS (ACC+S)	EB (ACC+S)	Y(MSL) (ACC+S)	X(MSL)
P-O	1,986,429	1.44	70	2,916,035	4,083,932	69,885,636	2,021,391	2,936,036	0
change	0.00%	0.00%	0.00%	0.00%	0.00%	1563.38%	279.70%	-22.36%	-100.00%
OP-O	3,358,000	1.52	36	13,048,221	2,794,325	33,096,947	888,108	1,488,235	0
change	0.00%	0.00%	0.00%	0.00%	0.00%	1565.98%	242.28%	-38.32%	-100.00%
TOTAL	5,344,429	1.51	70	15,964,256	6,878,257	102,982,583	2,909,499	4,424,270	0
change	0.00%	0.00%	0.00%	0.00%	0.00%	1564.22%	267.44%	-28.58%	-100.00%
TB	9,884,429								

Funding		Retn on cost
TB	9,884,429	
CS+EB PAY	9,884,429	
FARES	6,291,216	
CSO	0	
less op COST	15,964,256	
prod surp	211,389	1.32%
CS+EB	105,892,082	
SS	106,103,472	
less SS Cost	9,884,429	
net SS	96,219,043	973.44%
TB undist	0	

P
9.334436%
9.334436%

Y (S)	CS (S)	EB (S)	Y(MSL) (S)
2,432,928	29,647,536	857,533	1,749,090
0.00%	1529.20%	279.70%	-22.36%
221,220	1,364,099	36,604	117,820
0.00%	1368.65%	242.28%	-38.32%
2,654,148	31,011,635	894,137	1,866,910
0.00%	1521.40%	278.01%	-23.61%

CB	PS	%PS	SS	%SS
105,892,082	211,389	1.32%	106,103,472	973.44%
1417.10%	0.00%	0.00%	1375.45%	-3672.73%

Y (ACC)	CS (ACC)	EB (ACC)	Y(MSL) (ACC)
1,651,004	40,238,100	1,163,858	1,186,946
0.00%	1589.50%	279.70%	-22.36%
2,573,105	31,732,848	851,505	1,370,415
0.00%	1575.65%	242.28%	-38.32%
4,224,109	71,970,948	2,015,362	2,557,361
0.00%	1583.37%	262.94%	-31.81%

Table 5: Model outcome for the 5%-PBC scheme

Model soln	X	q	#bus used	C	Y (ACC+S)	CS (ACC+S)	EB (ACC+S)	Y(MSL) (ACC+S)	X(MSL)
P-O	1,986,429	1.44	70	2,916,035	4,083,932	5,781,122	616,106	3,734,061	1,447,301
change	0.00%	0.00%	0.00%	0.00%	0.00%	37.60%	15.73%	-1.26%	-5.00%
OP-O	3,358,000	1.52	36	13,048,221	2,794,325	3,020,438	298,627	2,355,151	2,446,620
change	0.00%	0.00%	0.00%	0.00%	0.00%	52.04%	15.09%	-2.39%	-5.00%
TOTAL	5,344,429	1.51	70	15,964,256	6,878,257	8,801,560	914,733	6,089,212	3,893,921
change	0.00%	0.00%	0.00%	0.00%	0.00%	42.23%	15.52%	-1.70%	-5.00%
TB	9,884,429								

Funding		Retn on cost
TB	9,884,429	
CS+EB PAY	494,222	
FARES	6,291,216	
CSO	9,390,207	
less op COST	15,964,256	
prod surp	211,389	1.32%
CS+EB	9,716,293	
SS	9,927,682	
less SS Cost	9,884,429	
net SS	43,253	0.44%
TB undist	0	

P
5.086524%
5.086524%

Y (S)	CS (S)	EB (S)	Y(MSL) (S)
2,432,928	2,452,522	261,370	2,224,499
0.00%	34.77%	15.73%	-1.26%
221,220	124,488	12,308	186,452
0.00%	34.03%	15.09%	-2.39%
2,654,148	2,577,010	273,678	2,410,950
0.00%	34.74%	15.70%	-1.35%

CB	PS	%PS	SS	%SS
9,716,293	211,389	1.32%	9,927,682	0.44%
39.20%	0.00%	0.00%	38.05%	-101.61%

Y (ACC)	CS (ACC)	EB (ACC)	Y(MSL) (ACC)
1,651,004	3,328,601	354,736	1,509,562
0.00%	39.76%	15.73%	-1.26%
2,573,105	2,895,950	286,319	2,168,700
0.00%	52.92%	15.09%	-2.39%
4,224,109	6,224,550	641,055	3,678,262
0.00%	45.59%	15.44%	-1.93%

Table 6: Optimum "standard" operator strategy for mixed PBC schemes

X	q	#bus	C	Y (ACC+S)
5,344,429	1.51	70	15,964,256	6,878,257

The summary scheme results for the pure schemes and mixed schemes up to 30%-PBC are shown in **Table 7**, where outcomes are totalled/averaged across periods. Outcomes for each regulator strategy specified by (R, P) pairs are shown in each row of the table, where the R value is clear from the first column and the P value is shown in the second column. The declining Y^{MSL} values from which consumer surplus and external benefits are computed for the specified schemes, are shown in column 4. Consumer surplus and external benefits, both of which generate operator income under PBC schemes, are shown in columns 5 and 6 as a proportion of patronage above Y^{MSL}. As such, they show the unit incentive payment per passenger trip (above MSL patronage) from consumer surplus and external benefits respectively. These payments increase as the PBC component of the scheme increases, reflecting the decreasing value of Y^{MSL} (note that the EB unit rate is averaged across all patronage above MSL even though it is applicable only to car switchers). The producer surplus (PS) rate is equal to the case B rate of return (1.32%), referred to as the normal rate of return, and CB shows the total consumer benefit. Column 6 shows the SS level improving with CB, but these are not comparable across schemes due to varying Y^{MSL}. (This will be addressed later)

Table 7: Scheme results for mixed PBC schemes

Scheme	X(MSL)	P	PS	CB	SS	%PS	%SS	CS*P /(Y-YMSL) (ACC+S)	EB*P /(Y-YMSL) (ACC+S)	Y(MSL) (ACC+S)
Pure MSL	4,098,864	0.000000%	211,389	7,334,972	7,546,362	1.32%	-23.65%	0.00	0.00	6,194,356
1%-PBC	4,057,875	1.269504%	211,389	7,786,067	7,997,457	1.32%	-19.09%	0.13	0.01	6,173,167
5%-PBC	3,893,921	5.086524%	211,389	9,716,293	9,927,682	1.32%	0.44%	0.57	0.06	6,089,212
10%-PBC	3,688,977	7.966483%	211,389	12,407,521	12,618,911	1.32%	27.66%	1.02	0.09	5,986,042
20%-PBC	3,279,091	10.577781%	211,389	18,689,043	18,900,432	1.32%	91.21%	1.69	0.12	5,785,458
30%-PBC	2,869,205	11.352685%	211,389	26,120,066	26,331,456	1.32%	166.39%	2.17	0.13	5,592,292
Pure PBC	0	9.334436%	211,389	105,892,082	106,103,472	1.32%	973.44%	3.92	0.11	4,424,270

Through optimising SS, the model provides an environment, as specified by the regulator parameters, consistent with the resulting maximum returns for both the operators and the regulator. **Table 7** has shown that, changing the proportion (R) of PBC in the subsidy scheme will always allow current best operator practice, with a given fleet size and service quality, to lead to operator outcomes equivalent to the pure-MSL scheme, as given by the case B outcome. In this paper, service quality is controlled through constraint (10), which requires extra buses if the service level measured by RVKM is to be increased. In the next section, fleet size is added to the standard operator strategy parameters to assess the potential for market growth.

4.2. Operator strategy

To maintain community service obligations while pursuing the case B outcomes, the operator strategies (X,q) used above restricted fare changes to ≤5%, and precluded optimisation over fleet size and service quality (κ). In the above environment, reductions to *RVKM* are restricted by the MSL, and the maximum fare increase, and increases are restricted by the fleet size and minimum service quality levels. In this section, the service quality level is maintained and *#bus* is added to the operator strategy parameters to allow market expansion. In this way we establish the gains for a benchmark operator by increasing the service level. The impact of unrestricted fare increases is also analysed. These operator strategies are analysed in the context of varying regulator parameter settings.

4.2.1. Operator strategy: fleet size

To assess the effectiveness of PBC schemes in providing an environment within which patronage may be commercially expanded, the operator strategy parameter *dbus*, which gives the increase in fleetsize, is applied to both peak and off-peak bus deployment. For each scheme ranging from 0%- to 100%-PBC we start from the calibrated scheme, with *dbus*=0, and establish the sensitivity of outcomes to increasing *dbus*.

The optimum *standard* outcome for the 5%-PBC scheme is shown in **Table 5**. Under 5%-PBC the return to the operator (PS) varies with increasing fleet size reaching a maximum of 6.7% when 3 buses are added to the fleet. This approximates the maximum return under all other PBC-schemes.

A feature of the operator strategies for the 5%-PBC scheme is that increasing RVKM is associated with decreasing total patronage. This is explained by contrasting operator strategies between the peak and off-peak periods outcome, which is apparent from **Table 8**. *In the peak period*, the service level increases with increasing *dbus* up to *dbus*=3 and is stable thereafter. Fares increase by 5% when *dbus*=1 and are stable thereafter, Costs increase steadily over the range of increasing fleet size[24]. *In the off-peak period*, the service level, patronage and costs decrease with increasing dbus up to *dbus=3* and these are stable thereafter. Fares increase to the maximum when dbus=2 and are stable at that level thereafter. The result of the different strategies for peak and off-peak periods is that as the fleet size increases over the range of 0≤*dbus*≤3, total RVKM, and patronage decrease and are stable thereafter; costs decrease over the same range and increase slowly thereafter. The reason for the diversity of strategies is that the limited TB is more profitably secured from the peak market until *dbus*=3, after which the peak and off-peak markets are both stable.

Table 8: Peak and off-peak operator strategies: R=5%

dbus	X(P)	X(OP)	X(TOT)	q(P)	q(OP)	q(TOT)	C(P)	C(OP)	C(TOT)	Y(P)	Y(OP)	Y(TOT)	%PS	%SS
0	1,986,429	3,358,000	5,344,429	1.44	1.52	1.51	2,916,035	13,048,221	15,964,256	4,083,932	2,794,325	6,878,257	1.32%	0.44%
1	2,014,806	3,274,865	5,289,671	1.51	1.55	1.55	2,959,395	12,681,966	15,641,361	4,086,454	2,725,145	6,811,599	3.99%	4.61%
2	2,043,184	3,174,066	5,217,250	1.51	1.60	1.58	2,999,640	12,253,681	15,253,321	4,104,961	2,638,954	6,743,915	6.55%	8.41%
3	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,010,246	12,216,677	15,226,923	4,106,293	2,634,320	6,740,613	6.70%	8.62%
4	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,018,515	12,216,677	15,235,193	4,106,293	2,634,320	6,740,613	6.64%	8.53%
5	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,026,808	12,216,677	15,243,485	4,106,293	2,634,320	6,740,613	6.58%	8.45%
6	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,035,123	12,216,677	15,251,800	4,106,293	2,634,320	6,740,613	6.52%	8.37%
7	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,043,461	12,216,677	15,260,139	4,106,293	2,634,320	6,740,613	6.47%	8.28%
8	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,051,822	12,216,677	15,268,500	4,106,293	2,634,320	6,740,613	6.41%	8.20%
9	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,060,206	12,216,677	15,276,884	4,106,293	2,634,320	6,740,613	6.35%	8.11%
10	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,068,613	12,216,677	15,285,291	4,106,293	2,634,320	6,740,613	6.29%	8.03%
11	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,077,044	12,216,677	15,293,721	4,106,293	2,634,320	6,740,613	6.23%	7.94%
12	2,045,252	3,165,718	5,210,971	1.51	1.60	1.58	3,085,497	12,216,677	15,302,174	4,106,293	2,634,320	6,740,613	6.17%	7.86%

[24] Total cost in Table 8 is initially greater at dbus=0 then decreases before increasing beyond 3 buses. The reason for the initial decrease in C(TOT) as dbus increases is that X(OP) is decreasing fairly rapidly at that time and the cost function has (XA-XB) in the exponent. This is required to implement the trade-off of Y(OP) for Y(P) through a trade-off of the corresponding X's. Also, the X(OP)/X(P) rate of exchange is very high due to the relatively low kappa (OP) compared to kappa (P), where kappa measures average bus loading rates.

Funds available for the PBC component of the 5%-PBC scheme are $494,222, and this is realised by bus operators as *P*(CS+EB) where P* is around 5.1%. Based on the optimisations, the PBC payments are shown in **Table 9** to reach a maximum, on average, of 68 cents per passenger trip.

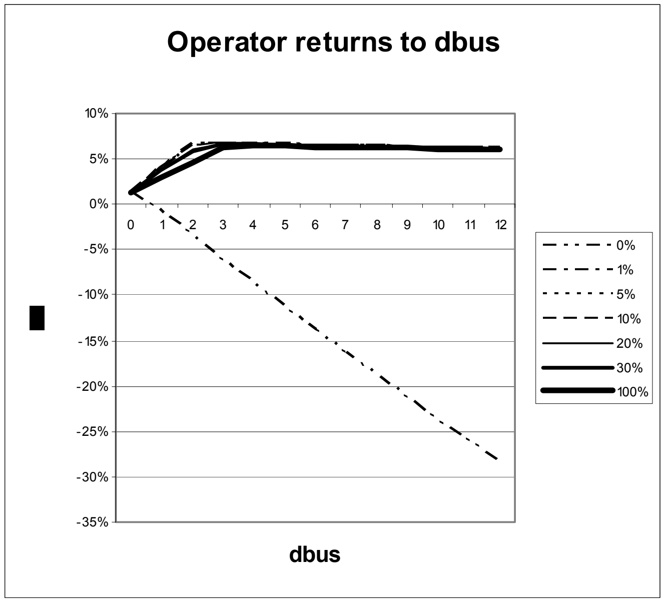
Table 9: Incentive payments
per trip: R=5%.

dbus	CS*P /(Y-YMSL) (ACC+S)	EB*P /(Y-YMSL) (ACC+S)
0	0.57	0.06
1	0.59	0.06
2	0.61	0.06
3	0.62	0.06
4	0.62	0.06
5	0.62	0.06
6	0.62	0.06
7	0.62	0.06
8	0.62	0.06
9	0.62	0.06
10	0.62	0.06
11	0.62	0.06
12	0.62	0.06

Similar analyses apply to operator strategies for other regulator schemes. In all cases the maximum achievable return to operators is around 6.7%.

Figure C shows that under 0%-PBC, SS is optimised by the operator maximising patronage in both peak and off-peak markets, by maximising RVKM and lowering fares to fill the buses available. This socially optimum strategy, with growing negative operator returns associated with increasing social surplus, is not practicable – the optimum social surplus will never be achieved. The dominant feature of **Figure C** is that the producer surplus rate functions for the various mixed-PBC schemes are similar, showing very little sensitivity to scheme parameters. The PS functions differ primarily for *dbus* up to 3, where they are in reverse order of R, indicating an operator preference for 1%-PBC.

Figure C: Operator Returns to Dbus for varying R (%PBC)



The contrasting behaviour between the pure-MSL and mixed-PBC schemes is the more interesting when related to the regulator surplus rate, as in **Figures D-F**. The model objective is to maximise the social surplus resulting from the regulator's scheme and the social surplus moves monotonously with the regulators surplus rate. **Figure D** shows that the interests of the operator are not consistent with those of the regulator for the pure-MSL scheme, but in Figures **E and F** these interests are seen to be aligned under PBC schemes. The important conclusion is that if the operator were to optimise performance under a given PBC scheme, the outcome will approximate that of the model. Indeed, the optimum operator strategy under all PBC schemes is *dbus*=3 and the other strategy components *X*, and *q* are as in the optimum social surplus outcome for the dbus=3 case. The significant conclusion, therefore, is that a mixed PBC scheme brings together the operator and regulator objectives, to provide approximately optimum social surplus outcomes.

Figure D: Operator and Societal Returns to Dbus for 0%PBC

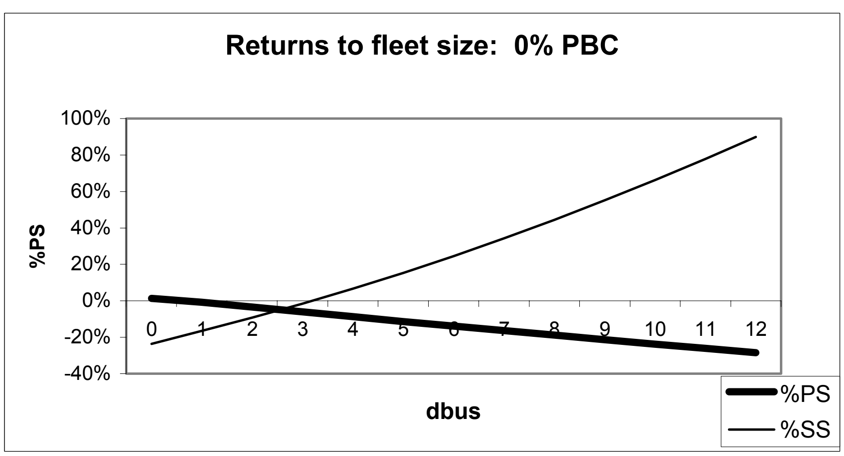


Figure E: Operator and Societal Returns to Dbus for 1%PBC

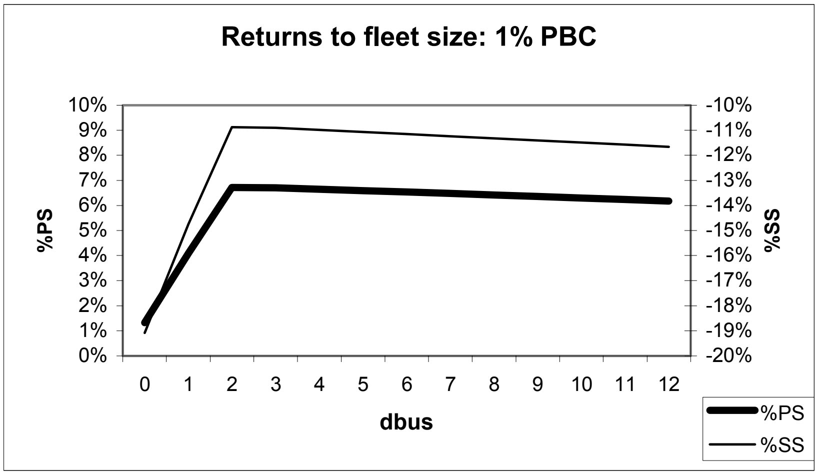
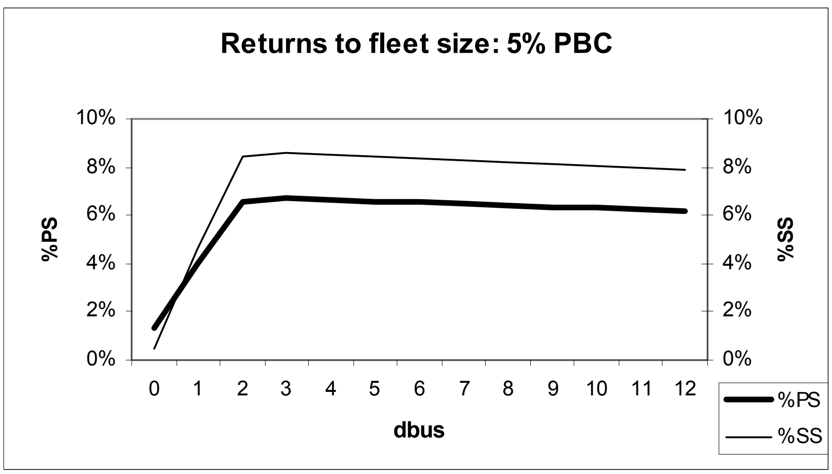


Figure : Operator and Societal Returns to Dbus for 5%PBC



Outcomes for social surplus are greatly influenced by the different Y^{MSL} points[25] for the alternative schemes and hence SS is not comparable across schemes. The schemes may be brought to comparability by adding to SS for each scheme, a single valued estimate of the consumer surplus *below* Y^{MSL}. These CS estimates are shown in **Table 10**. The result is to order the schemes' SS performance in reverse order of R. Given that R=0% has no practical value, best outcomes are indicated by 1%-PBC. Given the PS function as shown in **Figure E**, the optimum operator strategy is to increase the fleet size by two and implement the corresponding strategy as shown in **Table 11**. Incentive payments for 1%-PBC are shown in **Table 12**.

[25] As we change the value of R (or 1-R), the baseline patronage changes and makes all patronage above it eligible for an incentive payment (through the determination of CS + EB).

Table 10: CS below Y^{MSL} Estimates

R	0%	1%	5%	10%	20%	30%	100%
CS Below Y(MSL)	213,311,719	210,286,631	198,400,981	184,016,746	156,761,490	131,418,594	1,580,438

Table 11: Peak and off-peak operator strategies: R=1%

dbus	X(P)	X(OP)	X(TOT)	q(P)	q(OP)	q(TOT)	C(P)	C(OP)	C(TOT)	Y(P)	Y(OP)	Y(TOT)	%PS	%SS
0	1,986,429	3,358,000	5,344,429	1.44	1.52	1.51	2,916,035	13,048,221	15,964,256	4,083,932	2,794,325	6,878,257	1.32%	-19.09%
1	2,014,806	3,277,713	5,292,519	1.51	1.60	1.58	2,959,395	12,723,770	15,683,165	4,086,454	2,695,163	6,781,617	4.09%	-14.74%
2	2,043,184	3,167,667	5,210,851	1.51	1.60	1.58	2,999,640	12,225,303	15,224,943	4,104,961	2,635,403	6,740,364	6.72%	-10.88%
3	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,008,409	12,216,677	15,225,087	4,105,259	2,634,320	6,739,579	6.71%	-10.90%
4	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,016,674	12,216,677	15,233,351	4,105,259	2,634,320	6,739,579	6.65%	-10.98%
5	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,024,962	12,216,677	15,241,639	4,105,259	2,634,320	6,739,579	6.59%	-11.06%
6	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,033,272	12,216,677	15,249,949	4,105,259	2,634,320	6,739,579	6.53%	-11.15%
7	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,041,605	12,216,677	15,258,282	4,105,259	2,634,320	6,739,579	6.48%	-11.23%
8	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,049,961	12,216,677	15,266,638	4,105,259	2,634,320	6,739,579	6.42%	-11.32%
9	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,058,340	12,216,677	15,275,017	4,105,259	2,634,320	6,739,579	6.36%	-11.40%
10	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,066,742	12,216,677	15,283,419	4,105,259	2,634,320	6,739,579	6.30%	-11.49%
11	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,075,167	12,216,677	15,291,844	4,105,259	2,634,320	6,739,579	6.24%	-11.57%
12	2,043,646	3,165,718	5,209,365	1.51	1.60	1.58	3,083,615	12,216,677	15,300,292	4,105,259	2,634,320	6,739,579	6.18%	-11.66%

Table 12: Incentive payments per trip: R=1%

dbus	CS*P /(Y-YMSL) (ACC+S)	EB*P /(Y-YMSL) (ACC+S)
0	0.13	0.01
1	0.13	0.02
2	0.14	0.02
3	0.14	0.02
4	0.14	0.02
5	0.14	0.02
6	0.14	0.02
7	0.14	0.02
8	0.14	0.02
9	0.14	0.02
10	0.14	0.02
11	0.14	0.02
12	0.14	0.02

4.3. Operator strategy: fare bounds

In the above analysis, fares have been free of a lower bound, but an upper bound of 5% increase has been in place as described in the introduction to Section 2. An upper fare bound to 10% with schemes calibrated as in the 5% example gives very similar results, but the returns to operators are higher. Again, the operator return functions are similar across schemes and the preferred scheme is 1%-PBC. The operator strategies and incentive payments for 1%-PBC are shown in **Table 13** and **Table 14** respectively. The returns to fleet size, shown in **Figure G**, indicate a fleet size increase of 4, and the associated optimum strategy is shown in the corresponding row of **Table 13**.

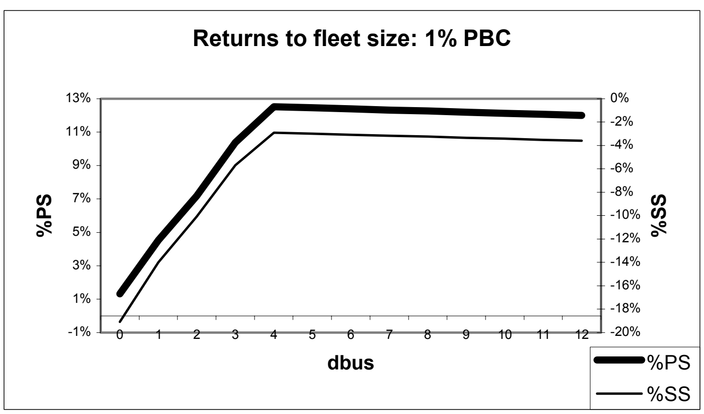
Table 13: Peak and off-peak operator strategies: R=1%, q(UB)=10%

dbus	X(P)	X(OP)	X(TOT)	q(P)	q(OP)	q(TOT)	C(P)	C(OP)	C(TOT)	Y(P)	Y(OP)	Y(TOT)	%PS	%SS
0	1,986,429	3,358,000	5,344,429	1.44	1.52	1.51	2,916,035	13,048,221	15,964,256	4,083,932	2,794,325	6,878,257	1.32%	-19.09%
1	2,014,806	3,292,858	5,307,664	1.59	1.67	1.66	2,963,186	12,844,858	15,808,044	4,070,113	2,647,894	6,718,007	4.53%	-13.98%
2	2,043,184	3,182,920	5,226,104	1.59	1.67	1.66	3,003,501	12,340,729	15,344,230	4,088,547	2,589,783	6,678,330	7.19%	-10.07%
3	2,071,562	3,051,104	5,122,665	1.59	1.67	1.66	3,044,465	11,765,347	14,809,812	4,106,556	2,516,475	6,623,031	10.37%	-5.68%
4	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,071,521	11,389,015	14,460,536	4,116,526	2,463,860	6,580,385	12.53%	-2.90%
5	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,079,959	11,389,015	14,468,974	4,116,526	2,463,860	6,580,385	12.46%	-2.99%
6	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,088,420	11,389,015	14,477,435	4,116,526	2,463,860	6,580,385	12.40%	-3.07%
7	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,096,905	11,389,015	14,485,920	4,116,526	2,463,860	6,580,385	12.33%	-3.16%
8	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,105,413	11,389,015	14,494,428	4,116,526	2,463,860	6,580,385	12.26%	-3.25%
9	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,113,944	11,389,015	14,502,959	4,116,526	2,463,860	6,580,385	12.20%	-3.33%
10	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,122,499	11,389,015	14,511,514	4,116,526	2,463,860	6,580,385	12.13%	-3.42%
11	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,131,077	11,389,015	14,520,092	4,116,526	2,463,860	6,580,385	12.07%	-3.51%
12	2,087,558	2,960,873	5,048,431	1.59	1.67	1.66	3,139,679	11,389,015	14,528,694	4,116,526	2,463,860	6,580,385	12.00%	-3.59%

Table 14: Incentive payments per trip: R=1%, q(UB)=10%

dbus	CS*P /(Y-YMSL) (ACC+S)	EB*P /(Y-YMSL) (ACC+S)
0	0.13	0.01
1	0.13	0.02
2	0.14	0.02
3	0.15	0.02
4	0.16	0.02
5	0.16	0.02
6	0.16	0.02
7	0.16	0.02
8	0.16	0.02
9	0.16	0.02
10	0.16	0.02
11	0.16	0.02
12	0.16	0.02

Figure G: Returns to fleet size and social surplus: R=1%, q(UB)=10%



The approach taken in this paper has been to define a set of regulator schemes (R, P) where P calibrates the "standard" operator strategy under R, and to allow operators to optimise their strategy within that scheme. The advantage of the proposed approach is that it aligns the interests of operator and regulator for all non-standard strategies, so that the operator left to optimise corporate performance will be working in the social interest. It is possible to calibrate other strategies, but this alignment-of-interests property is then lost.

4.4 The Preferred Transition Position for Reform in the Outer Metropolitan Area of Sydney

The previous sections present a large number of potential 'solutions'. Although we have discussed the range of outcomes based on specific assumptions such as the mix of MSL and PBC components and resulting user and environmental externality benefits together with the rates of return to the operator and the subsidy allocation, it is appropriate to conclude with what might appear to be a good starting set of condition for the introduction of performance-based contracts. A practitioner's guide to the recommended transition strategy is summarised in point form in Appendix A.

Assuming that the regulator will require an MSL component to the delivery of services, we recommend that the CSO payment for MSL delivery should be based on \$2.60 in the peak and \$2.30 in the off-peak per vehicle kilometre. The establishment of the incentive payment rates is determined externally for the environmental benefits (respectively for outer urban operators of \$0.627/car vkm for peak travel and \$0.177/car vkm for off-peak travel). The rate for user benefit (ie consumer surplus) per bus passenger trip is determined by the optimisation procedure, conditional on the proportion of the CSO to be implemented (1-R) and the incentive *payout rate* to the operators (P). Given a subsidy scheme defined as 1%-PBC with a payout rate of P=1.269504% and a total subsidy budget of TB=\$9,884,429, if fares are bounded above by a 5% increase, the benchmark operator may be expected to increase fleet size by two buses for a return on operator investment (PS) of 6.7%, and the average user benefit per passenger incentive payment may be expected to be \$0.14. This is additional to an average fare of \$1.51 (peak) and \$1.60 (off-peak). If fares are bounded above by a 10% increase, the benchmark operator may be expected to increase the fleet size by 4 for a return on operator investment (PS) of 12.53%, and the average user benefit per passenger incentive payment may be expected to be \$0.18. This is additional to an average fare of \$1.59 (peak) and \$1.67 (off-peak). The unit rate of incentive payment has been derived by averaging across all passenger trips above MSL even though the EB unit rate only applies to converted car VKM. The adoption of an average incentive payment per passenger trip above Y^{MSL} makes for a very simple administrative formula.

5. Conclusions

Performance-based contracts (PBCs) have emerged as a practical contracting regime with many virtues. Under a transparent partnership between the regulator and the service provider, a PBC offers a most effective way of delivering transport services, ensuring over time that the allocation of subsidy is determined optimally *from a system-wide perspective*, not on an individual contract by individual contract basis (as would be required under other contracting regimes)[26]. In achieving system-wide optimisation, all

[26] There is growing concern in England that concessionary fare subsidies are not matched by appropriate 'deliverable and measurable outputs' (DLTR 2002). The Director-General of the Greater Manchester Passenger Transport Executive stated in a submission to the House of Commons Transport Select Committee's inquiry on the bus industry that "We would like to reach a point where all the money paid to the bus industry is linked in some way to outputs'. The most interesting feature of the reform proposal is, over a 3-5 year period, to transfer some or all of the concessionary fares budget into a central pot. Operators would then be asked to come forward with proposals for delivering a network of commercial and supported services determined by the central authority and 10 metropolitan governments. This has been described as 'voluntary quality contracts' that push at the limits of quality partnerships but which is

parties should share the risks and rewards that quality partnerships can deliver (in contrast competitive tendering[27] suggests a principal-agent relationship which is not as partnership compatible).

The proposed system of subsidy which makes profit maximisation on the part of operators and social surplus maximisation coincide appears to offer a very attractive contract regime. Nash and Jansson (2002) in reviewing alternative reform schemes introduced over the last 15 years, conclude that "the regulatory phase could be better managed this time round, with an emphasis on 'light touch' regulation, perhaps combined with the appropriate use of subsidies per passenger kilometre and infrastructure charges to incentivise the franchisee to provide the socially optimum fares/service combination'. This is the intent of PBCs both in transition and post-transition.

The method developed and implemented in this paper is sufficiently flexible to be applicable under a large number of regulatory and operating regimes. For example, it is feasible to consider alternative fare increase caps, different aggregate subsidy budget levels (be they increments of decrements on existing levels), variations in minimum-service levels and incentive payment rates for environmental benefits, and acceptable commercial returns. The ability to recognise the full extent of consumer (ie user) surplus benefits to society and to determine the amount that might reasonable be paid to operators to ensure that the returns are incentive-compatible, without delivering unacceptable high rates of return on investment from the provision of public funds, is a very appealing feature of the approach.

Looking ahead, it is important to keep in mind that the model developed herein is a model for the benchmark (in terms of cost efficiency) operator who begins from an optimum position. The model performance reflects this. Hence it is an appealing transition model. With the existing #bus the case B solution is optimum; and, as the fleet is expanded, improved "non-standard" strategies are found. These are, however, trade-off positions, typically involving an expansion in the peak period and a cut back in the off-peak period. The trade-off is required by the total subsidy budget and is consistent with PBC funding being essential for a benchmark operator's expansion.

The approach of optimising within a given R, and calibrating to the "standard" strategy is fundamental to the specific PBC implementation strategy. First, SS comparisons across R are not made within the model (nor should they be); and second, calibrating to other strategies departs from the assumption of a benchmark operator, and also provides

necessary to improve the increasingly poor quality of service levels of bus provision (which has evolved out of economic deregulation and competitive tendering of non-commercial services).

[27] Although competitive tendering of PBC's is possible it must be based on a selection system that involves quality criteria rather than the conventional tendering processes (is the 'lowest price wins'). Telemark County in southern Norway has recently adopted this model, although it is too early to see how it compares with PBC's per se. The ability to optimise system-wide social surplus still remains a challenge however. In a recent review of competitive tendering in Adelaide and Perth, Bray (2002) in commenting on Hensher and Stanley (2002) statement 'performance based contracts should deliver better long-term value for money to governments and consumers than the competitive tendering (CT) of bus contracts' concludes that 'they may well be correct'. He then asks a question: "If the CT process was run again in Perth and Adelaide would any further meaningful savings be achieved particularly when considering the enormous cost of the tendering process for regulators and operators?".

schemes with competing operator-regulator interests. An unrestricted optimisation across R, P, X, q, and dbus will give the nonsense outcome: R=100%, P is calibrated to 100% and %PS is large and negative.

Hensher and Houghton (in progress) recognise that the PBC framework developed herein can be extended beyond the transition stage, to encourage growth from transition, and to establish the social surplus maximisation solution under an unconstrained total subsidy budget. This stage of growth after transition will consolidate the fuller extent of value for money under a PBC regime. The transition stage however is crucial in an environment where established operators have demonstrated (to varying degrees) the ability to deliver service quality. The transition to an incentive-compatible contract scheme should ensure greater gains to society in the future which may have been denied by the existing contract regime[28]. Future research will develop decision rules for applying the scheme in new regions.

Acknowledgements

The comments of Erik Carlquist, Odd Larsen, Nils Fearnley, Darryl Mellish and John Stanley are very much appreciated as is the feedback from numerous bus operators and regulators in Australia. We are indebted to Stephen Rowe and Busways for providing the data required to illustrate the implementation of the PBC system. The opportunity to discuss our ideas with John Rogan and Johanna Quilty of Transport NSW is gratefully appreciated (especially in the development of the transition scheme).

References

Bray, A. (2002) Competitive performance, *Australasian Bus and Coach*, 14 (10), June, 22-29.

Bus Industry Confederation (2001) Getting the Prices Right: Policy for More Sustainable Fuel Taxation for Road Transport in Australia, Submission to the Commonwealth Fuel Tax Inquiry, October.

Carlquist, Erik (2001) Incentive contracts in Norwegian local public transport: the Hordaland model, paper presented at the *7th International Conference on Competition and Ownership of Land Passenger Transport*, Molde, Norway, June.

de Weger, T.H.D. and de Jong, L. (2001) PT infrastructure for bus systems in the Netherlands, paper presented at the *7th International Conference on Competition and Ownership of Land Passenger Transport*, Molde, Norway, June.

[28] Benchmark operators (as we have analysed in the case study) claim all of the subsidy budget by moving to their existing (developed) position. But lesser operators will be more seriously influenced by the percentage of PBC in the scheme. At 1%PBC, 1%TB is spread over service levels from 99%MSL to MSL+ development potential, and the lesser operator is unlikely to be much influenced to change. Consider, therefore, an increasing %PBC, where the increase is staged in a way that allows adequate time for operators to progressively improve efficiency as the scheme moves increasingly further away from the status quo. The final position would be 100%-PBC over the range 0% MSL to the full development potential. Hensher and Houghton (in progress) present this range of opportunities.

Department of Transport, Local Government and Regions (DTLR) (2002) *Transport Statistics Bulletin Survey of Concessionary Bus Fare Schemes in England 2001*, DTLR, London.

Fearnley, N. and Carlquist, E. (2001) A tale of seven cities: subsidy reductions in Norwegian public transport, paper presented at the *7th International Conference on Competition and Ownership of Land Passenger Transport*, Molde, Norway, June.

Hensher, D.A. (2002) A systematic assessment of the environmental impacts of transport policy: an end use perspective, Invitational paper for a Special Issue of *Environmental and Resource Economics* on 'Tools of the Trade for Environmental Economists' guest edited by Richard Carson, 22, 185-217.

Hensher, D.A. (2002a) *Urban public transport delivery in Australia: issues and challenges in retaining and growing patronage*, Institute of Transport Studies, The University of Sydney, May.

Hensher, D.A. (2002b) *Contract areas and integrated fares for public transit provision: some thoughts,*, Institute of Transport Studies, The University of Sydney, July.

Hensher, D.A. and Houghton, E. (in progress) *Growth after transition under performance-based contracts,*, Institute of Transport Studies, The University of Sydney.

Hensher, D. and Macario, R. (2002) Organisation and ownership of public transport services, *Transport Reviews*

Hensher, D.A, and Prioni, P. (2002) A service quality index for area-wide contract performance assessment regime, *Journal of Transport Economics and Policy*

Hensher, D.A. and Stanley, J. K. (2002) Performance-based quality contracts, Institute of Transport Studies, University of Sydney, June (version 2.7a).

Hensher, D.A., Stopher, P.R. and Bullock, P. (2002) Benchmarking and service quality at a market segment level, (presented at the 2002 *Annual Transportation Research Board Conference*, Washington DC.) *Transportation Research A*.

Jansson, J.O. (1984) *Transport System Optimization and Pricing*, Wiley, New York.

Jansson, J.O. (2001) Efficient modal split, paper presented at the *7th International Conference on Competition and Ownership of Land Passenger Transport*, Molde, Norway, June.

Johansen, K.W., Larsen, O. and Norheim, B. (2001), Towards economic efficiency in public transport, *Journal of Transport Economics and Policy*, 35 (3), 491-511.

Larsen, O I. (1996) Efficient public transit subsidies. In Hensher, D.A., King, J. and Oum, T. A. (eds): *Proceedings of the 7th World Conference on Transport Research*, Pergamon Press, Oxford, Vol 3, 225-236.

Larsen, O. I. (2001) Designing incentive schemes for public transport operators in Hordaland County, Norway, paper presented at the 7th *International Conference on Competition and Ownership of Land Passenger Transport*, Molde, Norway, June

Mills, G. and Gale, J. (2002) Funding of public transport and infrastructure: Theme D, workshop report *7th International Conference on Competition and Ownership of Land Passenger Transport*, Transport Reviews.

Nash, C.A. and Jansson, K. (2002) Competition and regulation in public transport: Theme B, workshop report *7th International Conference on Competition and Ownership of Land Passenger Transport*, Transport Reviews.

Prioni, P. and Hensher, D.A.(2000) Measuring service quality in scheduled bus services, *Journal of Public Transport*, 3 (2), 51-74.

Sansom, T., Nash, C., Mackie, P., Shires, J. and Watkiss, P. (2002) *Surface Transport Costs and Charges: Great Britain 1998*, Institute for Transport Studies, University of Leeds.

Ton, T. and Hensher, D.A. (1997) RouteInfo - A GIS based bus planning program for route planning and establishing minimum service levels *Proceedings of the 21st Australasian Transport Research Forum*, 21 (Part 2), 869-884.

Appendix A: A Summary of the Main Features of a Practical PBC Transitional Scheme for Sydney

1. This appendix sets out the main elements of a PBC system introduced in a transition phase before moving to a fuller PBC scheme. In the transition phase we commit the government to the exact same level of financial support as currently received under each contract. The majority of this support is from the school subsidy transport scheme (SSTS) and concessional reimbursements.

2. We call this total support TB (total subsidy budget). It will be imposed in the transition phase as an upper limit. The method developed in the body of the paper enables us to vary the TB upwards (or downwards) which will be desirable in the post-transition phase as government seeks out the best value for money solution.

3. Maintaining the notion of a minimum service level (MSL), the first step is to identify the community service obligation ($CSO) payment in order to see what will be left over from TSB as an incentive payment (provided patronage is grown). (An important aside: any concern about an operator's ability to survive without high CSO payments does not become an issue since the PBC scheme in the transition phase will support existing financial arrangements).

4. Calculation of $CSO requires determination of the appropriate MSL. We will base it on existing levels as defined by RVKM (revenue vehicle kilometres). Given RVKM associated with MSL and average fare (as well as the existing ratio of seating capacity and RVKM (a proxy for service quality)), the PBC method uses a simple demand model to establish patronage levels associated

with MSL (see Section 3). We distinguish 'adults, children and concession' (ACC) from 'school children' (S), since the fare level does not apply in the latter's demand model.

5. The resulting patronage is called Y^{MSL}. This patronage has a fare associated with it (if ACC) which is collected and kept by the operator in addition to the $CSO, the latter based on $/VKM multiplied by $RVKM^{MSL}$. We are using benchmarked best practice costs ($2.60 for peak and $2.30 for off-peak) for private operators in Sydney. These unit costs could be varied if there is evidence to support an equity-adjusted cost efficient benchmark. (SSTS and all concessions reimbursements are no longer paid, which is a huge administration gain).

6. The total revenue associated with $CSO plus Y^{MSL} patronage fares can be built on by attracting additional patronage (above Y^{MSL}).

7. Given that we want to ensure that society gets value for money in the spending of TB, we need a way of calculating the maximum achievable social surplus. This involves recognising that the social surplus may well exceed TB and hence the operator should get only part of this social surplus.

8. Because of different capabilities of operators to attract patronage (because of different operating environments) we need a way of ensuring some equity in establishing the incentive payment available. We do this by taking each operating area and running the social surplus (SS) maximisation model in which we hold $CSO fixed but allow VKM(RVKM) to increase above $VKM(RVKM)^{MSL}$, fares to vary up or down with a 5% cap on fare increases, and fleet size to increase but holding service quality fixed (the latter defined by ratio of seating capacity and patronage, must not decline).

9. This SS maximisation model (developed and detailed in the body of the paper) will enable us to identify the most likely achievable patronage growth (ie patronage above MSL level), some of which operators already have by providing better than MSL services.

10. The additional patronage will pay fares (if ACC) or travel for free if they are school children (our model makes this distinction). Together with $CSO and fare revenue for MSL-level patronage, we can calculate the total fare and CSO payment revenue. The difference between TB and ($CSO plus all fare revenue) is the amount available as incentive payments to be paid out for the additional patronage. (Note: this is determined by our fixed TB).

11. Under the fixed TB, all incentive payments would actually be distributed because they are achievable (ie passenger trips above Y^{MSL} are already being undertaken). However if TB were further increased, that money would not be automatically provided without additional patronage growth.(This latter growth is linked with what we refer to as '*growth after transition*') But now we have an appropriate framework to ensure that each additional subsidy dollar delivers value for money.

12. When we compare all income sources to the total annual costs of running the business including an acceptable return on investment we should have operator balance.

13. What we have is a contract system that has led to the removal of SSTS and concessional reimbursements and re-focused on incentives to grow patronage. Although the case study in the body of the paper imposes a budget limit based on the existing TB level, it is now possible for the government to increase TB but only return the increase to the operator if they grow patronage. We now have an incentive-compatible contract scheme for the first time.

Appendix B: Partial withholding of fare revenue

The model may be used to test a variety of scenarios, in the manner of the 10% fare cap in the text. In this appendix we consider an alternative scenario to assess the effect of a partial withholding of fare revenue. Here, the regulator withdraws from the operator, fare revenue generated by $Y<Y^{MSL}$. The motivation is the belief that operators are already paid at benchmark cost rates for $X\leq X^{MSL}$ and fare revenue would repeat the payment. However, the fares are currently a part of the operator's revenue, and the total subsidy budget (*TB*) has replaced the SSTS subsidy. On this basis, the benchmark operator has expanded the service level to its current level which exceeds X^{MSL} by 50%. Clearly, if the service level is to be maintained, withdrawing the fare revenue as proposed will convert the current 1.32% rate of return into a serious loss.

Outcomes are shown in **Figure Z**, where optimum rates of return across R for both the operator and the regulator are seen to be negative. Clearly, the scenario is impracticable.

Figure Z: OPTIMUM %PS AND %SS FOR SCENARIO 3