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THE ANALYSIS OF BUS COSTS AND REVENUES BY TIME PERIOD
Part I. LITERATURE REVIEW

by

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Abstract

Bus operators serve many markets characterized both spatially and temporally. An objective of these companies is to tailor fares and service provision to these myriad markets. The past 20 years have seen an unprecedented desire by bus companies to analyze costs and revenues at the micro level to permit this tailoring. This was initially on a route-by-route basis and later on a time-of-day/day-of-week--or time period--basis. The methodology was developed in three stages: (1) apportioning methods for allocating costs and revenues to route level were developed in the UK and the US in the period 1968 to 1974; (2) further developments post 1974 were chiefly in the US and Australia and concentrated on prediction methods for incremental costs resulting from expanding/contracting service at particular times of day; and (3) there was a resurgence of interest in the UK post 1979 with analysis of both allocated and incremental costs and revenues. This assumed great practical interest with deregulation of the industry in 1986.

The paper traces the development of the literature over the period and indicates that costing methodologies have been extensively analyzed but revenue methodologies are still in their infancy. On the costing side, two methodologies, one from the United Kingdom and one from Australia, are available. The paper describes these two techniques and in comparing them identifies a trade-off being predictive accuracy and simplicity of application. The paper concludes that the development of micro-level analytical techniques has proved to be both practical and desirable. Areas for potential future research are also identified.

1. Introduction

The past twenty years have seen an unprecedented desire by bus companies to analyze costs and revenues at a micro level. The level of analysis was initially on a route-by-route basis, but recently methodologies have focused on different days of the week and even by time of day on individual routes (referred to here as `time period' analysis).

Given the interest in this subject, and its relatively long history, it is surprising that no definitive review of the literature exists. The explanation appears to be twofold. First, the analytical techniques have a checkered history with fluctuating levels of professional interest, and more importantly a line of development that extends over three continents (initially in Great Britain, then in the United States and Australia, and then a resurgence to Britain). Secondly, much of the scholarly research in the area has been conducted by consulting companies and not reported in academic journals.

Therefore, this paper is intended to tie together, for the first time, the strands of the development of the science. The paper is in two parts. This first part considers the rationale for wishing to make such micro-level analyses, the environmental factors that have shaped the curious inter-continental two-decade methodological development, and a review of the literature.

The second part provides a brief description of the nature of the emerging consensus on recommended methodology. However, the paper is explicitly not intended as a cookbook of methodology, and the reader interested in this aspect is referred to the source documents. The paper concludes with highlighting the areas which could profit from future research and answering the question of whether micro-level analysis is both practical and desirable.

2. The Rationale for Time Period Analysis

Bus operators serve many markets. These markets can be characterized both spatially (i.e., geographically) and temporally. Specially, the markets may be characterized by origin-destination pairs (which because they are so diverse are usually proxied by individual bus routes or corridors). Temporally, traditional classifications have included separating out, for example, peak periods, weekends, evenings, etc. The important implication is that not only will the level of demand vary between these markets, but also the characteristics (sensitivity to price and frequency changes) of the potential riders will vary.

Whilst the characteristics of riders will vary by route, depending on the area serviced, it is perhaps by time period that the greatest variety occurs. Results from the City of Cheltenham (ITS, 1984) in Britain and similar analyses in other towns support the simple observation that the age, sex, and journey purpose of riders on a route varies markedly by time of day/day of week.

From a theoretical viewpoint the variety of levels and characteristics of demand has important implications for the setting of fares and frequencies of service. To achieve a maximization of social welfare, an objective of transport policy must be to tailor the supply of transit services to best fit the myriad of different markets. In its basic form, economic theory requires the equating of price and marginal cost across all markets served to obtain Pareto efficiency. Whilst in practice the actual equilibrium will be determined by a more complex formulation (due to externalities, `second best' considerations, fiscal constraints on maximization, and demand and supply interdependencies), it is clear that management need to make decisions at a micro level specific to each market served. Importantly the need for making these micro-level analyses (albeit with different maximization formulation and constraints) does not change whatever political regime the bus company operates within, be it the provision of commercial services, the subsidization of individual unremunerative services or network-wide subsidy.

Given the seemingly compelling reasons for making such analysis, it is not unnatural to inquire why only some parts of the world-wide bus industry have adopted such techniques and then only recently. Indeed the implicit implication that differences in resource cost and

differences in rider characteristics between routes and time periods would justify differential levels of fares runs contrary to observed actual pricing policies of most operators, where the time at which the trip is made has little bearing on the level of fares paid (see Cervero's 1986 review of time-of-day pricing in this journal).

Nevertheless, acceptance and use of techniques appears to be increasing. The reasons for this are described in detail in section 4. However, it is appropriate to highlight here the changes in the political environment which has prompted the recent renewal of interest. The last 10 years have seen a move away from strict governmental control, ownership, and regulation of many areas of the economy. Transport has been no exception. In the United Kingdom (UK), United States (US), and increasingly in Australia and within the European Economic Community, a competitive atmosphere is being introduced. In the bus industry, the United States is moving to a system whereby operators compete on cost for the right to operate particular routes, whilst in the UK the industry has been deregulated. In the former case the implication is that operators have to have a detailed knowledge of costs to be able to make tender bids at a route level. Whilst in the latter case operators have also had to decide which of their services (both by route and time of day) can be provided without subsidy and then price and provide service appropriate to a competitive market. In both cases this has resulted in a need for micro-level analysis.

Underlying this has been another change. Previously it was an accepted (if not governmentally encouraged) practice to `cross-subsidize' some loss-making services from profits earned on other services. With such an ethos it is not surprising that detailed analysis of financial performance of various sections of a bus company's operations were not required. However, in the late 1970s the system of cross-subsidy was subject to intellectual scrutiny and exposed as both potentially undesirable and damaging to the industry. Therefore, a major thrust of the institutional reforms of the 1980s has been designed to eradicate cross-subsidy or at least make the amount and direction of the cross-subsidy flows very apparent. This has also resulted in increased need for micro-level analyses.

3. Some Important Definitions and Distinctions

Before proceeding any further it is important to address two sets of important definitions. The first deals with the level at which analyses is undertaken (i.e., how `micro' a level is the analysis to be conducted at), and the second is the differentiation between `allocated' and `incremented' analytical techniques.

3.1 Level of Detail

The first group of distinctions that must be made is regarding the level at which travel markets are identified. For management purposes these are:

1. route-by-route level;
2. time-of-day/day-of-week level on individual routes which will give a matrix of financial performance both by route and time-of-day/day-of-week. It is common to colloquially refer to this type of level of analysis as time period analysis; and

3. different geographical segments on an individual route at particular times; which is particularly pertinent in the move to deregulation as operators consider truncating lightly-used ends of routes.

However, meaningful financial calculations for individual route segments have traditionally been very difficult. This is because the true cost of operating a certain segment can only be found by comparing the current route cost with the cost of only operating the remainder of the route. Calculation of the latter requires the rescheduling of staff and vehicles. Whilst one of the costing methodologies we will discuss (the `Adelaide' model from Australia) has the capabilities to undertake such analysis, the complexity of the task means that no simple rules-of-thumb can be developed. The revenue effects of such service changes are, at present, a matter of conjecture. This is, however, an area for further work. Therefore, the remainder of this paper concentrates on calculations by time-of-day/day-of-week on individual routes.

This, of course, is looking at the problem from a managerial perspective. From a socioeconomic or political perspective we may wish to observe the economics of providing service to particular types of user, characterized by age, sex, journey purpose, car ownership, income, and other demographic factors. The traditional way of doing this level of analysis is to undertake a time-of-day/day-of-week/route level financial appraisal and draw socioeconomic implications by knowing (by survey techniques) the rider characteristics in various time periods. An example of this was work undertaken on the social effects of cross-subsidy (ITS, 1984 and Allen, 1980). At the financially best performing times of day (typically the mid-day) there is a predominance of shopping trips undertaken by women and old-age pensioners. At unremunerative times (typically the evenings and Sundays) social trips appear to be dominant. At these times there appears to be a higher than average proportion of male passengers and a much lower than average proportion of elderly people. Analysis at this level of detail obviously lends itself to more objective decision making by governmental authorities wishing to allocate subsidy funds.

Having decided to make a time-period analysis, thoughtful attention must be given in choosing the time-bands for analysis, to make them relevant to decision making by operators. Particularly, if the information is used in deciding service levels, a meaningful choice of time periods should ideally reflect the times that particular resources are employed. For example, peak operations should be separately analyzed, as some manpower and vehicle resources are often employed solely at this time. Evening and early morning service represent employing staff outside an overlapping straight shift, 0700h to 1900h, service; and daytime Saturday and Sunday services represent staff working overtime shifts in many cases. This will probably indicate that the following divisions of time will be meaningful:

- weekday peak
- weekday mid-day off-peak
- weekday early-morning and evening
- Saturday daytime
- Saturday early-morning and evening
- Sunday all day
- Night services

The actual time boundaries between these periods will depend very much upon local conditions. From a costing viewpoint, the peak periods should be bounded by the times that additional peak vehicles leave/run into their garages (i.e., a supply side definition) rather than be determined by the peak demand.

3.2 Allocated versus Incremental Analysis

The second set of important distinctions is derived by considering that managers of bus companies need to have information for two purposes. The first is to monitor how `well' (compared with their desired fare/frequency objectives) they are servicing an individual market, and to detect if any exogenous changes in the market place are causing a deviation from their desired objectives; and the second is to project what will happen if it is desired to change price or service provision in individual markets.

3.2.1 Monitoring of Individual Markets

Operators need to measure how well they are equating supply with demand. Due to differing demand and cost characteristics between markets, this can only meaningfully be done at a micro level. However, it is not only the operators who have an interest in such information. Political authorities have been increasingly involved in the financing of public transportation. Recent limitations on public funds have brought demands for more accountability. The political authorities want to know precisely where their subsidy monies are being spent, on what routes, at what times, and, therefore importantly, on what type of consumers. This movement can only be encouraged as it engenders objective decisions on the costs and benefits of spending public money.

Additionally, the success of any business is determined by the ability of that business to know the characteristics of its market, and recognize and react to changes in the demand for its product. In bus transportation the heterogeneous nature of the consumers makes detailed information important. Changes in external factors (such as rising unemployment reducing the number of journey-to-work trips) can have severe effects but only on particular markets. Therefore, disaggregate information is vital.

Both of the above reasons have universal application, even when bus operations are highly regulated. Deregulation, however, heightens the need for this type of information. Managers are forced to react on an almost daily basis to changes in financial performance of individual markets caused by the entry of rival operators. The availability of good information, at a micro level, in deciding on and monitoring competitive price and/or frequency changes should not be underestimated.

3.2.2 Changes to Individual Markets

The monitoring of individual markets will trigger management attention to markets where there may be a mismatch of demand and supply. This triggering may also take place if the subsidy regime changes resulting in operators having to alter fares and/or frequencies to achieve a new economic equilibrium based on the revised financial constraints.

The information required in these circumstances is different from the monitoring case above. Whilst monitoring of markets both cross-sectionally or on a time series can be (and usually are) conducted by looking at average or allocated measures of costs and revenues; changes in service require a different set of cost and revenue measures. Data needs to be available to answer questions such as "what types of costs will change and by how much" and "how much will revenue change by." These measures are known as incremental measures, although they are often also referred to as marginal or avoidable measures (generally the term `avoidable' is reserved for looking at the specific case where a service segment is completely withdrawn). These measures require information on a very micro level.

4. The Inherent Difficulties in Making Time-Period Analyses

Historically, bus companies have found it very difficult to obtain the kinds of financial measures described in the section above.

Costs cannot be easily allotted to individual time periods, because many of them are joint in nature. An individual bus driver may drive in both peak and off-peak periods within an individual spell of work; a vehicle will also be used in different time periods and perhaps on different routes. These interworkings of staff and vehicles have been identified by Panzar and Willig, 1981, as "economies of scope" because individual markets can be served at lower costs as a result of the utilization of resources in complementary spatially and/or temporally separated markets. Additionally, there are the traditionally recognized joint costs such as the provision of bus garages, and the provision of central services such as finance and administration. These costs cannot be attributed directly to any one individual market. Indeed in some cases the costs may not vary depending on whether the market is served or not (i.e., fixed costs).

Even revenues have been difficult to associate directly with individual markets. There are a number of reasons for this. The first is a practical reason that ticketing systems and cash collection and/or auditing do not allow revenue collected in individual markets to be separated. Secondly, demand is itself usually joint. People do not make single trips in isolation; they are concerned with getting from home to one, or more, activities and back again. These return journeys--or trip chains as they are known--can be complex and can, occasionally, be spread over several days (see Hanson, 1979, for a review). Within the set of trip chains, there are subsets which involve public transit. Typical examples might be:

- an early-morning outward work-trip with a return in the afternoon peak;
- an outward leisure trip in the mid-day, returning in the evening;
- a leisure trip entirely in the evening; and
- a single trip home in the afternoon peak (the passenger having taken a car lift to work in the morning).

It is clear that many bus users make trips with multiple legs to them. In recent years bus companies have changed their pricing structure to reflect this. Traditionally the selling of bus trips was based on transactions for each single trip, but now passengers can purchase:

- transfers to allow travel on multiple routes in a single trip;
- point-to-point season tickets;
- multi-journey tickets, i.e., tickets prepaid for a given number of journeys, of fixed denomination, cancelled on each trip; and
- travelpass, a season ticket or pass which permits unlimited use of the network or zones thereof, either for just bus transit or for all modes, during a defined period.

Therefore, not only is demand often joint, but in many cases, the recording of transactions of cash for tickets does not mirror the actual demand characteristics.

The problem posed by joint costs and revenues and overhead costs has obvious implications for incremental analysis. On the cost side, changing service in one time period may or may not require additional vehicles and staff depending on whether the resources are available as a result of service provision in another time period (e.g., an introduction of an off-peak service might not require the company to buy additional vehicles; and in certain circumstances an additional run might not require additional crews to be used because its existing crew roster has

dead time in it). Additionally, no a priori assumption can be made on the effects of any change in service on the overheads of the bus company.

Problems also occur with incremental revenue. As we have described, passengers undertake trip chains which in certain cases overlap several routes and/or time periods. Therefore, if fares and/or frequencies change on a route at a particular time then some of the trip chains will be disturbed and, thereby, affect ridership and revenue on other routes/time periods.

5. The Development of Time-Period Analysis

The problems involved in devising analytical processes to break down cost and revenues on a route and time period basis are clear, but so are the reasons for wanting managerial information on individual markets for bus services. It might seem strange that it is only in recent years that techniques have been developed. The explanation lies on the changing environmental factors affecting the economics control of the industry. Therefore, any description of the evolution of the methodology cannot be taken in isolation from its historical context.

A review of the literature indicates that the development of techniques appears to have occurred in three phases.

1. Apportioning methods for allocating costs and revenues to route level were developed in the UK and the US in the period 1968-74 for monitoring purposes and to substantiate subsidy claims. More sophisticated methodologies also introduced the framework for making allocations on a time-of-day basis, but this was not widely adopted.
2. Further developments post 1974 were made in the US and Australia and primarily concentrated on prediction methods for incremental costs resulting from expanding/contracting service. Allowance for time-period effects on incremental costs (particularly staff costs) were incorporated in these methodologies. A feature of this era appears to have been that costs were extensively studied, but incremental revenues were comparatively overlooked.
3. Whilst development work continued in the US and Australia, there was a resurgence in the study of the economics of providing service in particular time periods in the UK from 1979. The studies considered both allocated and incremental methodologies. The resurgence was initially motivated academically, but later assumed great practical interest due to the deregulation of the local bus industry in 1986. Recently incremental revenue was analyzed in a sophisticated way for the first time.

In this section we chart the development of the literature and attempt to explain the rather curious development that span 20 years and three continents.

5.1 Prior to the Late 1960s there was Little Perceived Need for Analysis

A basic premise must be that because many costs and indeed some revenues occur jointly between markets, there are inherent difficulties in making specific financial calculations on a disaggregated basis. Therefore, unless the need for making such calculations is pressing, firms will not make the investment to do so. The importance of this argument in the precomputer age, when large data manipulation was time-consuming, should not be underestimated.

Indeed until the early 1960s there were good reasons for not making such calculations. The bus companies in the UK were profitable, on a firm-wide basis, and the form of government

control (Chester, 1937) required operators to provide service to unremunerative markets from profits made elsewhere (cross-subsidy) to retain a protected monopoly position. The extent, and characteristics, of the cross-subsidy was usually unknown. Except where instinctive changes were necessary to meet changing demand conditions (e.g., construction of housing estates, a reduction in evening services as the popularity of cinemas declined in the face of television), bus companies had limited incentive to investigate the economics of individual markets on a detailed and scientific basis.

5.2 The Introduction of Subsidy in the Late 1960s Required Route-by-Route Analysis

From a peak in demand in the mid-1950s the UK bus industry went into secular decline. By 1968 the continued provision of rural services (which were traditionally the heaviest loss makers) had come into doubt, as demand had declined significantly and bus companies no longer earned large profits elsewhere to cross-subsidize them. The 1968 Transport Act allowed, for the first time, local authorities to make money available to support bus services. However, they could only support, by specific grants, individual rural services. This required bus companies to apportion costs and revenues to the route level in such a way as to claim the subsidies. There was similar experience in the United States, where there was a similar need for operators to substantiate subsidy claims, particularly if an operator provided service across boundaries between political areas, and wished to claim subsidy from various sources. In fact, the pioneering work was undertaken in the US.

Several different, but similar methodologies were proposed to make the necessary cost and revenue allocations. In the United States the development was by the consultants Simpson and Curtin (now part of Booz.Allen & Hamilton) (Ferreri, 1969), and in the UK by four groups: R. Travers Morgan, 1976; Arthur Andersen and Company, 1974; the London Transport Executive; and by the National Bus Company (initially in association with the University of Manchester Institute of Science and Technology, and later adopted by the Chartered Institute for Public Finance and Administration--CIPFA, 1974). A useful summary of the various UK methods is contained in the report of a comparative seminar held by the UK Department of Transport (TRRL, 1975). All were essentially very similar and allocated costs to routes on four bases:

1. the relative number of bus miles run on each route was used to allocate such costs as fuel and tires;
2. the relative number of bus hours run was used to allocate the costs of crews;
3. the relative number of peak vehicles employed on each route was used to allocate the costs of owning the vehicles, providing the garage and apportioning any central administrative costs; and
4. the number of passenger miles (or bus departures) on each route was used to allocate passenger related costs (mainly accidents and injuries to passengers). This variable appears only in the US literature.

All methods seemed to assume that existing methods (i.e., on-board ticket checks by inspectors) were sufficient for allocating revenues. The principal differences between the different systems were disputes as to which allocative method (i.e., bus miles, bus hours, peak vehicles) should be applied to certain cost line items. Some of the divergences were because of philosophical differences between proponents over which variable most influenced a particular item, whilst others were because of the difference in circumstances between operators. For

example, London Transport retains their crews on the same route and could therefore directly allocate crew costs to routes.

It should be emphasized that these were allocation methodologies only and (in general) only disaggregated to route level.

5.3 Further Refinement of These Methodologies Resulted in Time-Period Allocations

It is clear from reading the early literature that the analysts were less than happy about one portion of their work. Routes that had similar peak vehicle requirements, but had different off-peak requirements attracted identical allocations of `fixed costs' (although, of course, they would receive differential allocations of crew, fuel and tire costs). This was considered somewhat inequitable.

Resolution of this problem was overtaken by a desire to analyze the peaks and off-peaks on a route separately. Interest in this issue had been heightened by authors (like Ponsonby, 1958, who had considered the issue in theory and Tyson, 1972, who analyzed it empirically) who began to question the traditionally held view that the peaks were the financially better time for providing service.

The first study to really tackle this issue was R. Travers Morgan, 1976, in their analysis of bus service in the City of Bradford, West Yorkshire. In making their time-period allocations, two issues were highlighted. The first concerned the treatment of fixed costs, including the cost of owning the vehicle. The allocation of these costs between peak and off-peak raises a philosophical issue. Two contrary views were identified. One is: "because we exist as an organization to meet demand at the peaks, the fixed costs of operation should be solely allocated to peak period and other time periods should be costed on an incremental basis" and the alternative viewpoint is that "we exist to provide a comprehensive service, therefore, fixed costs should be allocated across all the time periods, with only those assets solely used in the peaks being exclusively costed to those time periods." The report favored that latter definition and proposed an allocation system that is described in detail in the second part of this paper.

The second issue raised was that unit crew costs varied between time periods because of overtime payments and different levels of productivity over the day/week. A series of "weights," based on actual experience, was proposed to adjust the bus hours in individual time periods to reflect different productivity and pay premiums. A more realistic allocation of crew costs would thus result.

The Bradford Bus Study (BBS) is one of the landmarks in the history of bus costing. The influence of this report can be detected in the development of time-period allocation methodology later in the 1970s. In the United States, Levinson, 1978, used BBS vehicle costing methods and higher unit crew pay cost in the peak to modify the traditional four-variable allocation model to obtain peak/off-peak costing. At Booz.Allen and Hamilton (Cherwony and Mundle, 1978) a slightly different approach was adopted by estimating two 4-variable allocation models, one for the peak and one for the off-peak with a differential bus hours coefficient, and the peak vehicle variable only used in the peak equation (this, unlike the BBS and Levinson, is adopting the philosophy that the peak should bear all fixed costs).

5.4 A Change of Funding Structure Removed the Need to Fully Develop Disaggregate Analysis in the UK

Many operators adopted the new techniques not only to claim specific subsidies, but also to produce management information at the route level for the whole of their networks. Indeed by the early 1970s a consensus had developed, at the route level at least, on the best practice for doing this.

However, a turn of events in the UK appears to have halted further interest. By the early 1970s most operators had moved to a position of making an overall financial loss. Legislation in the early 1970s (Local Government Acts of 1972 and 1974) permitted local authorities to pay overall network subsidy instead of just specific rural route subsidies. There was, therefore, no longer the need to present route-by-route analysis, as the subsidy was often agreed on the basis of the financial performance of the whole organization. Indeed some socialist local authorities went beyond just paying a network support to assist in maintaining some unremunerative services, to providing larger subsidies to permit increased frequencies and/or lower fares in general. There was thus less pressure for developing sophisticated disaggregate cost and revenue methodologies.

5.5 Further Methodological Development Continued in Australia, Concentrating on Incremental Costs

Predicting accurately the cost effects of changes in service levels on a route has traditionally been problematic. Questions arise as to the changing requirements for vehicles and crews (the crew issues has tended to be more problematic, as it is usually obvious by looking at the proposed service change whether a variation in the number of vehicles used is needed), and the changes in overhead costs such as garages, administration, etc. It is accepted that these overhead costs have a `stepped' function with regard to output.

Previous wisdom was that incremental costs could only be determined by making a detailed study of each service change to determine the change in requirement for vehicles and crews. The rationale for this "casual factors" method is explained by Kemp et al. 1981, who point out that incremental costs can only really be determined on a case-by-case basis, as any service change can be accommodated by an operator in several ways, including using existing resources more intensively (perhaps only temporarily); reallocation of resources by reducing other services; acquiring new resources; or contracting in additional capacity. All of these might result in markedly different incremental cost for a particular service change. However, this is by definition not a predictive model and would be very time consuming when a number of alternative service changes have to be considered.

The genesis of the methodology that has emerged was the Bradford Bus Study. However, its maturing occurred in Australia, and the approach is now commonly referred to as the Adelaide model (R. Travers Morgan Pty., Ltd., 1980; Hill et al. 1984). The essence of the approach is an attempt to predict changes in crew costs as a result of a service change. As we have identified this is usually the most problematic area in incremental cost allocation. The model not only can predict cost changes for changes in an entire route but also predicts changes resulting from changes in specific time periods on a route. It does this by using a computer algorithm to calculate from the number of vehicles in traffic at specific times, the number and types of crew shifts required. The model inherently requires knowledge of the work rules regarding length of duty, meal relief, etc., applicable to the operator in question.

Incremental crew costs of a service change are obtained by initially calculating the effect of the change on the profile of vehicles in traffic, then rerunning the model to calculate changes in the number and types of crews required to man the rest of the schedule, and hence the difference is the incremental crew cost. Incremental overhead costs as analyzed by specifying a stepped function with regard to operator size (usually measured by vehicles owned).

Allocative methodologies can be derived from the above. Basically, incremental costs are calculated for each route/time period pair using the methods just described, and then any residual joint or fixed costs are allocated on the basis of the methods used in the UK.

These methods found immediate use in Australia/New Zealand. There had been a rapid fall in cost recovery and substantial increases in operating deficits (in real terms) in all urban public transit services since the mid-1970s. With increasing pressure to contain public expenditure in recent years, there was a political demand to achieve "better value for money." Questions of the type: where are the subsidies going, who is benefiting from them, what can be done to reduce subsidies by specific service change, and what financial impacts will these have, were raised.

The Adelaide model, providing both incremental and allocated cost data, has been adopted on many Australian and New Zealand cities in the past decade to provide answers to such questions. Interestingly, recent features have been the application of these methods to train and suburban rail modes as well as bus; and the interfacing with the operating accounts system in Melbourne and Adelaide to provide data on a routine basis (R. Travers Morgan, 1986).

In should be stated that incremental revenues, other than the application of fairly crude elasticities, were not investigated to the same level of detail.

5.6 The Adelaide-Style Incremental Methodologies Have Been Tested in the United States

In the United States, work was sponsored by the government to critique existing incremental cost methodologies (Booz.Allen & Hamilton, 1981) with the aim of specifying a preferred model. Booz.Allen & Hamilton, 1984, adapted the Adelaide model for use in the United States (where labor work rules differ from Australia). In a trial in St. Paul, Minnesota, the model performed well. Hence the US Urban Mass Transportation Administration hired other consultants to test the model in cities other than St. Paul. No published reports are yet available on these trials.

However, government policy decisions have led the allocative costing methods to become prominent. The US reaction to concerns about rising subsidy levels and alleged inefficiencies in large transit operators is to seek the contracting of a certain proportion of routes to private operators. The offering of existing transit routes for tender has required formulae for comparing the cost bids of rival firms. The US government has taken the view bids on allocated costs are more "realistic" in the long-term than incremental cost bids. Recent advice on this subject has been given by Price Waterhouse, 1987, albeit that route level allocations suffice. The report makes no new methodological developments, but clarifies (for publicly owned companies) what is to be included as costs, and offers advice on depreciation calculations for assets.

Some incremental cost work is continuing in the United States. Giuliano and Teal (1987) have done some work for the US government on how costs will decrease for existing transit operators if certain of their services are `lost' to other operators under tendering arrangements. As in Australia, it should be noted that despite the intense study of costs, scant attention has been

devoted to incremental revenues. Of course in this case the transfer of routes from one operator to another is assumed to have no revenue impacts.

5.7 Demand for Public Accountability of Subsidies in the UK in the Early 1980s Called for Specific Market Analysis and a Renewed Interest in Time-Period Analysis in the UK

However, the early 1980s saw a reversal in the subsidy trend in the UK, and a consequent demand for specific information on the economics of providing service to individual markets. The Conservative Government elected in 1979 felt that subsidies to public transport had risen to unacceptable levels in the 1970s, and thereby introduced constraints on local authorities to curb the size of subsidies. This required operators to look, in detail, at their networks to see where savings could be made. This type of analysis also met demands by local authorities to know what markets, and hence what type of consumer, was actually receiving the benefit of the subsidy. These events were concurrent with a quickening in the pace of patronage decline (caused partly by increasing unemployment levels undermining work journey trips). Managers were being forced into a position where the structure of their networks (much of what was essentially unchanged for 50 years) was called into question. The state-owned National Bus Company revised its network country wide under a series of Market Analysis Projects (MAP). Most of these revisions were based on route-by-route analysis. An extension of existing allocation methods permitted evaluation of the incremental cost effects of a route service change. The approach (generally referred to as the National Bus Company model) is based on a three-by-three matrix built up to show costs divided into their allocative method (e.g., bus hour, bus miles, or peak vehicles--the passengers variable seems to have been dropped in the US by this time) on one axis and the degree of marginality (variable, semivariable, and fixed) on the other. Any service change is assessed on the basis of changes in vehicle requirement, hours and miles; and some view being taken on extend to which costs will vary (a major change might be assessed to alter semivariable costs).

However, it was probably a more academic development that resulted in methodological advancement of time period rather than just route analysis. The system of cross-subsidizing unremunerative markets from profitable ones came under intellectual attack, and was exposed as being both undesirable and damaging to the industry (see Savage, 1985a, chapter 8, for a critique). Therefore, it was desired to know exactly which markets were cross-subsidizing which other markets. It became clear that the cross-subsidy was not only between routes but also between times of day and days of week on individual routes. Sunday and evening service had long been suspected of being the principal loss makers, but questions such as "does the additional revenue collected in peak periods justify owning some vehicles exclusively for use at that time," which had been raised in the early 1970s (Tyson, 1972) were a priori more difficult to answer. In short, it was necessary to extend the route-by-route analytical techniques to permit analysis by time period. The initial study was commissioned by the National Bus Company and conducted in-house in the Taunton area of Somerset. The methods were based on the Bradford Bus Study and only considered allocations of costs to individual routes/time periods to assess profitability. Reading the report it is clear that the authors were not clear as to the philosophy of the allocation of fixed costs. The results were calculated by both possible methods, i.e., allocating them all to the peak, alternatively allocating them across all time periods BBS style.

The National Bus Company commissioned further work in the early 1980s. In conjunction with the Institute for Transport Studies (ITS), University of Leeds, four further geographic areas were investigated. Different costing philosophies were tested including one

where a network was built up from scratch noting where cross-subsidy emerged. This study clarified thoughts on the patterns of cross-subsidy. Whilst the amount of cross-subsidy present varied by location, generally the weekday interpeak and Saturday daytime were identified as the main profit generators, and the evenings and Sundays as the principal loss makers. The financial position of the peak periods varied considerably depending on the shape of the peaks and the number of vehicles solely reserved for use at that time.

5.8 UK Deregulation was the Main Spur to the Adoption by Industry of Time-Period Analytical Techniques

In 1985 events made the analysis of profitability by time period of intense practical, and not just academic, interest. The newly reelected Conservative Government passed the 1985 Transport Act which deregulated the local bus industry in October 1986. General network subsidy and support for `cheap' fares was outlawed. It was replaced by specific subsidies to individual routes, or time periods on individual routes, that would not be provided in the free market but were, nevertheless, felt to be socially worthwhile.

The transition to deregulation involved operators registering those routes/time periods that could be operated without subsidy; then the local authority tendered the residual loss making services. This meant that operators had to undertake the unprecedented step of determining the financial performance of not only whole routes but also individual time periods. The importance of the time of day analysis became highlighted because not only were whole routes (e.g., rural service) suspected of being unremunerative, but also it was suspected that early morning, evening, and Sunday services might be unremunerative, even on routes that may well run commercially in other time periods.

The local authorities who funded bus operations were also interested, as they feared that the reduced cross-subsidy (caused by competition on the better services) would increase the bill for support of existing loss-making services. Some local authorities commissioned studies to determine the extent of cross-subsidy in their areas and to predict the consequential effects on the total subsidy bill post-deregulation. The MVA Consultancy, 1985, conducted a study in Plymouth (Devon), whilst Booz.Allen & Hamilton, 1985, were engaged by Surrey County Council.

Both studies initially looked at allocations of costs and revenues at the time period level to determine the extent of cross-subsidy. The methods adopted were based on the BBS. An interesting feature of the Surrey study was that the methods had to be tailored to require the minimum of information, as the elected authorities were not privy to detailed costs and revenues from the operators (see Savage, 1985b).

A second feature of both consultants' analyses was that they went beyond allocations to consider incremental costs and revenues. An incremental analysis was considered pertinent at the time as deregulation was feared to lead to many service withdrawals as cross-subsidy declined coupled with constant or reducing public finance. Therefore, financial appraisals needed to be made to calculate cost and revenue implications of a `slimmed-down' network. This kind of analysis was undertaken at the time-period level as well as at the route level. The methodology was to take the time-period cost allocations and then assign (in a similar way to the method discussed in section 5.7) a degree of marginality (variable, semivariable, and fixed) to individual cost items. A full description of the time-period version of the National Bus Company model is contained in Savage (1988).

The work undertaking by operators at this time could by implication be more detailed, as much data was available internally. The National Bus Company developed their earlier work into a microcomputer "Bus Driver" system to assist in identification of commercial networks and strategies. Other operators either had internal resources to undertake the task as engaged consultants. Lamentably, for the scholar, the competitive environment has meant that, unlike under the days of regulation, these reports are unlikely to ever become public knowledge. Indeed the author's experience, reflected in this paper, was gained as part of such an assignment to a major metropolitan operator.

The transition to deregulation was completed by January 1987, but this did not diminish the need for specific analysis of route/time period performance. The competition and the ever present threat of competition in the deregulated environment have made the monitoring of service performance by management the critical issue for company survival.

5.9 The Transition to Deregulation Highlighted the Need for Analysis of Incremental Revenues

Traditionally the revenue impacts of changing frequencies were assessed by applying empirically based service-level elasticities (see Webster and Bly, 1981, 1982). However, this does have limitations. For example, the revenue impacts of a 25-percent frequency reduction across the whole day on a route can be perfectly adequately predicted by using these elasticities. However, how can the revenue impact of a 25-percent reduction in the evening only be assessed? Previously most studies of this kind of problem applied known elasticities to the revenue allocated to the time period in question. Implicitly this means that there is assumed to be no impact on revenues collected at other times of day. In the polar case these studies assumed, for example, that if the evening service on a route was withdrawn then the bus company would lose all revenue allocated to the evening service, but none at other times of day. In other words, in this case, allocated and incremental revenues are identical. The need to make many time-of-day service changes in the transition to deregulation highlighted to the industry that the traditional assumption was highly dubious.

Independently conducted work using data from London by Savage, Scholefield, and White, 1986, looked at the theoretical definitions of incremental revenue, and then attempted to estimate it for evening bus service withdrawal. This analysis suggested that, in the case considered, the traditional definition of incremental revenue being equal to allocated revenue in the event of total service withdrawal in a time period has undervalued the revenue loss by up to two-fifths. The author is aware that these incremental revenue methods have been incorporated in some of the recent confidential deregulation strategy studies undertaken by UK bus operators.

There is, of course, a natural extension of this kind of work. Whilst for financial appraisals of service changes, an estimate of total incremental revenue usually suffices, from a transport planning perspective more detail is required. Bus companies need to know which other time periods will be effected by a service change, say in the evening, and the magnitude of the change in that time period. This issue is discussed in Part II of the paper.

6. Summary

Whilst the importance of knowing detailed information on individual markets is undisputed, it is clear that it is only in the 1980s that the institutional framework was such that bus

managers demanded time-of-day/day-of-week information. Importantly this demand arose both under regulated regimes, as well as deregulated ones.

A feature to note is that two methodologies have developed for costing, both of which offer allocative and incremental analysis. The first was developed in the UK (the National Bus Company model) with its basis as an allocative system; the second was matured in Australia (the Adelaide model) with its basis as an incremental system. Part II of this paper describes these methodologies and compares their strengths and weaknesses. It also describes the comparatively recent work to give revenues the rigorous treatment that costs have received.

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