Modelling Quality Bus Partnerships[1,2]

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Introduction

Quality Bus Partnerships (QBPs) are defined as an agreement (either formal or informal) between one or more local authorities and one or more bus operators for measures to be taken up by more than one party to enhance bus services in a defined area. (TAS, 1997). They arise from the fact that no single organisation has control over all of the factors that govern the quality of supply of bus services. Partnerships between the relevant agents are therefore seen as a way to overcome this problem. Typically they involve the local authority providing traffic-management schemes that assist bus services, while the bus operator offers better quality is various dimensions.

By definition, the introduction of a QBP will alter the quality of bus service provided. This is likely to have implications for passenger demand and the cost of operations, which in turn will influence the degree and type of competition between operators. It is the aim of this paper to provide a framework to determine the effect that QBPs may have on the structure of the bus market. To this end, we have developed a bus operations model capable of forecasting the outcome of different competitive situations and in particular the effect of Quality Partnerships on market structure and performance.

Crucial is the need to be able to model the effects at corridor level, understanding the dynamics of competition. Therefore the main modelling effort has been at the corridor level. We have worked on the assumption that there exist well-defined corridors which form the basis for operator strategies, which might be profit centres for operators, and which may be the subject of QBP arrangements. Although clearly not picking up all QBPs, this is a realistic description of many.

In terms of what the model actually does, it has been designed to answer the following questions:

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- is the QBP likely to generate benefits (for users, operators, other road users, society at large);
- is the QBP needlessly restrictive;
- under what circumstances may a QBP eliminate competition;
- will a good share of the benefits accrue to consumers?

The parameters within the model can be set flexibly enough to be capable of dealing with various levels of spatial interaction and competition between routes. Model outcomes are determined by

- the relevant values and elasticities on walk, wait, in-vehicle time, comfort and fare, some of which are known with more confidence than others;
- costs related to distance, time and peak vehicles required;
- cost differences between operators;
- the relevant fare and service strategies adopted by operators.
- inter-operator elasticities.

In the remainder of this paper, we outline the workings of the model; examine the derivation of theoretically consistent demand elasticities; and demonstrate the usefulness of the model in a case study.

Model structure

We have developed a model structure that is simple but flexible enough to deal with a variety of QBP arrangements. Working on the assumption that there exist well-defined corridors that form the basis for operator strategies the model consists of a series of n zones, with j parallel bus routes running through each zone. Demand for travel between any two zones in the network is then allocated to available individual services (e.g. the 0704 departure from zone 2 on route 1) according to the sensitivity of demand to the generalised cost of travel and the socio-economic characteristics of the travellers. Although clearly not picking up all QBPs, this network specification is a realistic description of many QBP arrangements and can be used to examine competition between QBP and non-QBP operators on the same or parallel routes.

The temporal aspects of the model are constrained, by and large, by the availability of base input data. For example, if data on base demand levels is only available as daily totals there is little point in trying to successfully model the spread of traffic throughout the day. We have set the default timescale for the model to be a representative one-hour period. Here, the analyst can run the model for key hour periods during the day/week/season and gross-up the estimates to give weekly or annual totals. With relatively minor changes to the source code, the model can be set up to cover any time period desired. A key requirement of the model is that it should be able to predict year round profitability. Applications of the model should therefore take account of seasonality.

The cost model

On the cost side, we have used an approach similar to the CIPFA fully-allocated costs method which relates costs to vehicle hours, vehicle miles and the peak vehicle requirement. While this is not perfect from an economist's perspective, it is essentially the approach used by operators in determining how much various aspects of their operations cost and thus is a sound basis for mimicing operators' decisions.

The Chartered Institute of Public Finance and Accountancy (CIPFA) developed a fully allocated cost formula for the National Bus Company in 1974 (CIPFA, 1974). The formula attempts to allocate variable, semi-variable and fixed costs to measures of physical output, and identifies three measures of physical output to which costs can be allocated:

(i) Fuel, oil and tyre costs were allocated on the basis of distance operated, that is they were allocated according to vehicle kilometres (VKM);
(ii) Staff costs and vehicle maintenance costs were allocated on the basis of time operated, that is they were allocated according to vehicle hours (VH);
(iii) Vehicle depreciation and building costs were allocated according to peak vehicles (V).

An example of the fully allocated costing approach is given below. As can be seen, total costs are a linear function of VH, VM and V, with average cost (in terms of vehicle miles) being inversely proportional to speed (VKM/VH) and vehicle utilisation (VKM/V) which is itself determined by the peakiness of the operation.

$$TC = aVH + bVKM + cV$$

From DETR (2000) we have established that for an average vehicle in 1999, a=£16.41 per vehicle hour, b=£0.091 per vehicle km, and c=£15.16 per vehicle. To more accurately reflect costs it will be sensible to develop the model to reflect different vehicle types (mini, midi, single deck, double deck, low floor), different local operating conditions and different levels of quality (QBP and non-QBP traffic).

Passenger Infrastructure Costs

Passenger infrastructure costs can vary considerably across QBP types, a reflection of both the diversity of the road systems covered by QBP areas and the passenger infrastructure elements that are included in a QBP. Given this it is impossible to arrive at a universal average cost figure for QBPs, nor is it possible to report an average figure for similar types of QBPs (for example, those with high quality infrastructure), e.g. the average kilometre cost of the Line 33 QBP in Birmingham is around £150k, whilst in Edinburgh the cost per kilometre of Greenways is around £310k. What are therefore required are some detailed costs of specific attributes. At a recent QBP Conference organised by TAS (June, 2000), Clive Evans from CENTRO outlined some specific costs (2000 prices) associated with some QBPs:

- £8k to provide a Kassel kerb and paving at a bus stop;
- Driver training at £200 each;
- £6.2k for real time information at each bus stop; and

- £4.5 for a high specification QBP bus shelter.

The demand model

On the demand side, we assume the individual to be the decision-making unit and that all decisions are taken at point of sale. Using decision rules based on utility maximising, a given individual has to consider:

- whether or not to make the journey, and
- which mode to use.

We call this a 'level 2' or upper-level decision. If the individual chooses to make a journey and travel by bus, the following additional considerations are of interest:

- which stop to board and alight (if available),
- which operator to travel with (if available),
- which service to use (time of departure), and
- which ticket type to use.

We call this a 'level 1' or lower level decision. Note that, although for analytical and modelling convenience we have structured the problem hierarchically, this does NOT mean that individuals are assumed to take decisions in this way. This two-stage process allows for the allocation of passengers between operators and also allows for the overall size of the bus market to expand or contract as service levels change.

<u>Choice of Service (level 1)</u>

For a given individual (i) travelling between a given OD pair, the choice between available services is modelled as a function of the generalised cost of travel for each service (s). Here, generalised cost is represented by the fare paid plus a cost attribute vector, comprising in-vehicle time, adjustment time, ticket flexibility, and operator quality.

$$GC_{is}^{OD} = Fare_{is}^{OD} + \sum_{x=1}^{X} \alpha_{ix} C_{isx}^{OD} \tag{1}$$

where fare is taken to be average fare per trip, C_x is cost attribute x (e.g. in-vehicle time), and α_x is its associated monetary value (e.g. value of time).

By making some assumptions about the distribution of bus user characteristics (child, adult, pensioner) and their most desired departure times, we can derive the probability that an individual will choose a particular service (P_{is}) by way of a multinomial logit model:

$$P_s = \frac{\exp(-\theta_1 GC_s)}{\sum_{s=1}^{S} \exp(-\theta_1 GC_s)} \tag{2}$$

where θ_1 is the spread parameter that governs the sensitivity of choice to changes in generalised cost. As the value of θ_1 approaches zero, market share is split equally between all S options whereas as the value of θ_1 increases, the market share of the option with the lowest generalised cost tends to one. The value of θ_1 therefore determines the cross elasticity between services.

The market share for each service (route, departure-time, operator and ticket type) is taken as the average probability of using each service over all simulated individuals.

Choice of Mode (level 2)

The upper level of the model is concerned with mode choice and therefore the overall size of the bus market. This decision is modelled by way of an incremental logit model and is based on the overall attractiveness of bus services relative to other modes and not travelling at all.

$$P'_m = \frac{P_m \exp(\Delta V_m)}{\sum_{m=1}^{M} P_m \exp(\Delta V_m)} \tag{3}$$

where:

P'_m is the new probability of choosing mode m

P_m is the base probability of choosing mode m

$\Delta V_m = \theta_2 (EMU_m^{new} - EMU_m^{base})$

$EMU_m = Expected\ \ Maximum\ \ Utility = \log(\sum_{s=1}^{S} \exp(-\theta_1 GC_s))$

θ_2 is a structural coefficient ($0<\theta_2<1$)

Here θ_2 governs the sensitivity of individuals to changes in the level of bus services offered and is determined by the elasticity of demand for bus travel. We have chosen to use an incremental logit at this level so we can hold factors external to the bus market constant during the modelling process. This model pivots around existing market shares as a function of changes in the overall level of service and fares in the bus market (ΔV_b).

From the description of the demand model presented above, it is clear that there are three elements needed for model calibration. Firstly, evidence is needed on passengers' monetary valuation of bus journey attributes, for example, their value of time. Secondly, evidence is needed on the sensitivity of travellers to changes in generalised cost (or an element of generalised cost) between services. We therefore need information on cross elasticities between services to determine the θ_1 spread parameter. Finally, evidence on the overall sensitivity of the market with regard to changes in generalised cost (or elements of generalised costs) is needed to determine the θ_2 structural parameter. This information will come from well-documented evidence on fare elasticities. However, there are some theoretical relationships between these parameters and the elasticities which can help us to reduce the information requirements and, at the same time, ensure internal consistency (Taplin, 1982; Toner, 1993). It is to the these we turn in the following section..

The model outlined above produces snap shots of company profits (revenue minus costs) under different operating assumptions. There is also an evaluation module which estimates changes in consumers' surplus. At the moment, this uses the rule-of-a-half, though this may change in the future. Thus, by adjusting the input parameters and the assumptions about competitive behaviour, the outcomes under different scenarios can be tested, including:

two operators matching frequencies;
unequal frequencies but both in scheme;
unequal frequencies and not all in scheme;
fares competition.

As a result of this, we are able to assess whether market entry is any of: (a) feasible; (b) sustainable; and/or (c) desirable and thus whether Quality Bus Partnerships can yield the advantages claimed for them for the main parties concerned – users, local authorities and operators.

Internal demand elasticity relationships

In general, we will refer to ε_{ij} as the ordinary (or Marshallian) elasticity of demand for good i with respect to the price of good j. The effect on demand of a price change as represented by such an elasticity comprises a substitution effect and an income effect. These are the elasticities most commonly estimated in practice by analysts studying demand for particular goods.

There are two key properties of systems of demand equations which we use: the homogeneity condition; and the symmetry condition (see, for example, Silberberg, 1978). It is possible to use these rules in a restricted system to estimate relevant elasticities with only partial information (Toner, 1993). Using h to denote compensated elasticities, it is easy to show that there is a direct relationship between pairs of cross elasticities:

$p_i x_i h_{ij} = p_j x_j h_{ji}$

In the case where we use ordinary (Marshallian) elasticities, there needs to be an adjustment to take account of the income effects. The relationship between compensated elasticities (denoted h) and Marshallian elasticities (denoted ε) is given by:

$\varepsilon_{ij} + \kappa_j \varepsilon_{iY} = h_{ij}$ where κ_j is the share of income spent on good j and ε_{iY} is the income elasticity of demand for i.

So, using Marshallian elasticities and rearranging, we have

$\kappa_i \varepsilon_{ij} = \kappa_j \varepsilon_{ji} + \kappa_i \kappa_j (\varepsilon_{jY} - \varepsilon_{iY})$

Thus if the income elasticities for i and j are the same, there is still a directly symmetrical relationship between the cross elasticities. Even if this is not the case, if the proportion of income spent on i and j is small (say 10% on each) then the adjustment is only 0.01 times the difference in income elasticities.

So far, so good. Now, suppose that goods i and j are bus trips by two different operators (or, indeed, two services of the same operator). It is clearly too much to consider the relationship between these and every other commodity, but it is possible to construct a theoretical composite good "everything else" and still make the homogeneity and symmetry conditions hold. So, denoting the composite good by the subscript e, we have

$$\varepsilon_{ii} + \varepsilon_{ij} + \varepsilon_{ie} + \varepsilon_{iY} = 0$$
$$\varepsilon_{ji} + \varepsilon_{jj} + \varepsilon_{je} + \varepsilon_{jY} = 0$$
$$\varepsilon_{ei} + \varepsilon_{ej} + \varepsilon_{ee} + \varepsilon_{eY} = 0$$

and this fully describes our system. The quantity of composite good is defined in any units required; for convenience, it can be defined as expenditure on all goods other than i or j and with price of unity.

We now introduce the concept of a *conditional elasticity*. London Transport, as a multi-mode operator, is often interested not just in the pure own-price elasticities of demand for bus or underground, but in a combined "what happens to bus demand when bus and underground fares rise?" and similarly for underground demand. This joint effect, or conditional elasticity (henceforth C.E.), is the sum of (for bus) the own-price elasticity of demand for bus and the cross-price elasticity of demand for bus with respect to the price of underground.

In our case, we are quite clear what happens to the overall demand for bus when the price changes – at least in the short run – but much less so what happens when, say, there are two competing bus companies or two different services of one operator and we have to decide what happens to demand on one of them when its price changes but that of the other service does not. However, our system above allows us to make some simplifications:

The first equation rearranges to: $\varepsilon_{ii} + \varepsilon_{ij} = -\varepsilon_{ie} - \varepsilon_{iY}$ of which the LHS is definitionally the conditional elasticity of demand for operator i when all operators (i,j) change prices by an equiproportionate amount.

Likewise, the second equation of the system rearranges to: $\varepsilon_{ji} + \varepsilon_{jj} = -\varepsilon_{je} - \varepsilon_{jY}$ where similarly the LHS is the conditional elasticity of demand for j.

Four unknowns in two equations is rather more than satisfactory; but assuming weak separability of the utility function reduces this. If we assume weak separability, then there is a relationship between the elasticity of demand for good i with respect to the price of the composite good e and the income elasticity of demand for good i of the form:

$\varepsilon_{ie} = \gamma\varepsilon_{iY}$ and similarly $\varepsilon_{je} = \gamma\varepsilon_{jY}$

We can thus express the C.E. for a good in terms of its income elasticity:

$C.E._{\cdot i} = \varepsilon_{ii} + \varepsilon_{ij} = -(1+\gamma)\varepsilon_{iY}$; and
$C.E._{\cdot j} = \varepsilon_{ji} + \varepsilon_{jj} = -(1+\gamma)\varepsilon_{jY}$

such that the difference between conditional elasticities is a function of the difference between income elasticities. A corollary is that Conditional Elasticities are the same if and only if income elasticities are the same.

In practice, any difference between income elasticities is likely to have very little effect on the conditional elasticities. Consider again

$C.E._{\cdot i} = \varepsilon_{ii} + \varepsilon_{ij} = \varepsilon_{ii} + (\kappa_j\varepsilon_{ji} / \kappa_i) + \kappa_j(\varepsilon_{jY} - \varepsilon_{iY})$

where κ is the share of total expenditure. For bus travel, this is small: even for regular bus users on low incomes it is unlikely to exceed say 4% of income which means that even for a difference in income elasticities of 0.5, then the last term of the above expression might be at most 0.02 and this in the context of anticipated condiitonal elasticities of at least –0.4. Given the imprecision with which elasticities are known, we think it unlikely that any real difference between income elasticities for different operators, or equivalently any difference in conditional elasticities between operators, can be substantiated.

If we assume that all operators face the same conditional elasticity and we know what that elasticity is (for example, C.E.= –0.4) then we have a system of two equations in four unknowns, ie

$\varepsilon_{ii} + \varepsilon_{ij} = -0.4$
$\varepsilon_{ji} + \varepsilon_{jj} = -0.4$

However, the symmetry condition implies a relationship between the cross elasticities, so we actually have two equations in three unknowns. There is therefore just one degree of freedom, that is one parameter to be decided upon, which, used in conjunction with known prices, market shares &c., means just one piece of external evidence to determine the whole consistent system once a conditional elasticity has been specified. Unfortunately, little is known about any of the relevant parameters; but we can simplify the information requirements further by specifiying the cross elasticities in terms of diverison factors.

A diversion factor δ_{ji} is defined as the proportion of those who, ceasing to use mode j consequent upon some deterioration in j, move to mode i. Clearly the sum over all alternatives diffreent from j (including not travelling) must be unity. It is then possible to define a cross-elaslasticity ε_{ij} as:

$$\varepsilon_{ij} = -\varepsilon_{jj}\frac{s_j}{s_i}\delta_{ji}$$

Suppose 75% of those who transfer from bus when the price of bus rises switch to car. That would give, in the above example, a cross-elasticity of 0.12. We can perform a similar operation for the elasticity of demand for train with respect to the price of bus. For a recent in-depth application of this procedure, see Bejarano (1999).

In our case of two bus operators and a composite good, exactly the same approach can be used, since the composite is an artificial construct and it is the *relative* market shares of the two bus services, not the absolutes, which are relevant in determining cross-elasticities. A further advantage is that we can incorporate generation effects; if 90% of those who cease to use service i when its price rises go to j then, given our three good system, the other 10% must be suppressed (= negative generated) traffic (at least as far as that bus operator is concerned). The diversion factors will depend on how good a substitute the two bus services are for each other and, of course, need not be symmetric; in fact, chances are they won't be.

Combining the two approaches

On the assumption of identical conditional elasticities, we have $CE_i = \varepsilon_{ii} + \varepsilon_{ij} = \varepsilon_{ji} + \varepsilon_{jj} = CE_j$

From the diversion factor approach, we have ε_{ij} expressed in terms of ε_{jj} and ε_{ji} expressed in terms of ε_{ii}. Thus

$\varepsilon_{ji} = -\,\varepsilon_{ii}\delta_{ij}(s_i/s_j)$ and $\varepsilon_{ij} = -\,\varepsilon_{ii}\delta_{ij}(p_j/p_i)$

From the symmetry condition, it is possible to show that, for identical income elasticities and with identical prices,

$CE_i = \varepsilon_{ii} + \varepsilon_{ij} = \varepsilon_{ii}(1\text{-}\delta_{ij})$ and $CE_j = \varepsilon_{jj} + \varepsilon_{ji} = \varepsilon_{jj}(1\text{-}\delta_{ji})$

The equivalent results where the two goods have different prices are:

$CE_i = \varepsilon_{ii} + \varepsilon_{ij} = \varepsilon_{ii}(1\text{-}(p_j/p_i)\delta_{ij})$ and $CE_j = \varepsilon_{jj} + \varepsilon_{ji} = \varepsilon_{jj}(1\text{-}(p_i/p_j)\delta_{ji})$

Combining all these, we can obtain a relationship between the two diversion factors so that, on the assumption of identical conditional elasticities (equivalently, identical income elasticities) of demand for bus, there is only one degree of freedom – ie one diversion factor can be freely estimated given observed market shares and relative prices. Everything else falls out of the system.

In particular,

$$\delta_{ji} = \frac{p_j}{p_i}\left[1 - \frac{1}{1 + \frac{s_i}{s_j}\frac{\delta_{ij}}{\left(1 - \frac{p_j}{p_i}\delta_{ij}\right)}}\right]$$

Example

Suppose operator i has 80% of the market and operator j has the remaining 20%. Suppose also that $\delta_{ij} = 0.3$, that is if the majority operator increases fares, 30% of those who stop using I will use j's buses and the rest will find something else to do. This is perhaps reasonable because, with a lesser coverage of the area (in time or space, it does not matter), j's buses are not particularly good substitutes for i's buses. We also assume conditional elasticities of –0.4 and that the prices charged are the same.

Given $\delta_{ij} = 0.3$, $s_i = 0.8$ and $s_j = 0.2$,

$\varepsilon_{ii}(1- 0.3) = -0.4$, or $\varepsilon_{ii} = -4/7$;

$\varepsilon_{ji} = -\varepsilon_{ii}\, \delta_{ij}\, (s_i/s_j) = 0.686$ or 24/35

$\varepsilon_{ij} = \varepsilon_{ji}\, (s_j/s_i) = 0.171$ or 6/35

$\varepsilon_{jj} = -0.4 - \varepsilon_{ji} = -1.06$ or $-38/35$

$\delta_{ji} =$ 0.63 or 12/19.

Now suppose that the minority operator 2 charges fares at 90% of the level of the big operator but that $\delta_{ij} = 0.3$, $s_i = 0.8$ and $s_j = 0.2$ still. Then

$\varepsilon_{ii}(1-0.9*0.3) = -0.4$, or $\varepsilon_{ii} = -40/73$

$\varepsilon_{ji} = -\varepsilon_{ii}\, \delta_{ij}\, (s_i/s_j) = 0.658$ or 48/73

$\varepsilon_{ij} = \varepsilon_{ji}\, (p_j s_j/p_i s_i) = 0.148$ or 10.8/73

$\varepsilon_{jj} = -0.4 - \varepsilon_{ji} = -1.06$ or $-77.2/73$

$\delta_{ji} =$ 0.56 or 108/193.

This accords with intuition; δ_{ji} is a measure of how close a substitute the majority operator's service (i) is for that of the minority operator and should be bigger than δ_{ij}. In fact, the diversion factors are only obviously equal for equal market shares and equal prices. Once the minority operator has lower fares, then the majority operator's services are less good substitutes ceteris paribus.

Transforming "ordinary" elasticities into logit elasticities

This part draws heavily on Taplin (1982). In the first instance, we use equal prices for the two operators.

If:

E is a matrix of ordinary own- and cross-price elasticities

S is a matrix of market shares consisting of a row vector ($s_1, s_2, \ldots, s_n$) repeated n times (so that column i is a column of s_i's)

I is the identity matrix,

then the matrix of mode share elasticities, **M** , is given by:

$$\mathbf{M} = (\mathbf{I} - \mathbf{S})\,\mathbf{E}$$

It is then merely mechanical to derive from the matrix of ordinary elasticities

$$\mathbf{E} = \begin{pmatrix} -0.57 & 0.17 \\ 0.69 & -1.09 \end{pmatrix}$$

the corresponding mode share (or logit) elasticities

$$\mathbf{M} = \begin{pmatrix} -0.25 & 0.25 \\ 1.01 & -1.01 \end{pmatrix}$$

The difference between the ordinary and the mode share elasticities is constant in each column; -0.32 for column 1 and -0.08 for column 2. Aggregated, these should yield the common conditional elasticity –0.4, which they do. What this says is that for a 10% increase in both bus prices, overall demand falls 4% and of that 4% total, 3.2% is suffered by operator 1 and 0.8% by operator 2 that is, in proportion to their existing market shares of 80:20.

Similary with unequal prices,

$$\mathbf{E} = \begin{pmatrix} -0.548 & 0.148 \\ 0.658 & -1.058 \end{pmatrix}$$

and the corresponding mode share (or logit) elasticities are

$$\mathbf{M} = \begin{pmatrix} -0.24 & 0.24 \\ 0.964 & -0.964 \end{pmatrix}$$

Again, the difference between the ordinary and the mode share elasticities is constant in each column; -0.307 for column 1 and -0.093 for column 2. Aggregated, these yield the common conditional elasticity –0.4. For a 10% decrease in both bus prices, overall demand rises 4% and of that 4% total, 3.07% is gained by operator 1 and 0.93% by operator 2. In other words, once we have differential prices, the generated traffic is not allocated in proportion to existing shares; instead, the cheaper operator gets more than its "fair share" of the growth.

The conditional elasticity is what we use to scale θ_2, the upper level structural parameter.

We generate θ_1, the lower level structural parameter, as follows:

Recall that logit price elasticities (denoted m) are defined as:

$m_{ii} = \theta p_i(1 - s_i)$ and $m_{ji} = - \theta p_i s_i$ for a linear additive utility function (and similarly for j)

(Note that to use generalised cost, we just specify $\theta(p + v_1 t_1 + v_2 t_2 + \ldots)$.)

Then θ is given by $-m_{ji} / p_i s_i$. Suppose in our uniform price example the price was 100p. Then $\theta = -0.01257$

For the differential price case, we have two operator-specific θ's. This means that we will have different coefficients for the two operators in the logit model, θ=-0.01205 for the higher fare operator and θ=-0.01339 for the low fare operator.

Note that the logit elasticity (ie the inter-operator mode share elasticity) is not a constant multiple of the conditional elasticity; the relationship varies according to the relative market shares.

<u>Using the theory</u>

What follows is for illustrative purposes. In the model, we can use different elasticities and values of time for the different time periods, viz peak, inter-peak, evening, Saturday, Sunday.

For the consumer, the decision is travel by bus or not travel by bus. If s/he decides to travel by bus, s/he then has to decide which bus to catch. The previous subsections of section 8 have dealt exclusively with this latter decision.

Assume we have the case as above with conditional elasticities of –0.4, market shares of 80/20 for operators A and B, a diversion factor δ_{AB}= 0.3 and A and B charging 100p and 90p respectively. Then, we have established $\theta_A = -0.01205$ and $\theta_B = -0.01339$. The coefficient on any other variable is simply the monetary value of the variable (in pence per relevant unit) times θ. So if the value of in-vehicle time is 2p/minute and the value of waiting time is 3p/minute, the coefficients are –0.0241 on IVT and –0.03615 on wait for operator A and –0.02678 on IVT and –0.04017 on wait for operator B. This gives utility functions

$V_A = ASC_A - 0.01205*FARE_A - 0.0241*IVT_A - 0.03615*WAIT_A$
$V_B = -0.01339*FARE_B - 0.02678*IVT_B - 0.04017*WAIT_B$

The ASC_A is adjusted to bring the market shares from the logit model into line with observed market shares once fares, IVT and waiting times have been entered.

We turn now to the bus/not bus decision. This is based on the utility of travelling by bus, VT as against the utility of not travelling by bus, VN.

$VN = \mu k$
$VT = \mu \log(\exp(V_A) + \exp(V_B))$

and parameters μ and k are jointly and uniquely determined so as to (i) replicate the existing bus market share and (ii) ensure that if all bus operators increase their fares by the same infinitessimally small percentage, the bus market share changes in accordance with the conditional elasticity of demand for bus.

We are now in a position to assess the effects of various quality measures. Suppose it is proposed to introduce real-time information, valued at 9p/trip, low-floor buses at 3p/trip and nice bus shelters at 6.5p/trip. If all operators participate in the scheme, the improvement in utility of bus A is (9+3+6.5)*0.01205 = 0.222925 and for bus B (9+3+6.5)*0.01339 = 0.247715. Adding these constants into V_A and V_B will improve the overall utility of travelling by bus, VT, and we will have new mode shares for bus compared with not travelling by bus and new shares for each operator. If only operator A participates, then only V_A is increased. This will both increase the overall share of bus and increase A's share of the bus market.

	coeffA	attA	coeffB	attB		condel
fare	-0.01205	100	-0.01339	90		**-0.4**
ivt	-0.0241	15	-0.02678	15		
wait	-0.03615	5	-0.04017	15		
ASC		*0.9242*				
QUAL:		0		0		
		0.43909		0.109772		
	bus shares	0.800001		0.199999		
	expEMU	0.75253		mu	*0.47393*	
	UN	1.755901		k	*1.187901*	
			0.3	shares	0.7	
			BUS		NOTBUS	

In the above spreadsheet, the coefficients are as derived earlier and some travel and waiting times have been assumed. An ASC of 0.9242 has been chosen to bring the forecast operator shares of 80% for A and 20% for B.

The parameters μ and k have been chosen to ensure a conditional elasticity (condel) of –0.4 and an observed overall bus market share of, say 30% in the current situation. We can now assess the effects of quality measures.

If both operators participate in a QBP, then each has the utility of its service increased and the effects are as below:

	coeffA	attA	coeffB	attB	

fare	-0.01205	100	-0.01339	90	
ivt	-0.0241	15	-0.02678	15	
wait	-0.03615	5	-0.04017	15	
ASC		0.9242			
QUAL:		0.222925		0.247715	
		0.548743		0.140628	
	bus shares	0.796005		0.203995	
	expEMU	0.838375		mu	0.47393
	UN	1.755901		k	1.187901
			0.323163	shares	0.676837
			BUS		NOTBUS

The overall bus share is now 32.3%, a growth of 7.7% relative to the base. Each operator has roughly the same share as before, though B has improved its position slightly. If just operator A participates in the QBP, the effects are to grow the overall market (now 31.8% is the share which bus has) and operator A has an increased share, 83.3%, of that larger market. A has both taken traffic from B and taken traffic from other modes/generated trips. A actually has more trips in this case than when B participates in the QBP! Thus, although it is in B's interest and in the public interest for all operators to participate, it is in the larger operator's interest to be the sole Quality operator.

	coeffA	attA	coeffB	attB	
fare	-0.01205	100	-0.01339	90	
ivt	-0.0241	15	-0.02678	15	
wait	-0.03615	5	-0.04017	15	
ASC		0.9242			
QUAL:		0.222925		0	
		0.548743		0.109772	
	bus shares	**0.833304**		0.166696	
	expEMU	0.820376		mu	0.47393
	UN	1.755901		k	1.187901
			0.318435	shares	0.681565
			BUS		NOTBUS

The full model is, of course, rather more complex than this, but this shows the essentials of how the parameters are derived and how the effects of a QBP are assessed.

An application of the model

The model was initially validated on simulated data for a hypothetical bus route. However, more recently, we have been able to validate the model on real data. We now describe a series of model runs for looking at the introduction of quality and subsequent entry into the market by a second operator. It is intended that this case study is viewed as a demonstration of some of the capabilities of the model, rather than an in-depth analysis of the potential for QBPs.

Description of the case Network

Briefly, the route is 18.5km long incorporating 25 bus stops. The route is currently supplied by a single operator for most of its length, who operates a more or less uniform frequency of 4 buses per hour, between 6am and 6pm. The services are essentially inter-urban commuter services serving the outlying regions of a mid-sized British city. Within the city limits, the service faces on street competition. The data supplied shows the daily (6am to 6pm) demand for services from Monday to Friday in late July 1999 at approximately 1170 passengers. If all passengers pay full fare (i.e. assume that the difference between concessionary and full fares is made up by the local authority) and the average fare on the route is £1.09, the incumbent generates base daily revenue of £1280.40. There are a total of 1628 bus kilometres in the timetable and if each is costed at an average of £0.79, then we estimate total costs at £1286.12 and daily profits of £-6.20. For this time period, the incumbent is shown to more or less breakeven on this route, though we suspect that late July is not a typical operating period and that increased profits will be made at other times in the year. That said, we believe that this is a solid base to examine the impact of QBP.

Modelled Scenarios

We have chosen to look at the impacts of the introduction of a QBP using a scenario-based approach. In the first instance we look at the impact of a QBP on a monopoly supplier and assess whether the investment can be justified on increased revenues or whether a wider social cost benefit analysis in needed to justify investment. Following this, we use the model to look at the impact of new market entry and assess imnpact on operators and consumers of alternative competitive strategies based on fares, service levels and service quality.

How does a QBP impact on the monopoly supplier?

Table 1 shows the annual demand and revenue implications of an increase in service quality for a monopoly operator. Quality enhancements valued at 5 pence per trip (say the provision of real time information) leads to a 2.2% increase in demand and a corresponding increase in revenue of £8,100. Assuming that the QBP has no cost or capacity implications for the operator, profitability is set to rise by £8,100 annually. Not surprisingly, consumers benefit from the increase in quality, with their net gain valued at £18,540 annually. Combining both operator profitability and consumer surplus gives a measure of benefit to society as a whole - excluding the capital and operating costs of the QBP investment, this benefit is valued at £26,640 annually. Additional model runs have been made for more significant increases in quality and these results are shown also.

Table 1: Demand implications of a QBP for a monopolist

Quality	Increased Demand	% Growth in Demand	Increase in Revenue	Increase in Profit	Change in CS	Change in Welfare
5 pence per trip	7632	2.2	£8,100	£8,100	£18,540	£26,640

10 pence per trip	15300	4.4	£16,272	£16,272	£37,440	£53,712
15 pence per trip	23148	6.6	£24,696	£24,696	£56,772	£81,504
20 pence per trip	31104	8.9	£33,300	£33,336	£76,536	£109,872

Assumes 6am to 6pm operation for a 300 day year.

As well as improving bus quality, improvements to journey times and frequencies could also be assessed using this model together with complications such as second round effects on capacity requirement and demand levels. It is therefore quite easy to see how this model could be used to assess investment possibilities in a single operator case.

A Framework for Assessing Competition

If the increase in demand brought about though the introduction of a QBP is sufficient to trigger new entry into the market, then we need a methodological framework to be used to assess competition. In the short run, we have specified a series of plausible competitive scenarios rather than define a set of supply side algorithms that lead model convergence at an equilibrium. The competitive strategies available to each agent include those based on: pricing, quantity, service quality and cost reduction. The costs and benefits associated with each scenario are then compared with base statistics for operator profitability, consumer surplus and overall economic welfare.

The base case is a single operator not in a QBP scheme. There are four levels of quality improvement worth 5p, 10p, 15p and 20p respectively to the consumer which can used by both operators, that is each operator can decide the extent to which, if at all, they participate in the scheme. The incumbent operator is assumed to maintain fares and services at current levels, whereas it is assumed the entrant may take on a range of strategies. In the long run, we will also test a range of incumbent responses to entry.

To simplify presentation, the outcome of all tested scenarios have been analysed by a series of dummy variable regression runs with operator profitability and changes in consumer surplus and economic welfare taken as the dependent variables and the incumbent's and entrant's levels of quality and the entrant's price and frequency strategies taken as the independent variables. Each model is calibrated on output data derived from 485 simulation runs. The coefficients tell us the average effect of each element of strategy.

Table 2: Regression Analysis on Operator Profitability, Consumer Surplus and Welfare - £ per day (t-stats shown in brackets)

Dep Variable / Variable	Incumbent Profit Model (a)	Change in CS Model (b)	Change in Welfare Model (c)

Constant	-72.05 (4.9)	46.23 (3.2)	54.63 (4.2)
ASC 5 -Incumbent	58.25 (8.5)	39.13 (5.7)	61.80 (9.9)
ASC 10 – Incumbent	119.03 (17.9)	78.86 (11.9)	124.82 (20.7)
ASC 15 – Incumbent	181.35 (27.7)	119.76 (18.4)	189.50 (31.9)
ASC 20 – Incumbent	245.15 (37.4)	162.03 (24.8)	256.32 (43.3)
10% Fares Discount	-123.94 (30.9)	51.53 (12.9)	21.52 (5.9)
20% Fares Discount	-254.48 (63.6)	119.44 (29.9)	35.45 (9.8)
30% Fares Discount	-379.63 (94.9)	204.94 (51.5)	42.24 (11.7)
1 Service per hour	-69.81 (4.8)	-11.85 (0.8)	-336.19 (25.5)
2 Service per hour	-266.11 (18.4)	74.10 (5.2)	-583.96 (44.4)
3 Service per hour	-439.31 (30.3)	156.09 (10.8)	-832.15 (63.2)
4 Service per hour	-559.37 (38.6)	239.77 (16.6)	-1066.99 (81.0)
ASC 5 – Entrant	-45.22 (11.7)	27.48 (7.1)	31.02 (8.8)
ASC 10 – Entrant	-91.72 (21.2)	56.34 (13.1)	63.76 (16.3)
ASC 15 – Entrant	-139.14 (27.6)	86.50 (17.3)	98.20 (21.6)
ASC 20 – Entrant	-187.51 (28.3)	117.97 (17.8)	134.32 (22.4)
Cost [0,-10%]	na	na	87.69 (34.3)
Adj R^2	0.98467	0.95668	0.99141
Observations	485	485	485

Model (a) Incumbent Profitability

The constant shows a base daily operating loss of £72.05 for the incumbent operating without quality enhancements. Subsequent improvements in quality, valued at increments of five pence per trip, generate an increase in profitability of £58.25, £119.03, £181.35 and £245.15. Entry into the market by a second operator progressively reduces the incumbents profitability as the entrant's service levels increase, fare levels reduce and quality improves, for example a new entrant operating 4 buses per hour, with a 30% fares discount and a high level of quality will reduce the incumbent's profitability by £1126.51 per day if the incumbent does nothing. This level of entry is, in fact, not sustainable as it requires the entrant to absorb significant operating losses. From the incumbent's perspective, an increased quality of service maintains a modest level of profitability even with some fringe competition, though it is likely that the incumbent would increase frequency to blockade entry. For example, an entrant offering one bus an hour with a 10% fare discount but not in the quality scheme would reduce the incumbent's profits by £193.75 on average. However, were the incumbent to take part in a QBP scheme worth 20p per passenger, it could increase its profits by £245.15.

Model (b) Change in Consumer Surplus

Model (b) shows the results of an increase in competition on the welfare of consumers. As would be expected, consumers benefit as quality is improved, service levels increased and fares reduced. Taking the case above of an entrant coming in with 4 buses an hour, offering a 30% discount on the incumbent's fares and participating in the scheme while the incumbent does nothing, the increase in consumer surplus is £562.68.

Model (c) Change in Welfare
The change in overall economic welfare brought about if competition occurs is by-and-large strongly welfare negative. The dominant impact here is the reduction in operator profitability brought about as a result of entry. Here, welfare is taken to be the sum of profits from both operators together with consumer surplus. It is clear from this analysis that this route can not support two profitable operators unless the incumbent operator were to reduce its frequency or the overall size of the market were to grow significantly. Using the same example, overall social surplus would reduce by £890.43, made up of gains to consumers of £562.68, losses to the incumbent of £1126.51 and losses to the entrant of £326.60. On this route, it would seem that entry is a socially undesirable leading to wasteful competition unless there is a reduction of service by the incumbent. Of course, in the longer run, the overall market elasticity is sufficient for fares increases to improve profitability; the question is whether the dynamics of competition would permit this.

Case Study Conclusions

The situation described assumes that both operators act independently of each other and that the cross elasticities of demand between services are high. In fact, if operators were to collude or the cross elasticities of demand are lower that assumed, the best strategy for each firm would be to price high and produce low. This strategy would be justified on the basis that the overall market elasticities on the route are low. Unless the market can grow significantly, or the incumbent reduce output levels, this route is unlikely to support two operators and although consumers would benefit from competition, society as a whole would suffer welfare losses. It remains for us to find market conditions and competitve behaviour which could enhace social welfare.

Overall Conclusions

We have demonstrated the capabilities of a model to evaluate the benefits of a Quality Bus Partnership scheme under various assumptions about the number of operators and the competitive strategies they may adopt. As part of this, we have developed a method of ensuring that the input data on elasticities, which drive the parameters of the demand model, are consistent with up to date external evidence and are internally consistent. A number of challenges remain:

- to test the model with different conditional and operator specific elasticities;

- to test the model with different consumer responses to quality and frequency improvements, including more robust evaluation of consumers' willingness to pay for quality improvements;

- to develop the appraisal capabilities of the model, in particular the attribution of costs and benefits for consumers with heterogeneous tastes;

- .
- to explore possible operator responses and strategies for competition, possibly within the QBP, for example, timetable response;

- there is a growing body of evidence to suggest that long run elasticities are higher than short run elasticities. We couldconsider ways of making the model dynamic;

- at present the model tests scenarios, it could be developed as an optimisation model (using profit maximisation or forms of social welfare function). In this case we might need a less detailed specification of the route.

Wait for the next version in two years' time…

References

Bejarano Vicario, AJ, 1999, *Diversion Factors and Cross Elasticities*, unpublished MA dissertation, Institute for Transport Studies, University of Leeds

Bristow, AL and Shires, JD. (2001) "A review of the values of time, elasticities of demand and other parameter values for use in the Quality Bus Partnerships model", Report to the Department of the Environment, Transport and the Regions. February 2001.

Bristow, AL, Shires, JD and Mackie, PJ, 2001, "Quality Bus Partnertships: New Evidence on Performance", *paper to be presented at the 9th World Conference on Transport Research, Seoul.*

Chartered Institute of Public Finance and Accountancy (1974) "Passenger Transport Operations" London.

Silberberg, E, *The structure of economics: a mathematical analysis*, McGraw-Hill, 1978
.
Taplin, JE, 1982, "Inferring ordinary elasticities from choice elasticities", *Journal of Transport Economics and Policy*, 14(1), pp19-35

Toner, JP , 1993, "Estimating elasticities with limited information", *Institute for Transport Studies Technical Note 335*

Whelan, GA, Toner, JP, Mackie, PJ and Preston, JP, 2001, "Modelling Quality Bus Partnerships", *paper to be presented at the 9th World Conference on Transport Research, Seoul.*