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**THE ANALYSIS OF BUS COSTS AND REVENUES BY TIME PERIOD**  
**Part II. METHODOLOGY REVIEW**

by

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*This manuscript does not include the tables or figures*

In Part I of this paper the development of allocated and incremental cost and revenue techniques was described. Two costing methodologies, the British National Bus Company (NBC) model (CIPFA, 1974; Savage, 1988) and the Australian Adelaide model (R. Travers Morgan Pty., Ltd., 1980; Hill et al. 1984), have become predominant. In contrast, methodologies for dealing with revenues, particularly incremental measures, are in their infancy.

Part II of the paper describes the state-of-the-art for these methods. This review is explicitly not meant as a cookbook of methodology, and the reader interested in these aspects is referred to the source literature. The paper concludes with a comparison of the NBC and Adelaide costing models, and comments on the areas of potential future research.

In structuring the paper it is clear that the methodologies used to treat costs and revenues are quite distant. Therefore, they are treated separately here with costs being considered first. However, a problem emerges on deciding whether to treat allocated measures before incremental measures or vice-versa (I am indebted to Ian Wallis for pointing out this problem).

The Adelaide model assumes that cost allocations flow from incremental analysis. The argument is that costs can be basically viewed as having three components. The first is costs that can be uniquely attributed to a route/time period. These would be costs that would be saved if that route/time period was completely withdrawn. This, in effect, is an incremental cost calculation. The second type of costs occur jointly between routes/time periods and could only be avoided if several or all routes/time periods were withdrawn, but not if only one service segment is withdrawn. The third type is the remaining 'fixed' costs which are avoided only if the whole operation closes down. The cost allocation methodology follows from this analysis in that the incremental costs (the first type) are directly attributed to a route/time period, and then the joint and fixed costs are allocated in some fair way across the time periods. Unlike the assigning of the incremental costs, which is scientifically based, the allocation of joint and fixed costs is to some extent arbitrary and not related to cost causality.

The National Bus Company method approaches the problem from the other direction. All costs are initially allocated to routes/time periods. An assumption is also made as to which of the allocated cost line items are variable, semivariable, or fixed a service change occurs. A major service change might be judged to influence semivariable as well as variable costs. Incremental cost of a service change in any time period is calculated by adjusting the costs allocated to that period on the basis just described.

Intuitively, the Adelaide approach would seem more appealing, and thus any exposition should treat incremental costs before allocated costs. The gains from using this ordering are offset because it would be almost impossible to explain the NBC methodology in this order. Literary exposition has been the guiding principal in deciding to describe allocated before incremental measures.

## 1. Cost Allocation

Individual cost line items are usually grouped together for the purposes of allocation. The groups being determined by the cost type and the method by which they will be allocated to time periods.

A typical breakdown of cost line items is shown in figure 1. Certain bus operators might consider that a certain cost line item should really appear in a different grouping. This obviously does not affect the methodology described here.

\*\*\* *Table 1 about here* \*\*\*

Additionally the 'level' in the organization that cost data is usually available at is shown. This has important implications for the amount of disaggregation necessary to provide time-period allocations. For example, central administrative costs are incurred at the top level of the operator and then have to be disaggregated down the organization. Crew costs, however, are incurred at garage level and only need to be disaggregated to route and then to time period. The emphasis of this paper is on the final disaggregation from garage or route level to time period, so the reader should be aware that some measure of prior disaggregation might be needed.

The methodologies for this final disaggregation, as they apply to different cost options, are now described, highlighting the differences between the NBC and Adelaide models.

### 1.1 Crew Costs

Crew costs represent the costs of drivers and conductors (where applicable). These staff are often referred to as platform staff in Britain.

This is the area where the NBC and Adelaide models are most different. The Adelaide model uses information on vehicles in traffic on a route or route group to simulate the number and types (early duties, midday duties, evening duties, peak only 'split' duties) of crew duties required. The inputs to the calculation are a profile of the number of vehicles in traffic in 30-minute time bands, and knowledge of the staff working agreements with regard to shift length, meal relief, etc. The computer algorithm works backwards across the day to predict the number of shifts required. An example, in table 2, shows how specification of the number of vehicles in traffic can be used to determine that five morning shifts, four spread-over shifts (i.e., staff working each peak period), and four afternoon shifts are required to run the service.

\*\*\* *Table 2 about here* \*\*\*

The computer algorithm therefore needs to be tailored to each operator studied to reflect the variation in labor work rules. In example more intricate than that described in table 2, the algorithm is programmed to concentrate on certain 'crucial' times of day to start the analysis. Examples of the latter are where there is a certain time by which all spread-over shifts need to be completed.

The Adelaide model then calculates the crew costs saved by withdrawing service in any individual time period. It does this by rerunning the model with the vehicles in traffic input for that time period set to zero. The difference between the resulting cost of the crew shifts required and the original cost is the avoidable (avoidable is the polar case of incremental costs where a service segment is totally withdrawn) cost that can be solely attributed to that time period. There will, of course, be some crew costs that are truly joint between time periods, for example, spread-over shifts will only be saved if both and not just one of the peak service is withdrawn. The Adelaide model allocates such truly joint costs on the basis of the relative number of bus hours in the periods in question.

The Adelaide model therefore produces very precise calculations but requires considerable amounts of information and algorithms tailored to the work rules of a particular operator. The NBC method by contrast is noted for its simplicity (some would say oversimplicity). The underlying philosophy is that total crew costs are allocated based on the proportion of total bus hours run in each time period. Some increased sophistication is required because

1. on weekends, staff are receiving overtime rate;
2. the use of spread-over shifts involves some premium payments; and
3. staff productivity tends to be lower in certain time periods due to scheduling constraints.

As a result, studies have used a weighting on the number of bus-hours run in individual time periods, to take account of these factors. Using these weights, a total "paid" hours relative can be calculated for each time period on each route, and crew costs can be allocated accordingly.

Ideally these weights should be calculated based on the actual work rules of the individual operator. However, most studies have adopted a series of weights that resulted from research covering a large number of operators in the late 1970s reported by McClenahan et al. 1978, indicated that typical weights were:

Peak operations	2.5
Other weekday operations	1.0
Saturdays	1.1
Sundays	1.4

In the course of recent work, re-estimation of these coefficients has brought the current validity of the McClenahan et al. weighting factors into question. In particular, it was felt that the reduction of the 'peakiness' of service in the 1980s had reduced the staff cost penalty associated with the peak. It is thus highly appropriate that McClenahan et al.'s work be updated.

It should be emphasized that the NBC and Adelaide models really take a substantially different approach. The Adelaide model iterates crew scheduling to attribute avoidable crew costs to individual time periods and then allocate any remaining joint crew costs. The NBC model only tries to equitably allocate crew costs based on the current shift pattern. Therefore,

even if McClenahan-style weights are accurately calculated for an operator, the NBC method would not be equivalent to the Adelaide model.

### *1.2 Crew Duty Related Costs*

There are two cost items in this category: variable overheads, that depend on the number of crews employed; and semivariable overheads, which also tend to vary with the number of crews.

Both types of costs are allocated according to the number of crew duties required on an individual route in a particular time period. It should be noted that if there is a mix of one- and two-person operation in the fleet, then it would be appropriate to weight the allocation of certain costs which are directly related to the number of employees (such as training, medical, and catering) towards the two-person-operated routes.

Costs are assumed to be able to be disaggregated from company to garage level on the basis of the establishment of crews allocated to each garage. Further disaggregation to route and time periods will obviously vary between the Adelaide and NBC models. The Adelaide model inherently calculates the number of crew hours attributed to each time period, and therefore allocation can be made on a straightforward basis.

In the NBC model costs are allocated to time periods on the basis of the distribution of 'duty' or attendance hours. This will obviously be different from bus hours because of allowances for signing on, travelling to relief points, etc. In addition, there will be lower productivity in certain time periods. It will also be different from the 'paid' hours coefficients described in section 1.1 as bonuses and premium payment adjustments are not included. Whilst in the course of recent studies the author has seen such coefficients calculated, using regression techniques; there is alas no publicly available references. Using these weights a total 'duty' hours relative can be calculated for each time period on each route, and costs allocated accordingly.

### *1.3 Mileage Related Costs*

Costs such as fuel, oil, tires, daily maintenance materials, and minor mechanical parts are commonly assumed to vary with the amount of mileage run by vehicles, and therefore can be very simply allocated. The NBC and Adelaide models are identical in this respect.

### *1.4 Vehicle Requirement Related Costs*

Cost items in this category are: vehicle ownership costs; semivariable overheads that are assumed to vary proportionally to the number of vehicles the company owns; and fixed overheads that are assumed to be related to the size of the organization, measured by the number of vehicles owned.

In traditional route-by-route costing, it has become accepted to allocate these kinds of costs to routes on the basis of the number of peak vehicles required on each service. However, for time period costing, the emerging view is that this has two deficiencies. First, whilst in some circumstances this cost allocation might be appropriate in inter-route costing, there is no reason for these costs to be solely burdened on the peak. Costs should be allocated in such a way to reflect the usage of capital equipment across the whole week. Second, the traditional

route allocations make the implicit assumption that the 'peak' requirement for vehicles occurs at the same time on all routes. However, consider the following example. Routes A and B operate from a large garage, along with many other routes. The peak vehicle requirement for the garage as a whole occurs on weekday mornings. Route A requires 10 vehicles on weekday mornings, but only 5 on Saturday. Route B, however, requires on 5 on weekday mornings, but 12 on Saturday. Under traditional costing methodologies route A gets burdened with twice as much vehicle related costs as route B, which would seem somewhat inequitable.

To control the problem of peak vehicle requirements occurring at different times on different routes, the cost allocation should be made directly from garage level to time periods, rather than via an intermediate disaggregation to route level.

The recommended allocation system (derived from the Bradford Bus Study) is illustrated--in a fictitious but realistic example--in figure for garage X. In this allocation system:

- the Cost of 3 vehicles (i.e., the minimum number of vehicles required at all times of day/night) is spread over all time periods in ratio to the bus hours worked by those vehicles in each time period;
- the cost of 30 vehicles (i.e., the Sunday early and late requirement [33] less the 3 all periods requirements) is spread over all periods except nights, in ratio to the bus hours worked by those vehicles in each time period;
- the cost of 4 vehicles (i.e., the next lowest requirements on Saturday early/late [37] less the previous total) is spread over all periods except nights and Sunday early/late, in ratio to the bus hours worked by those vehicles in each time period; and so on until
- the cost of 11 vehicles (i.e., 93-82) which work only both of the Monday to Friday peak periods is spread over Monday-Friday 07:30 to 09:30 and 15:30 to 18:30, in ratio to the bus hours worked by those vehicles in each time period; and
- The cost of 2 vehicles (i.e., 95-93) is allocated solely to the Monday-Friday afternoon peak, 15:30 to 18:30.

\*\*\* *Figure 1 about here* \*\*\*

Having thereby split the garage totals for vehicle related costs to time-period levels, the costs can then be further allocated to individual routes (within each time period) on the basis of the relative number of bus hours run on each route.

Of course, the allocated fleet in the garage will exceed 95 buses to cover maintenance and provide a backup for failures in services. Therefore, the total costs of all the vehicles at the garage is the appropriate sum to allocate not just the cost of the vehicles needed for service.

A refinement is occasionally needed. Not all vehicles will have the same cost characteristics (different vehicle types may vary in depreciation and maintenance cost). Therefore, when an individual garage has more than one vehicle type allocated to it, the unit of analysis should be the 'garage-vehicle type' paid.

Another possible refinement is based on the practice in the bus industry for some vehicles to be given routine maintenance in the midday off-peak, thereby allowing them to be available for service to meet peak demand. By implication, if the excess peak was eliminated then some vehicles in addition to the off-peak vehicle requirement would be needed to cover for this type of maintenance. It would seem unjust to burden the peak with the sole cost of these vehicles. Therefore, the proportion of the 18 peak-only vehicles which are in maintenance in the off-peak

should be identified. The cost of these vehicles should then be spread across all time periods based on the proportionate split of bus hours.

The Adelaide and NBC models are similar in this regard as well. The current form of the Adelaide model does use a somewhat coarser version where only a peak/off-peak distribution is made in allocating vehicle requirement related costs.

## 2. Incremental Costs

### 2.1 *The NBC Model*

The philosophy of the NBC model is that each cost line item is assessed to determine whether it is variable (will vary with every service change), semivariable (will only vary if the change is of a certain severity), or fixed. Recent uses of the model have adopted four steps of service change severity to assess which costs should be considered incremental.

Step 1--Mileage Withdrawal: reducing frequency on or withdrawing, say, an evening service will probably result in saving only the crew, fuel, tires and maybe some inspectorate expenses;

Step 2--Peak Vehicle Savings: reducing peak frequencies or withdrawing whole routes will, in addition to the above savings, also permit the saving of the costs of owning a certain number of vehicles;

Step 3--Garage Closure: withdrawing a route which is the sole (or sole remaining) route out of a garage will, in addition to the above, also permit the costs of owning, maintaining, and staffing the garage to be saved and probably also allow a slimming of certain parts of the senior management; and

Step 4--Operator Folds Up: withdrawal of the sole remaining route of the organization will, in addition to the above savings of crews, vehicles, and the garage it operates out of, also mean that the fixed costs of operators are avoided (the bus company folds up!).

A suggested grouping of costs, using the same cost categories as in section 1, as they might relate to these 'steps' or indivisibilities in incremental costs is illustrated in table 3. It will always be a matter of some dispute over what costs fall into what category, and individual bus companies will, in practice, wish to make a division appropriate to their own circumstances.

\*\*\* *Table 3 about here* \*\*\*

### 2.2 *The Adelaide Model*

The incremental analysis in the Adelaide model can be thought of as having three components--incremental crew costs, incremental mileage related costs (i.e., fuel, tires), and all other costs.

We have already described the sophisticated way that the model calculates incremental costs. A modification of the vehicles in traffic profile to represent the service change will predict the change in crew shifts required. Therefore, unlike the NBC method that assumes that any service change will change crew costs, the Adelaide model can be regarded as being a more accurate reflection of reality.

Mileage related costs such as fuel simply vary with the number of miles run, as in the NBC model.

The Adelaide model lumps all other costs together as overhead costs and assumes that the total level of these costs will vary in a stepped pattern with the size of the operator. The number of vehicles owned is used as a measure for operator size. This approach has a long history in the development of costing techniques. Coefficients relating fleet size and total level of overhead costs are typically estimated by using regression techniques using data from many, variably sized operators.

### **3. Comparison of the NBC and Adelaide Costing Models**

Comparison of the methods was sponsored by the United States Department of Transportation in the early 1980s with a view to recommending a methodology for use in the US. The work was undertaken by the consultants Booz.Allen and Hamilton, who reported in 1981 and 1984. It should be pointed out that the evaluation used versions of both the NBC and Adelaide models that are somewhat different from the current versions. The time-period elements of the NBC model had yet to be fully developed, and therefore, only the basic 1974 version was used. The Adelaide model tested relied on the computing power available at the time and hence was rather slow in processing time. Recent computing advances, including the introduction of microcomputers have eliminated this problem somewhat.

In table 4 we show the results of a survey of US transit professionals from the 1981 Booz.Allen & Hamilton report, who were asked to rate the models (on a scale of 0 to 10, with 10 representing excellent) with regard to certain criteria. The professionals were further asked to weight the importance of the various criteria so that a weighted scale could be calculated.

**\*\*\* Table 4 about here \*\*\***

The views of the transit professionals highlight that the Adelaide model is preferred overall, primarily because it takes a more logical and intuitive approach to cost causality, but suffers because as a result, it requires more data input and computer processing. Calculations using the NBC model can, by contrast, almost be made on the 'back of an envelope' or certainly in a simple microcomputer spreadsheet.

This issue was highlighted by a very interesting experiment conducted by Booz.Allen and Hamilton, 1984, where the NBC model, the original Adelaide model, and a version of the Adelaide model adapted to US work rules, were pitted against each other in predicting 12 service changes in St. Paul, Minnesota. In terms of predictive power, all did very well for service changes of greater than one percent of existing route service.

Whilst the Adelaide and US proposed method were, in general, better predictors, the trade-off described above was exposed by the study. The NBC style calculation could be made quite simply with minimal data requirements and also great expediency in computer time. The Adelaide and US methods require a great deal of data and lengthy computer processing time. It should be repeated that recent computing advances have lessened the latter point. Communication with Ian Wallis of R. Travers Morgan Pty., Ltd., suggests that service change runs that required processing times of up to 24 hours on the mainframe computer 1977 version of

the Adelaide model can now be accomplished in 30 minutes on a microcomputer, with routine allocated profit/loss statements being processed in 10 minutes.

Practitioners are therefore faced with a choice of greater accuracy versus simplicity and some time saving. It could certainly be argued that techniques need to give a good approximation to actual operational and cost changes, or they are not accepted by operational staff and hence by operations management.

The author is somewhat skeptical of some of these arguments. One wonders what significant benefits there are from using more sophisticated costing techniques when, as we will see, allocated and incremental revenue methodologies are very unsophisticated. Indeed, existing incremental revenue predictions are close to a 'stab in the dark.'

#### **4. Revenue Allocation**

Revenue consists of two elements. The first is cash fares paid, data on which is usually allocated to routes on the basis of waybill information. The second is the allocation of monies collected from off-bus payment (travelpasses and local government payments for elderly and school travel) to routes. This latter allocation is achieved by standard ticket examination surveys by bus company inspectorate who can determine level of demand and the distribution of concessionary travel, travelpass, and other ticket-type distinctions.

The combination of on-bus surveys and cash revenue data generally provides extremely good information. However, it should be noted that the spread of prepaid (off-bus) ticketing has increased the need for survey work. These surveys also cover passengers paying cash, for while there is an increased use of electronic ticketing systems, the data produced only give a partial picture.

The further disaggregation of revenues from route to time-period level is based on the number of passenger-miles in each period. This is usually calculated by taking the product of average load factors and bus miles run in each time period. The load factors are usually obtained from the inspectors' reports mentioned above.

#### **5. Incremental Revenues—“Revenue at Risk”**

Unlike costs, revenues will not only be affected by the level of service but also by the level of fares.

Estimating the effects on revenue of fare or service level changes has a long history. Calculations of price and service elasticities is well developed (a useful summary is Webster and Bly, 1981, 1982). Indeed differential price and service elasticities by time of day/day of week have been determined in many cases. However, a feature of most analysis to date is that the differential elasticities by time of day are usually applied in cases where fare or service changes have been implemented by bus operators to all time periods (i.e., the relative level of fares or service level in each time period remains the same). Therefore, analysis of how--and to what extent--fares or service changes in one time period only, impact other time periods is lacking. On the fares side, some light has been shed on this when differential peak/off-peak fares schemes are introduced (a recent notable case was the introduction of a 30p off-peak maximum in West Yorkshire, England). Here, not only would the lower off-peak fare attract new riders, it would



also cause some existing riders to re-time their previously peak-period trips. The problem that the researcher faces is that many of these studies are conducted internally by operators and are not available publicly. On the service level side, some analysis has been made by operators in cases where evening services have been curtailed to estimate the effects on patronage in the middle of the day. These reports are also not avoidable publicly.

Therefore, unlike incremental costs analyzed in section 2 above, incremental revenues have received less comprehensive scholarly attention and will therefore have to be treaded here at greater length. It has become usual to refer to incremental revenue as 'revenue at risk' (I am indebted to David Bruce of Bristol Polytechnic for suggesting this title to me), which, by its very name, indicates that the kind of service changes commonly contemplated in the industry recently have featured increased fares and decreased service levels.

The definition of revenue at risk is the change in total revenue resulting from a change in fares and/or service levels. As we have already emphasized, for our purposes, however, we wish to be more precise. Not only do we wish to predict the overall change in revenues, but we also wish to know the incidence of this change disaggregated by individual time periods.

Taking the case of a fare and/or frequency change in one time period, calculation of the revenue at risk has three stages. First, the fare/service level changes will have a direct impact on the ridership and hence revenue in that time period on the route in question. Secondly, in the case of service level changes, some riders will be able to transfer to parallel services and hence their trips might not be seriously affected. Third, there are the inter-time period effects. We will look at processes used to estimate these three stages in detail in the rest of this section.

### *5.1 Direct Effects*

These effects are the clearest and the least controversial. They are the direct impacts on the revenue on a route in the time period being studied caused by changes in fares and/or service levels. They are in effect very similar to traditional price and service elasticities of demand. The difference is that they only measure the revenues impact within the route and time period under review. To the author's knowledge, these elasticities have never been calculated in any empirical study, although there would be no great problem in doing so.

### *5.2 Parallel Routes*

Empirical predictive study of individual service changes of the type described above will, in practice, need to be made using globally calculated fare and some elasticities. The globally calculated figure cannot by definition incorporate some of the salient characteristics of a route which might influence the extent of revenue loss. The most important of these factors is the availability of parallel service. These other services might run along the same road, or run nearby, and because they run at convenient timings and service similar destinations act as a substitute for the reduced service. Therefore, in the case of a service reduction, some riders will be able to transfer to these parallel services, and the operator will retain the revenue.

In order to calculate this effect it is necessary for a bus company to calculate parallelism factors, which show the proportion of the direct revenue loss that will be retained because riders can transfer to other routes when service is reduced on the route in question. These factors will be time-of-day specific and show explicitly which routes will benefit from increased patronage. These are derived by comparisons of the destinations accessible on parallel service, how much of

the route is paralleled, and the related frequency between the parallel service and the reduced one. It obviously requires a considerable amount of investment by a bus company to compile such a database. Nevertheless, once collected it is a simple task to update it when service changes occur. Such data has already been in use with some operators. For example, comprehensive parallelism factors by route and time of day are an integral part of the London Regional Transport/London Buses Limited "Management Decision System" used to evaluate service changes.

### 5.3 *Linked Trips*

The issue is how much revenue is lost--or is at risk--at certain times of day due to service level and/or fare alterations at another time, or more precisely, which time periods are effected and to what extent. The reader is reminded that these inter-time period effects result because people do not make single trips in isolation, but rather, trip chains based on the home. Some of these chains will have legs which are made in different time periods. Service changes in one time period will disturb some of the chains and thereby affect ridership and revenues in another period. Therefore, investigation of patronage and revenue at risk from changing service in particular time periods can only be undertaken with data on the matrix of trip chains between time periods, which are usually obtained from travel diary type surveys.

Savage, Scholefield, and White, 1986, conducted a theoretical and empirical investigation of revenue at risk. Their first conclusion was that on a priori grounds it was difficult to predict the nature and magnitude of revenue at risk. An example will illustrate the problem. Let us consider the range of potential effects on patronage (for reasons explained later it is beneficial to differentiate between patronage at risk and the associated revenues), in ascending order of impact to a bus operator, of the total withdrawal of an evening service.

1. The most favorable outcome for the bus operator is if only those trip chains (generally home-based) wholly contained in the evening period are lost. The return legs of trip chains started earlier in the day are retained because people retime their return journey to fit in with the last scheduled daytime bus.
2. The bus operator loses all the trip chains wholly contained in the evening, and the homeward evening leg of trip chains started earlier in the day (the first leg of these latter chains being still made on the bus). In effect, the loss of patronage is equal to the allocated measure of patronage, and there is no change at other times of the day. (As we have indicated, most studies to date have implicitly used this assumption.)
3. The bus operator loses all legs of all trip chains which have at least one leg in the evening. Now the operator loses its evening patronage and also patronage at other times. To ascertain which other times will be affected requires knowledge of a matrix of start and end times of trip chains.
4. The worst outcome for the bus operator occurs if the service withdrawal forces former users to consider alternative modes for all bus travel, for example, purchase of a personal car. The former users then substitute the alternative mode for all bus journeys, irrespective of whether they are in the evening or not. Therefore, the worst case for the operator is if it loses every trip made by individuals who formerly patronized the evening services. This has similar but more severe impacts to scenario 3.

A priori it is not obvious where the patronage at risk will be between these bounds. Indeed, the ability of people to reschedule their existing travel patterns further complicates the issue. For example, people who previously visited hospitals in the evening might, after withdrawal of services at that time, decide to retime their entire trip chains into the afternoon when a bus service is available.

The uncertainty of deciding on the level of patronage at risk becomes greater when trying to convert this to revenue. Under cash paid ticket systems and multi-journey ticket systems (in which part of the ticket is cancelled for each single trip), revenue loss corresponds closely to the number of trips lost (allowing for a weighted average by trip length and ticket type). However, where travelpasses are used, the relationship is less direct. So long as the user continues to find renewal purchase worthwhile, even if scope to make some additional weekend/evening trips is reduced, then no change in ticket sales or revenue will occur until some critical threshold is reached, at which point behavior may change radically. However, where a work trip leg forms part of the period affected, then travelpass use might cease very soon.

Savage, Scholefield, and White used empirical data (a 1981 travel diary survey) to calculate patronage 'at risk' measures resulting from total withdrawal of evening bus services in London. They found a high sensitivity of the resulting measures depending on which of the four scenarios listed above was felt to be most appropriate. For example, adoption of scenarios 3 or 4 could result in estimates of patronage at risk some 60-80 percent higher than the traditionally assumed value (scenario 2).

At this point we have reached the limit of definitive research. This leaves two unanswered questions. The first is which of the four patronage at risk scenarios is closest to reality, and the second is how to convert changes in patronage to changes in revenue. Pending new, original research the author offers the following suggestions. One possible way to make an assumption on which of the four scenarios of patronage at risk is appropriate, is to differentiate between trip chains that involve a visit to an individual's place of work or education (called fixed chains), and others (nonfixed). As fixed chains tend to be performed at set times and on a regular pattern, it is likely that scenario B is most appropriate. If one leg of the trip (e.g., the journey home from work) was not possible by bus, the user could still decide to make an outward bus journey but choose an alternative mode (e.g., taking a lift) for the return. For nonfixed chains, it was felt that removing the choice of a bus for one leg of the trip would mean that either the trip was not made, or the entire trip was made by another mode. Therefore, scenario 3 is most appropriate.

In determining the revenue rather than the patronage at risk, a differentiation should be made between cash payers and off-bus ticket holders. For cash payers there is obviously a direct relationship between patronage and revenue, whilst for off-bus ticket holders a more sophisticated relationship exists. The crucial factor being whether the rider gives up use of the travelpass (see White, 1984, for a discussion on the 'thresholds' for holding travelpasses). A plausible assumption is that if a fixed chain is disturbed the travel pass will be given up and the remaining trips made by cash payment, however, if a nonfixed chain is disturbed then the pass is not given up as it will still be used for the primary work/education activity. In the former case the revenue loss will be the difference between the face value of the travelpass and the combined cash fares for the remaining trip legs, and in the latter case there is no revenue loss. Paradoxically, in both cases the revenue per journey will go up at other times of day as, in the former case, single journey cash fares generally exceed the implicit cost per trip of using a

travelpass, and in the latter cases fewer trips are now being made using the travel pass so that there is now a higher yield per trip from pass use.

The reader will conclude that the derivation of accurate measures of revenue at risk is an area for future research. The reader will also have noted that the derivation of these measures can, in the extreme, require large amounts of survey data. However, the demands of the new competitive environment require analytical tools that are quick and easy to use. Therefore, it is likely that scholarly developments of revenue at risk analysis will only find widespread acceptance and use, in the current environment, if easy to use rules of thumb can be derived. Such rules of thumb as “evening service charges that result in the loss of one dollar of revenue in the evening, also result in a revenue loss of thirty cents in the afternoon peak” will prove to be a new and invaluable tool to the economic analysis of bus service provision. This is the challenge for future researchers in this subject.

## 6. Conclusions

Having discussed the rationale, the problems, and the state-of-the-art of micro-level cost and revenue analysis, the important question of “is it worth it?” needs to be addressed. In other words, is this level of analysis both practical and desirable.

The answer to the first of these (the practicality) is easily answered from a reading of the second part of this paper. We have now reached the state of the art where there is consensus emerging on best practice for allocation measures of both revenue and costs, and for incremental measures of costs. In general, the data requirements do not exceed that which are collected ordinarily by operators, and the data manipulation is well within computing capabilities. Indeed, most of the calculations described in this paper can be accommodated on a personal microcomputer. The outstanding area for research for further investigation into revenue at risk, and the development of rules of thumb (such as there are widely known existing rules of thumb for fares elasticities). It should be commented in passing that the author is somewhat perplexed by the extremely sophisticated methods for incremental cost developed in the 1970s. It would seem that it would have been more beneficial to devote the time to developing the extremely naive assumptions on incremental revenue rather than further refine the already detailed cost measures.

The question of desirability is really asking whether the (very clear and persuasive) benefits of this type of analysis outweigh the costs. On the benefits side, one can but observe that the bus industry serves a myriad of different markets (characterized by the levels and characteristics of demand). By far the greatest differences in demand occur by time-of-day/day-of-week, even on the same route. The desirability of matching demand and supply in some scientific way cannot be denied. It is pertinent to note that this desire exists whether services are regulated (and hence generally ‘transport planning’ exercises are conducted) or whether there is a deregulated environment, and the market directly imposes its own discipline. As this review indicates it has been the pressures of deregulation that have been the spur of widespread adoption of the techniques in Britain. As competitive pressures grow elsewhere in the world it would not be surprising to see micro-level analysis grow in acceptance and use. The very acceptance suggests that, for the operators, the benefits outweigh the costs.

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