THE DEVELOPMENT OF A MODEL FOR THE ANALYSIS OF BUS OPERATIONS AND COMPETITION

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Untuk susan, ibu dan bapa

ABSTRACT

The new competitive environment in the bus industry that has been created by deregulation has forced operators to face a new situation where financial constraint becomes the main issue. The operation of public transport system has become more commercial than before and there is a need for greater accountability. These mean that operators need new skills so that they can adapt the service offered according to the level and the pattern of travel demand and, more importantly, estimate revenue more precisely. This implies that extra precautions are needed in deciding on the route to operate, the type of vehicle, the level of fares, the level of service frequency, and so on.

Much prior work in the field of public transport operations has dealt with the operational strategy in terms of vehicle scheduling or crew rostering rather than considering it in a broader context. However, as the new operating environment has arisen in recent years, the broader questions mentioned above need to be addressed.

The research being presented in this work describes the development of models that are applicable for the analysis of the operation of bus services, particularly in the context of the operational strategies mentioned above. In doing so, two models have been developed : one of single-route bus operations and the other of bus operations on a network. Both forms of model have been developed to represent the responses of passengers (demand) toward the service offered by the operator (supply) under monopoly conditions as well as in a competitive market. In the development of the model it has been assumed that passengers' decisions on which path they want to take, and on which bus they want to ride, are based upon the disutility of the alternatives available. Several issues such as : passenger assignment, the split between walking and bus trips, and route choice have been taken into consideration.

Using the two models the implications of various operating strategies under the condition of a monopoly as well as a competitive regime have been investigated. The results of the exercises show that the performance of bus operation is strongly influenced by the level and the pattern of travel demand, and, more importantly, by the operational strategy of the service such as : the fare system, the type of vehicle used, and service frequencies.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

1.1. Background and objective of the study

In recent years some industrialised countries have tried to change the face of the public transport industry through deregulation. It reverses the trend, from the full involvement of government in the coordination, finance, and planning of the operation of bus services, to the dominance of market forces.

There were some arguments behind the introduction of deregulation. In the first place was the fact that in the last decade there has been an increasing number of deficits in the public transport operation. It has been argued that this process has been associated with the growth in car ownership and the decentralisation of population, which have reduced public transport patronage and have increased the cost of operation. To some extent, the deficits of public transport have grown to a point where they are placing an extra burden on budgets which is difficult to bear and consequently has been called into question by policy makers. The question was whether it would be more reasonable to put those with high resource costs to another use.

Secondly, the increase in the world of competition makes it necessary to seek greater efficiency in productive services, among which public transport plays a key role. Market mechanisms have proved to be an effective means of generating productivity gains. By the same token arises a question of whether public transport should also be regulated by the same mechanisms.

The deregulation of the public transport industry, therefore, relies upon a belief that only through deregulation can the productivity and efficiency of public transport be increased (and therefore subsidy reduced or eliminated), and also upon the belief that the forces of the public transport market are capable of stimulating adequate responses for public transport services.

In the U.K, the deregulation of the public transport industry (bus) was introduced through the 1980 Transport Act (for long-distance bus services) which was then followed by the 1985 Transport Act (for local bus services outside London).

Basically the form of deregulation is created by introducing a free market regime within the industry, that is, by allowing bus operators to run the services commercially. Within this framework any operator can participate in the provision of public transport services, provided that the services are registered.

The obvious consequence of this situation is that on any particular route the number of operators running the service will depend upon the attractiveness of the route concerned, especially in terms of the level of travel demand. At one extreme the number of operators who run the service on one particular route may be more than one and, at the other extreme, may be none. These situations are possible, as most operators will rush to provide services on the most popular routes.

For routes where no operator wishes to run the service, the responsibility to provide the services lies with the government. This is particularly so for the routes or services that are considered 'socially necessary routes' or 'socially necessary services'. In dealing with these routes, central government or local government usually offers the provision of the service to the private sector through tenders, or franchising.

In the U.K, two conditions emerged from deregulation : competition on-the-road and competition through the tendering process. Competition on-the-road occurs in the routes where the level of demand is high enough to sustain more than one operator, whereas competition through tenders is tailored for those routes where the level of travel demand is very low.

However, regardless of the conditions emerging from deregulation, the people that are most concerned with this new environment are the operators, because they are the ones who will be most affected by it. In general, deregulation has forced them to change the way they operate the service. Financial constraint becomes the main issue. The operation of bus services has become more commercialised than before and there is a need for greater accountability. They now need to have greater awareness of the cost and revenue implications of their decisions. The case becomes more complicated for the operators when competition-on-the-road affects them. In this case, they do not only have to consider their operational strategies but also have to take into account possible actions by their rivals.

There is no general rule in the formulation of an operational strategy of bus operation. For the routes that can be classified as self-contained, it can be expected that for certain route corridors the operational strategy of the operator will be unique. A good strategy in one particular route will not necessarily be applicable to the others. This is due to the fact that every route corridor has its unique characteristics : its pattern of travel demand as well as its geographical conditions.

For the routes in a network system, however, the problems of formulating the operational strategy are more complicated. One has to consider not only the route being dealt with, but also the other routes in the system. This is predictable since the interdependency between routes in the network system will be strong. A change in the provision of bus services on one particular route will affect not only the performance of bus operations on the route concerned, but will also affect the performance of bus operations in the other routes in the network.

Looking at this situation, one would come to the conclusion that in the new environment after deregulation, the operators will need to have new skills so that they can adapt the service offered according to the pattern of travel demand and, more importantly, so that they can estimate revenue more precisely. This implies that extra precautions are needed in deciding on the route to operate, the type of vehicle, the level of fares, the level of service frequency, and so on.

Much prior work in the field of public transport operations has dealt with the operational strategy in terms of vehicle scheduling or crew rostering rather than considering it in a broader context. However, as the new operating environment has arisen in recent years, the broader questions mentioned above need to be addressed.

This thesis will concentrate on the development of models which in turn will be used extensively to explore and analyse bus operations in the context of operational strategy in this new environment.

1.2. Outline of the report

The first part of this study (*Chapter 2*) consists of a brief description of bus route operations and some aspects related to the issue of deregulation. This is followed by *Chapter 3* which contains a general review of available literature on all aspects of the analysis of bus operation, including competition. This will provide the basis for deciding on the areas which warrant further attention.

Chapter 4 considers some methods of bus operation modelling, both for a single route as well as for a network system, and examines in detail the various aspects of bus operation that have been represented in most models, and indicates their weaknesses wherever possible. This gives a basis for the development of a better model of bus operation. Resulting from this, a new model of bus operation and competition is devised.

Chapter 5 describes in detail a bus operation model for a self-contained single route which was developed in this study. This includes cross reference to the previous chapter. The description of the data requirement for the model and the problems and the results of validation are considered in *Chapter 6*.

Chapter 7 gives some examples of the application of the model. It starts with the description of the data and then describes the results of applying the model. In this exercise the model was used to analyse the implications of various operational strategies of bus services under a monopoly as well as in a competitive market.

Chapter 8 describes further development of the model. In this case the model was expanded to a wider scale. The system under consideration includes routes in a network system. It starts by outlining the assumptions made and then describes the framework of the model. This is then followed by a description of the model in greater detail.

The problems of data compilation, sensitivity test and model validation are discussed in *Chapter 9*. These are followed by *Chapters 10* and *11* which illustrate the use of the model for the analysis of bus operations in two different situations. The first is in a monopoly in which data from the Roehampton area are used, and the second is when bus operation is subject to competition. Various operational strategies were discussed in these two chapters, both for a monopoly (*Chapter 10*) and for a situation where competition prevails (*Chapter 11*).

Finally *Chapter 12* contains the overall conclusions from the study and some proposals for further research.

CHAPTER 2
BUS OPERATION AND COMPETITION

2.1. Introduction

Public transport has become an essential feature of most cities in both developed and developing countries. Webster and Bly (1980) reported that the greater the size of a town, the greater the modal share of public transport. Moreover, they showed that for towns in West Germany, Canada and the U.K that have a population of more than 3 million public transport has a modal share of more than 20 per cent.

Of the various means of public transport, buses play an important part, particularly for towns in developing countries.

One may appreciate that there is a conflict between supply and demand for public transport. The conflict is between the needs of travellers (demands) and the costs of satisfying these needs (supply), and this leads to two different views with regard to the role which public transport should play. The first view argues that public transport is expected to pay its way with the service being provided in the most cost-effective way possible and paid for entirely through passengers' revenue, while the second view claims that public transport should be regarded as a services to the people which is to be funded largely from public money so that users pay much less than the true cost.

At one time the former view dominated the minds of most operators. This was the case when almost all public transportation in the world was provided by private operators, and when the provision of public transport was a profitable commercial activity. Government involvement in public transport services was restricted to only ensuring that privately owned companies did not take undue advantage of their monopoly position. However, as revenue in many areas fall below costs, public intervention has become necessary to sustain services and, therefore, public authorities have taken over the responsibility for providing urban bus services.

2.2 The trends in the features of bus route operation

Over the last two decades, the rise in costs of operating public transport system has been typically, 2 to 4 per cent per annum in real terms (Webster,1980), whereas the patronage has shown various trends ; some countries such as Finland and Sweden have been enjoying an annual increase in patronage of 1.1 % and 2.0 %, whereas other countries have generally shown a decline.

In the United Kingdom the overall picture of the bus industry has been declining since reaching a peak in the mid-1950's. This decline, however, has been stemmed in many areas in the 1980's with some modest growth in 1984 and 1985 (Stanley, 1987).

It has been argued by Webster (1980) that the increase in operating costs is mainly due to the increase in the real earnings of staff, and the main factor behind the decline in patronage is the increase in car-ownership. Although the operating costs have increased, which in turn raises the cost per passenger, the direct cost to the passenger has been buffered by the provision of subsidies. It has been found that the level of subsidy has been increasing in most countries. In general the level of subsidies ranges from 10 to 70 per cent of the operating costs (Webster, 1980).

The provision of subsidy for public transport is usually part of government policy on public expenditure. There is a need to distribute the public expenditure fairly equal between all modes of transport. It appears that its provision has been used for holding down fares and improving the level of service supplied, and it seems that this, to some extent, has attracted more passengers (compared with the presumed situation in the absence of subsidy).

loosened financial constraints and encouraged a decline in productivity (Pryke, 1977).

2.3. The deregulation of bus operation

As the level of subsidies for the provision of public transport has tended to increase each year and more public financial support has been needed to cover it, many experts have felt that liberalization of the market would raise productivity and efficiency. As a result, some Western governments have tried to change the face of their public transport industries through deregulation. They believe that only through deregulation can the trend be reduced or checked, and they also believe that market forces are capable of stimulating adequate demand for public transport services and thus provoking innovations in the performance and nature of supply offered by operators.

In the United Kingdom the deregulation of the market for bus route operations began with the introduction of the 1980 Transport Act followed by the 1985 Transport Act. Basically the 1980 Transport Act brought partial deregulation (i.e. of express coaches only), whereas the 1985 Transport Act brought complete deregulation (outside London).

Moreover, the Transport Act 1985 brought franchising and privatisation, and, more importantly, changed the legal framework in which the bus industry works. It introduced franchising and privatisation with the break up and sale of National Bus Company subsidiaries, and the new local authority tendering system for the supply of socially-necessary services. The purpose of the change in the legal framework is to introduce competition into the industry, by removing all of the quantitative licensing requirements previously used to control operators.

2.4. Competition in bus route operation

When the issue of deregulation arose, there were two different views about the most likely outcome. One of the views argued that by allowing competition in bus services it may induce rapid changes in the service, and therefore increase the level of uncertainty. In contrast, the other view claimed that it might lead to the passengers' benefit, and possibly a cheaper public transport service.

If the public transport market is open to competition it may be expected that real competition, or competition on-the-road, will only be seen on those routes which have high levels of demand. Only on those routes would the operators make those profits that would, at least, be capable of covering the short term costs and preferably all the long term costs of the operation. On those routes with a very low of levels of demand, however, no new operator would try to enter the market, but these could be subsidised to meet social needs if the local authority feels it necessary.

It has been argued (Stanley, 1987) that competition would be possible, or at least the participant can survive, if a route can generate revenues that are considerably above break-even point. The problem is that on many routes revenues are sufficient to support only for one operator, not two. As a result, competition on that route tends to be short-lived as one operator has to withdraw and the other emerges in a monopoly position.

However, if one tries to postulate the scenario of competition, one would find difficulties in doing so, because it depends mainly on the behaviour of the operators, and there are so many possible situations. There are a number of examples of competition-on-the-road which may give some idea on how unstable the conditions will be and how difficult it is to predict the behaviour of operators when the route is open for competition. A report from SEEDS (South East Economic Development Strategy) indicated that from three different cases of competition in three different areas numerous instances of uneconomic and unstable behaviour were encountered (Stanley, 1987). The following are some of the examples :

When competition was introduced in the trial area of Hereford, as a reaction to increase competition, one of the bus operators actually introduced a free bus service. The competing independent companies followed suit and, as a result, the local government had to extend some pressure to stop this.

In Nottingham, when the competitor (Erewash Travel) entered the market to compete against the existing bus operator (City of Nottingham Transport), they set the fare 50 % below the existing levels. This action provoked the existing operator into matching it and running a service 5 minutes ahead of the competitor's service. The result was that for every two hours on the route two buses would run with a few passengers, and one within minutes of each other.

In Cardiff an independent operator, Coaches Ltd, entered the market to compete with the existing bus operator (Cardiff City Transport). When the competition took place the competitor was offering fares at 14p below the existing fares. The existing operator retaliated with fare reductions and through an increase in service frequency. Due to competition the existing operator expected to have a loss in revenue and increased costs, but the competitor, on the other hand, found themselves in deep financial trouble and went bankrupt with huge debts, and later withdrew from the market.

From the examples described above, it is clear that the features of a bus route competition are unpredictable, and a whole range of outcomes are possible, and in some cases they might be self-destructive.

2.5. Studies of bus operation and competition

In recent times local government has been responsible for providing public transport subsidies. Consequently, most of the theoretical studies on the operation of public transport have been concerned mainly with technical issues. For example, on how to make the bus service more efficient for a certain level of travel demand, or, how to make the operation of a bus route more regular and reliable. The approach to analysing the problem was by describing the technical components of the system in detail. The costs considered were of the users, while the costs of supplying the service were rarely considered.

However, as the question of the financial performance of public transport becomes more important, some people have started to argue that to analyse the operation of a bus route one must consider both the cost of supplying the service as well as the costs of using it. This argument became particularly relevant when many of the western governments started to deregulate their bus industry.

One of the implications of deregulation is competition, and for that the scope for the analysis of bus route operations became wider. Many experts have attempted to examine not only the operation of bus routes as such but also the features of the competitive market.

Although many theorists have attempted to analyse and investigate the features of the competition of bus route operation, none of them has provided any general theory of bus route competition since none can fully explain the behaviour of the market. This is understandable, since, as mentioned in the previous section, the behaviour of the market is so unpredictable.

CHAPTER 3

A LITERATURE REVIEW OF THE ANALYSIS OF BUS OPERATION AND COMPETITION

3.1. Introduction

For the last three decades there has been a wide recognition of the importance of the use of mathematical models in examining and analysing bus route operation. The types of model used vary according to : the nature of the system being considered, the aspects of the system being represented by the model, the availability of knowledge about it and the purpose of the model itself (Jenkins,1976).

There are two types of model which are most commonly used in the modelling of bus route operations, namely analytical models and simulation models. In an analytical model the relation between the variables is expressed using a deterministic analytical expression which is usually in the form of an optimization problem, while in a simulation model the relationship between variables is, in some extent, represented to replicate the step-by-step interaction process between the elements of the system.

Of the two types, the analytical models are more widely used. This is partly due to the fact that mathematical problems to be formulated can be solved using calculus theory which ranges from the simplest to the most complicated ones, and partly because the amount of computation required to solve the problem is not too large.

The simulation models, on the other hand, are more applicable to the analysis of bus route operations for a number of a reasons : they are able to represent the movement of buses and passengers more realistically than in the analytical models, they normally represent the operation of the system by dealing with changes in the system in an evolutionary way and, most importantly, they allow gaming experiments to be conducted on the system in which a human operator interacts with the simulated system as time passes.

3.2. Models for the analysis of bus operation

It is well known that the factors affecting the operation of bus routes are many fold. They range from those concerned with passengers (demand) through those concerned with the technical aspects of operations.

Ideally, all of these factors should be incorporated in the development of models for the operation of bus route analyses. However, since the objective of the model varies from one to another and because the level of accuracy needed depends on its objective, not all the factors are considered in the development of bus operation models. As a result, one can find that quite a number of models, analytical models as well as the simulation type, have been developed to analyse bus operation.

Early attempts to use mathematical models in the analysis of bus route operations were mainly concerned with the characteristics of operations. One of the examples was the work of Newell and Potts (1964). They developed a simple analytical model to represent the movement of buses along an idealised route where the travel time by buses between all pairs of stops, and the passenger arrival and boarding rate at all stops are assumed to be constant. With this model they were able to show one of the characteristics of bus operation, namely the phenomenon of 'bus bunching'.

In a similar manner, Chapman and Michel (1978) developed an analytical model to investigate the position along the route at which the first bus causing a disturbance by running late is caught by the following bus to form a pair. Concerning this characteristic of bus operation, some authors attempted to develop strategies to control the phenomenon of bus bunching. Osuna and Newell (1972) and Newell (1974) developed models in the form of optimization problems which had the objective of minimising the average waiting time of passengers on a simple public transport system, whose trips are random variables ; Newell studied affects that would cause pairing, which was not included by Osuna and Newell.

Of the models described above, it appears that their main concerns were to investigate the variability in bus operation. Some other approaches to developing analytical models which include a more realistic treatment of the variability of such quantities as bus travel times and passenger arrival and boarding rates are outlined by Heap and Thomas (1976). They concluded that the realism attainable by analytical models is restricted by the inadequate representation of vehicle capacity, alighting of passengers and the way the time spent at the stop is related to the headways of buses.

This conclusion led to the argument that a better way to investigate the characteristics of bus operations is by means of a simulation model, since it would be expected to represent the dynamics of the operation far more realistically, including many details such as arrivals at the bus stop, boarding buses, and movements of buses in other traffic. The work by Bly (1973) analysing the operation of bus lanes is one example of this approach. The other example of the use of the simulation model to investigate the characteristics of bus route operations was the work by Bly and Jackson (1974). They developed a simulation model that represents a bus route in Bristol in a reasonably accurate way, and included many sources of variation. This model was used to investigate the relative importance of variations in time by buses at stops and between stops and the variations caused by poor time keeping at terminals.

Many other simulation models have been developed to investigate and examine the characteristics of bus route operations, including Jackson (1978), Gupta (1988) and Cowell (1988). A number of other simulation models that have been developed are described in detail by Jenkins (1976).

The general line of investigation presented by the various models described above, both analytical and simulation, was the technical characteristics of bus route operation. There are, however, some other features of bus route operations that have been analysed using mathematical models, including design and planning.

The models that have been developed which were concerned with the design and planning of bus route operations can be considered in two different groups. The first deals with an idealised system, and the second with actual routes.

In the first group, there has been extensive work done based on optimization methods in which one or several design parameters are selected so as to optimize an objective reflecting benefits to the passengers. Much of this work is based on an assumption of fixed demand and simple geometric configuration.

This line of work began essentially with a paper by Holroyd (1964) in which he analysed the ways of finding the optimum position of bus routes and the optimum frequency of buses on each line in an idealised urban area, where all routes are running across a square grid and have the same frequency. In the model the optimal route spacing and headway are developed by minimising an objective function defined by time cost and operating cost. Demand is assumed to be uniformly distributed over the area.

Byrne and Vuchic (1972) used a similar approach. They presented a method for deriving the line positions, headways and fleet size which minimize the total system and user costs. In their work they analysed a rectangular urban area from which passengers travel to and from the Central Business District (CBD). They found that the optimum line position is obtained when the population using the line on each side are equal, and the optimum headway occurs when the waiting time cost is equal to the operating cost.

At a later stage, some authors such as Bly and Oldfield (1974), Byrne (1975), Clarens and Hurdle (1975) and Newell (1979) tried to develop models of the optimal design of bus route using a similar approach to Holroyd.

Since these models were developed on the assumption of an idealised system and the specification of the city and the public transport network may be so far removed from reality, they are best suited to screening or policy analysis rather than final design. As such, they are not directly applicable to the task of route design in any real situation. As a result, these models tend to be an academic exercise rather than a practical one.

The second group of models, however, is more directly related to a real problem. Essentially, they were developed with the general aim of forecasting and estimating the implications of a particular plan. The level of detail required in the modelling process varies inversely with the length of the planning horizon. A much higher level of detail is required for short range operational planning than for long term planning.

As they are developed with the general aim of forecasting and estimating a particular plan, they seem to be more problem solving and more specific to particular conditions. As a result, it is sometimes difficult for one model to be used under different conditions. However, this condition started to disappear as many experts developed multi-purpose transport planning software, particularly when mini and microcomputers become widely available.

The design and planning models of bus route operations which deal with actual routes is understood to include both their development and evaluation. One of the earliest attempts was made by Lampkin and Saalman (1967). They developed a model using system analysis approach for the purpose of reorganising a municipal bus undertaking in a town of 100,000 inhabitants in the North of England. The model was formulated on the basis of complete planning tasks such as : to choose a set of route, to allocate bus frequencies to routes and, finally, to compile detailed timetables.

Using a similar approach the Voorhees group (1969) developed a suite of computer programs to investigate route revision of the Washington, DC transit system. The model was a computer system which is capable of evaluating certain characteristics of a given network of bus lines and frequencies, and a given trip demand. Although the model is more realistic than Saalman's model, it still contains weaknesses (Achim, et al 1976). One of the weaknesses was the lack of interaction between demand and supply. For example, it ignored the possible patronage increase due to the improved service.

A better approach in the development of a model for the planning and evaluation of bus routes was applied in the TRANSEPT model (Daly, 1973 ; Last and Leak, 1976). This model was developed by the Local Government Operations Research Unit (LGORU) for the bus network revision project for the City of Coventry. Essentially, the TRANSEPT model was a public transport assignment and evaluation model which uses the multi-path assignment of Dial (1971).

Another example of a model that can be grouped with the second set is the model of setting frequency by Furth and Wilson (1982). A number of recent models that are widely used for bus operation design planning are examined in detail by Wren (1986).

3.3. Models for the analysis of competition in bus route operation

3.3.1. The simple case

Modelling the features of competition in the operation of a bus route service is, in fact, not new. It began with a very simple feature of bus route operation, namely the problem of 'common bus lines'. In this feature some routes share a common section of the road and the passengers who wish to travel within that section must select the buses to be used.

The problem to be solved is how to estimate the proportion of passengers who wish to use each route. In this problem the decision that has to be made by the passenger not only depends on the characteristics of the bus operation but also on the behaviour of the passenger. As a result, in the formulation of the problem one must consider the behaviour of passengers in addition to the characteristics of the bus route operation.

A piece of work that is relevant to this problem is the model that was developed by Chriqui and Robillard (1975). In the development of their model they regarded the problem as the probabilistic one of finding the subset of routes which minimizes the expected total travel time for the passengers travelling within the common section served by two or more routes. Later Marquier and Ceder (1984) examined this problem in more detail using an analytical model. To some extent, the result of the study of the problem of common bus lines is very useful for the purposes of assignment in the public transport process.

3.3.2. Competition between bus service and other modes

In the simple case of the competition problem described above, the main issue in the development of the models was how to represent the behaviour of passengers. In that case they assumed that the behaviour of passengers can best be represented in terms of the cost of using the service.

However, a more interesting way of approaching the problem appears to be by considering the cost of providing the service in addition to the cost of using it. The work by Viton (1980) analysing the possibility of the operation of bus routes being profitable when competing with the automobiles is one of the examples of this approach. He examined this problem using an analytical model. The approach taken was to model the bus operator as the sole franchise between a residential area and a central business district, and to assume that the only existing competition in the provision of bus services comes from the automobile. The bus operator can vary the level of service he offers, and was assumed to do so in such a way that profit can be maximised. The behaviour of passengers was modelled as a discrete model choice by utility-maximising consumer. Using this model he examined whether the operation of bus services can make a profit without subsidy. The result shows that under certain conditions a profitable bus operation is possible. This finding tends to support the claim that a private firm can survive if it is allowed to participate in the provision of public transport.

The issue of the possibility of the participation of private firms in the provision of public transport has been considered by many experts in the last ten years, particularly when the trend of public transport financial performance has been being questioned.

3.3.3. Competition between bus operators

In terms of extending this issue to a more interesting one, namely competition between operators, Viton (1982) modified his previous model to represent the interaction between two carriers, one of whom is a profit-maximising private potential entrant, while the other provides a 'public utility' service. This model was developed to ascertain publicly-provided service when the private firm is allowed to participate in the provision of public transport.

More recently, the debate on this subject has spawned several similar studies that have been undertaken in order to investigate the issue in more detail, particularly when the British government introduced the 1985 Transport Act.

Glaister(1985) began with the claim that there is no reason to doubt the possible effects of competition in an urban area. Several authors such as Foster and Golay (1986), Oldfield and Emmerson(1986) and Evans (1987) have responded to this issue with various views which are based on their own studies. The features of their studies of this issue vary. Foster and Golay examine whether an equilibrium might occur with competition in the bus industry, Evans analysed the stability of service of bus route operations under a competitive regime using the theory of spatial competition, and Oldfield and Emmerson investigated the conditions under which several operators are likely to co-exist after the 1985 Transport Act.

All of these studies, except Glaister, were undertaken using analytical models in the form of an optimization problem and, in general, the assumptions embedded in the formulation of the models were similar : the system under study is a single route; they consider passenger demand at an aggregate level and it is elastic to changes in generalized costs; the models do not simulate individual buses and passengers, but work on averages.

Glaister, on the other hand, used a rather different methodology. He developed a simulation model to investigate the likely outcome of competition between two operators in the provision of public transport services. The system being considered was of multi-parallel routes which have the same link in the centre of the route. Travel demand was considered at a disaggregate level. The model simulates the interaction between two operators in the provision of services to the passengers. The rules for competitive entry to, and exit from, operation on the route were as follows. If the load is found to exceed the target load over a period of time profits would be made and a new vehicle could enter the market. Conversely, if the load were too low over a period, losses would be made and one of the vehicles currently making a loss would be eliminated. So, for a given load factor, type of vehicle, and level of fares for each operator this would produce an equilibrium situation.

In general, the intention of all these models was to try to represent the interaction between passengers and operators and between operators. The interaction between passengers and operators (the service they offer) can be represented in the models with some assumptions about the behaviour of passengers when they have to make a decision on which bus to take. One can argue that this behaviour should be treated endogenously in the models.

However, there are some problems when the interaction between operators is treated endogenously in the model as it is in all of the models described above. One can expect that the model will only produce a good forecast of the likely outcome of competition if the behaviour of bus operators in the real world agrees with the rules given in the model. The problem is of the accuracy in the representation of the behaviour of operators in the model since many factors have to be considered.

One possible approach to tackling this problem is by treating the behaviour of the bus operators in the model exogenously. One of the potential advantages of this approach is that the model can be applied to investigating various possible behaviour patterns of the bus operators. This is the approach to be adopted in this work.

CHAPTER 4

MODELS OF BUS OPERATION : A GENERAL REVIEW

4.1. Introduction

In this chapter the concept of modelling bus operations in general will be reviewed, particularly the ways in which aspects of bus operation have been represented in models. Two different type of models will be discussed in this chapter : models of single bus route operation and models of bus operations in a network. The review is needed as a background to the development of the new model of bus operations that will be described in *Chapters 5* and *8*.

In the first part of this chapter, models of bus operations on a single route will be reviewed, followed by a discussion on the modelling of bus operations in a network.

4.2. Models of single route bus operation

The definition models of single route bus operation is understood to include all models of bus operation where the route under consideration is a single route. The route can be part of a large route system or a self-contained route.

Aspects associated with bus operations in a single route can be considered as consisting of three different main components, namely the system, demand and supply. The system is the bus operation entities as a physical term, whereas the demand and the supply are the aspects of bus operation in economical terms.

4.2.1. The system

In modelling a single route bus operation, it is necessary to specify the components of the system being studied. Of course it is not practical to try to incorporate all of the components of the system in the model since this would make the problem unmanageable.

However, there are some key components which play a major role in the system and are commonly considered in the modelling process. Such components are : the route, the buses, the passengers and the operator.

4.2.1.1. The route The operation of a bus route is a collection and distribution process for people with common travel needs. The fact that passengers need not start at the same origin and end at the same destination implies that for each route there is a particular travel demand pattern.

In the operation of a bus route, the drivers are usually assigned to a particular route whose service is fixed in space. Fixed in space means that on a route there is a set number of specific stops in each direction where the buses stop to collect and distribute people. Geometrically, it can be described as two parallel lines each of which has a set of stops.

For the purpose of modelling, there are several approaches to represent the routes. Authors such as Evans (1986) consider the route as an infinite line along which the buses move in one direction. This is, of course, a very simplistic approach and very far from reality. Nevertheless, this approach is, to some extent, appropriate for a certain level of accuracy.

A different approach was given by Glaister (1985, 1986). In his work he represents the route as a set of stops in a line where the buses move along in one direction and when a bus reaches the end of the route, it is reassigned immediately to the initial stops. This way of modelling assumes in fact that the return trip has the same pattern. This may or may not the case, because it is very rare to find a route which has a symmetrical travel pattern.

It can be argued, therefore, that a better way to model the route could be to define a closed system where the buses can be represented as moving along the route continuously. The potential advantage of this approach is that both directions of the route can be considered in great detail, which in turn make it possible to represent the pattern of travel demand in the model.

4.2.1.2. The bus Most authors have tried to represent the bus in the model in as much detail as possible in order to replicate reality. The way it is represented in the model varies but, in general, it is usually represented in terms of the movement of buses when they are operated along a route.

There are three main topics of modelling the bus that need to be considered : how the model represents the movement of the bus, how the model estimates the travel time, and how the model calculates the time the bus spends at the stop.

a. Bus movement

The nature of the behaviour of buses when they are moving along the route is, in general, represented in the model as a sequence of movements between one terminal and another. The movement begins from one terminal and moves along the route from one stop to another, with or without considering the traffic conditions, until it reaches the other terminal.

In the modelling of a single route bus operation, two aspects of bus movement between two terminals need to be considered : the rule when the bus moves between stops and the rule when the bus reaches the stop. In the former case, the rule that is usually used is that the bus cannot be overtaken by or overtake another bus. This is quite valid if there is only one fleet of buses running on the route, and if the average speed of each bus is similar.

In the second case, however, the rule that is usually used is that the bus has to stop whenever it reaches a stop, without considering other factors. This ignores some factors : whether any passenger on board wishes to alight, or whether there are any passengers in a queue at the stop, or whether there is already a bus at the stop. This way of modelling is to some extent appropriate, particularly in the case of a bus operation which operates a rule of compulsory halting at a bus stop. But it will lead to a problem of bus bunching which, in turn, may cause other problems in modelling.

Consider a stop where some passengers stand in a queue and wait for a bus to come. Suppose a bus comes to the stop. In this situation some passengers will board the bus until the bus is full up. At this stage, there is no problem. But, what would happen if a short time after the first bus another bus comes along. If the rule of a compulsory stop is applied, there will be two, three, or maybe more, buses at the stop at the same time. Some problems arise at this stage which are difficult to solve : how does the model decide which bus leaves first and when does it leave the stop ?

Glaister(1985,1986) tried to solve this problem with the "First in first out" (FIFO) discipline, the first come to the stop being the first to leave the stop. This approach can mitigate the phenomenon of bunching, but it does not eliminate it, and does not really solve the problem.

One solution to tackle this problem with is to apply a rule that a bus has to consider the conditions at the stop concerned when it approaches. It has to consider whether there is another bus at the stop. The bus will stop if there is not a bus at the stop, whereas if there is a bus at stop it will stop just for the alighting process for those passengers who wish to alight. With this approach it can be expected that the phenomenon of bunching can be reduced.

b. Time between stops

The movement of buses between stops in the modelling of a single route bus operation is usually represented by specifying the time taken to travel between successive stops under a given set of traffic and other conditions. It is necessary to incorporate such a condition into the modelling process since it will represent the variation that exists in the real world.

The way of representing the variation in travel time between stops varies. One may try to represent this variation by explicitly incorporating details of the traffic and other conditions in the model. These include : the traffic flow condition for each link, the details about intersections and traffic lights, and the time lost by a bus accelerating from and decelerating to any bus stop. Indeed, if one tries to consider all of these features one will produce a model that really replicates reality. However, it will lead to a problem of a data requirements, since it will need a huge amount of data.

A common approach, therefore, is to represent the movement of buses between the stops in a more simplistic manner yet still considering variation. This approach considers the movement of buses between stops in two parts : a deterministic part and a random part. The deterministic part is represented as the average journey time and the random part is represented as the variation in delay which might occur.

With this approach the travel time between stops is calculated on the basis of the average travel time and a random number. For any one bus the model selects a random number to decide on the possible delay that may occur. The travel time between stop is then calculated as a function of the average travel time and the random number.

c. Time spent at the stop

It has been found that the time spent by a bus at a stop is affected by several factors such as : the number of doorways available, the operating system, the ticketing system and the type of bus. Of those factors, the number of doorways available and the operating system are the main ones which should be considered in the calculation of the time spent at a stop.

In terms of the numbers of doors available in the bus, the amount of time spent by a one-door bus at stop is higher than those of a two-door bus. In terms of the operating system, however, the amount of time spent by an OPO (One Person Operated) bus at a stop is less than that of a TPO (two person operated) bus.

There are two ways of calculating the amount of time spent by a bus at a stop. The first is to assume that the marginal boarding or alighting time is dependent on the number of passengers boarding or alighting. This means that the boarding time may sometimes be smaller for, say, the sixth and subsequent passengers than for the first five passengers. With this assumption the total time spent by a one-door bus at stop, T ,can be formulated as,

$$T = C_1 + C_2 + (A + \alpha)n_1 + (B + \beta)n_2 \qquad (4.1)$$

and for a two-door bus,

$$T = C + Max\{ (A + \alpha)n_1, (B + \beta)n_2\} \qquad (4.2)$$

where

A = average marginal alighting time
B = average marginal boarding time
C_1 = boarding deadtime
C_2 = alighting deadtime
C = boarding and alighting deadtime
n_1 = number of passengers alighting
n_2 = number of passengers boarding
α = difference between the mean alighting time and the selected time
β = difference between the mean boarding time time and the selected time.

It is not very clear in which situation this approach can be considered the best way to estimate the time spent by a bus at a stop.

However, the evidence from the study carried by Cundil and Watt (1973) suggested that marginal boarding/alighting time is independent of the number of passengers boarding and alighting, and the amount of time spent at a stop is a linear function of the number of passengers boarding and alighting. So, on the basis of this argument, for one-door buses, the total time spent at the stop, T , can be calculated as :

$$T = C_1 + C_2 + A.n_1 + B.n_2 \qquad (4.3)$$

and for two-door buses,

$$T = C + max\{ A.n_1 , B.n_2\} \qquad (4.4)$$

This holds where the parameters applied are the same as those in the two previous equations. The constant deadtimes in the four equations above represent the fact that, in practice, there is a time-loss caused by a number of components other than passengers boarding and alighting. These components include : the time taken to open or close the doors, and the time taken by the driver to check the traffic.

4.2.1.3. The passengers There are three relevant aspects of passenger behaviour that are commonly considered in modelling bus operation, namely : how they arrive at the stop, how they board, and how they alight.

a. Passenger arrival

The way the arrival of passengers is represented in the model has an important effect on the results of modelling the operation of the bus service. This is due to the fact that the passengers are one of the key elements in the system.

There are two factors that need to be considered in modelling the arrival of passengers : the pattern of arrival and the pattern of movement between stops.

There are some arguments about the pattern of arrival of potential passengers at bus stops. Observation of the arrival of potential passengers at stops by Seddon and Day (1974) indicates that the pattern of arrival of potential passengers depends on the headway of the buses. They argue that for short headways (less than 10 minutes) the potential passengers tend not to time their arrival for specific scheduled buses. For long headways, however, the potential passengers tend to time their arrival for a specific bus. They argue that for short headways the poisson assumption is fairly realistic. However, there is evidence from Jollife and Hutchinson (1975) that for various reasons there is a tendency for more potential passengers to arrive just before, or as, the bus arrives.

In the modelling process, the generation of the arrival of potential passengers depends on the assumptions made about the patterns of arrival of potential passengers. When it is assumed to be a poisson process then the process of generating them can be expressed using the probability distribution of inter arrival time t as follows

$$P_t = r \; exp(-tr) \qquad (4.5)$$

or,

$$P_t = \frac{(rh)}{n\,!} \; exp(-rh) \qquad (4.6)$$

Where r is the average potential passenger's arrival rate, h is headway and n is the number of potential passengers arriving for each headway interval h .

When a potential passenger arrives at the stop, it is expected that he knows which stop will be his destination, and this is not necessarily the same as that of others. This feature implies that it is important to consider the pattern of passengers' movement between stops in the model.

The representation of passenger movement between stops in the modelling of bus route operations varies. It depends on the assumptions taken and the data available. There are two possible assumptions to be considered. The first, the simplest one, is to assume that passenger movement between stops has a random pattern. The number of passenger alighting at stop *j* is independent of the number boarding at each earlier stop *i*. The second is to assume that for a particular route there is a specific pattern of passenger movement between stops.

The first assumption is very unrealistic, because, as mentioned in *section 4.2.1.1*, for a particular route the travel demand tends to have a specific pattern. It is, however, not clear under which conditions the assumption that passengers' origins and destinations are independent is sufficient. It would be expected that under the assumption of independence, the alighting pattern would be more regular than that found in practice, and there is some potential bias that might be produced from this approach.

In the first assumption, the arrivals of potential passengers are generated at each stop based on arrival rates, which have a different (or, maybe the same) value for each stop (see,for example, Glaister, 1985; 1986). The value of the arrival rate is usually based on the observation and in the form of the number of potential passengers per unit time. The number of potential passengers arriving can be generated using a poisson process or a constant rate, depend on the desired assumption. When the potential passenger arrives at a stop the model does not specify the destination of each passenger. The model will specify it as an average in the alighting process (*Section 4.2.1.3.c.*).

In the second assumption, however, one way of representing the pattern of passenger movement between stops is by introducing an origin-destination probability matrix in the model (for example, Bly and Jackson, 1974), each element of which is the probability of a passenger, Where r is the average potential passenger's arrival rate, h is headway and n is the number of potential passengers arriving for each headway interval h . The Poisson distribution is appropriate to generate the arrival of passengers because it produces non-negative integer values.

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In the second assumption, however, one way of representing the pattern of passenger movement between stops is by introducing an origin-destination probability matrix in the model (for example, Bly and Jackson, 1974), each element of which is the probability of a passenger, arriving at stop i, wishing to travel to stop j. So, when the model generates the arrivals of a potential passenger at stop i, he or she is assigned to a destination j according to the relative probabilities of travel between i and j. Thereafter a record is kept of the number of passengers in each queue or on each bus wishing to alight at stop j. As in the first assumption, the number of potential passenger arrivals generated at each stop is based on the arrival rate which, again, may or may not have a different value for each stop. The value of each cell of the origin-destination probability matrix is usually taken from observation, or calculated on the basis of the popularity of each bus stop.

This way of modelling can, to some extent, represent the movement of passengers between stops in the model better than the previous approach. However, there is still a problem of accuracy in the number of passengers represented in the model since the input data for this approach is only the arrival rate for each stop which is at an aggregate level.

One approach to tackling this problem is by using stop-to-stop origin-destination data as an input to generate the arrival of potential passengers. The potential advantage of this approach is that it represents the movement of passengers between stops much more realistically and a more detail.

at the stop depends upon the assumption taken regarding the pattern of passenger movement between stops. If the passenger movement between stops is assumed to follow a random pattern, that is, the number of passengers alighting at stop j is independent of the number of passengers alighting at each earlier stop i, then the representation of the alighting process can be treated in various ways. A very simple one is to assume that the number of passengers alighting at any stop has a poisson distribution with a mean equal to the average number of passengers observed to alight at the stop. This is of course an unrealistic assumption.

Another approach in representing the alighting process of passengers is by introducing an alighting probability P_j , to estimate the number of passengers alighting when a bus is at the stop. The simplest method of using this approach is to assume that the number of passengers who wish to alight at any particular stop will depend on the number of passengers on board when the bus reaches the stop, and will also depend on the attractiveness of the bus stop area.

If the attractiveness of the bus stop can be represented in the form of the alighting probability P_j, then the number of passengers alighting A at a certain stop can be calculated as :

$$A = Pj.M \tag{4.7}$$

where M is the total number of passengers on board the bus.

However, it can be argued that the way of estimating the number of passengers alighting at a stop suggested in the equation (*4.7*) does not represent the fluctuations which are found in practice. A better method of estimating the number of passengers alighting which also represents its fluctuation is by assuming that the number of passengers alighting at a stop follows a binomial distribution. This approach has been exemplified by Glaister (1985 ; 1986) in his model. The number 'A' of passengers alighting is calculated as a binomial distribution which is given as follows,

$$A = B\ (M,\ p,\ q) \qquad (4.8)$$

where q is the probability of any passenger remaining on the bus , $p = 1 - q$, and M is the same as in the previous equation. The probability of any passenger remaining on the bus is given by an exponential function, i.e.

$$q = exp\ (-s/t) \qquad (4.9)$$

where t is the average trip length and s is the distance travelled from the last stop.

This method of modelling has been commented on by Galvez (1986). He argued that this approach introduces an important bias in the resulting average trip length. He also argued that the number alighting produced from this approach is actually greater than those expected. He suggested his own model. The main difference between his method and Glaister's method was that the binomial distribution is used to obtain the stop where a passenger will alight instead of the number of passengers that will alight at the next stop.

As mentioned in the previous section, however, the assumption that the passenger movement between the stops has a random pattern is rather unrealistic, since, in fact, the travel demand in a particular public transport corridor tends to have a specific pattern. It can be argued therefore that all the models of passenger alighting described above have a potential bias, and a better way of modelling would be on the basis of the assumption that the passenger movement between stops has a specific pattern.

When the passenger movement between stops is assumed to have a specific pattern, as mentioned in the previous section, there are two ways of modelling. The first is by introducing an origin-destination probability matrix and the second is by using stop-to-stop origin-destination data to generate the arrival of potential passengers.

Since the two methods allow the model to keep a record of passenger destinations when they board the bus, there are no difficulties in the representation of the alighting process when the bus is at the stop. The number of passengers alighting is the number of passengers on the bus whose destination is that stop.

4.2.1.4. The operator In the modelling of bus route operations, the behaviour of the operator can be treated as an active or a passive component of the system. It is considered to be a passive component of the system if the model represents the behaviour of the operator endogenously and as an active component if it is represented exogenously.

In the former approach the behaviour of the bus operator is assumed in a simplified manner and formulated within the model as a function of some relevant variables in the system. For example, suppose that the operator is assumed to have a strategy of maximising the profit of his operation by adding to the number of buses operated whenever he makes enough profit. In the model this can be formulated endogenously by making the number of buses operated on the route as a function of the profit level (see, for example, Glaister 1986).

This method of modelling is only appropriate for certain systems of bus operation. However, in most bus operation systems, the actual behaviour of the operator is complicated. They do not relate to only one or two relevant variables in the system, but to many. Therefore it can be argued that it is extremely difficult to represent the behaviour of bus operators endogenously.

One way to tackle this problem is by considering the operator as an active component in the system, i.e. by treating the behaviour of the operator exogenously.

4.2.2. Demand

The representation of the demand side in the modelling of a single route bus operation is mainly concerned with the behaviour of passengers at a microscopic level as well as macroscopic one.

At the microscopic level the demand is considered in detail on the basis of how the passengers arrive at the stop and how they board and alight. The way in which they are represented in the models has been mentioned in the *section 4.2.1.3*.

At the macroscopic level, on the other hand, demand is considered in aggregate and is treated in such a way as to represent the causal relationship between demand and supply. In the modelling of a single route bus operation, the demand under consideration is assumed to be a captive demand for the route concerned. No consideration is taken concerning to the effect of other route. So the level of demand is usually assumed to depend only on the condition of the route concerned.

4.2.2.1. Demand elasticity In the modelling of a bus route operation, it is necessary to take into account the causal relationship between supply and demand. By the causal relationship is meant that any change in the supply side of bus route operation will affect the level of its demand.

The causal relationships between supply and demand is, in fact, complicated because there are so many relevant factors involved. However, there is one factor which plays a central role in this causal relationship. This is mainly a function of the supply characteristics of the bus operation system and can be considered as a supply parameter, namely the 'cost' of making the journey.

In general, the cost of making a journey can be considered to consist of the fare and the passenger's reaction to the the total time spent travelling, including his perception of the discomfort or inconvenience while waiting for and travelling to public transport.

There are several approaches to representing the responsiveness of demand to the change in supply. These depend upon the scope of the system under study. For a single route system, however, the approach frequently used is the concept of elasticity. This concept represents how demand responds to the change in supply in a simple manner.

It measures the extent to which demand is likely to change following a unit change in a specific supply parameter. If **x** is considered as a supply parameter that affects the level of demand, then **e**, the **x** elasticity of demand, in general can be defined as the percentage change in demand caused by a 1 % change in **x**. In this case the supply parameter **x** can be the fare paid, the generalised cost, or some other supply parameter.

The concept of elasticity has been used mainly in the modelling of bus operations where only a monopoly market is considered. However, it is not clear whether this concept is still appropriate in representing the responsiveness of demand if the model is considering a competitive situation. One would expect that in a free market regime, where competition exists between operators , the situation would be more difficult to model and forecast. There would be some features of the market which are difficult to explain.

For example, consider a bus route on which two operators run a fleet, each of which has a different level of service. What would happen when one of the operators increases his level of fares, while his rival decreases it. In this situation there will be some conditions that vary between passengers : some new passengers may be attracted by the operator who decreases the level of fares; some existing passengers will disappear because they are worst off; and some potential passengers will go to the operator who has a cheaper fare. The question that arises is how many new passengers will be generated, how many passengers will disappear and so on. The elasticity approach cannot answer such questions in detail since it works at an aggregate level.

4.2.3._Supply

Looking at the supply side of bus operations, one can see that the main consideration is how to represent the aspects of bus operations that are under the full control of the operator. These include the level of service, the costing and fare system.

4.2.3.1._Level_of_service Theoretically, the aspects associated with the level of service of public transport can be considered to consist of three categories (Webster,1980) :

1. Aspects concerned with service scheduling and the route network, including the time and effort passengers must spend in walking to and from the route, waiting for the vehicle to arrive, and riding the vehicle.

2. Aspects concerned with the predictability of the service and the extent to which the operation departs from the published schedule.

3. Aspects covering the comfort, convenience and safety of the service, both in the vehicle and at the stop or station.

Of the three aspects above, the first is the one that is easiest to measure, and therefore considered as the main aspect of the level of service of public transport. There are, however, two different ways of measuring the level of service of public transport system. The operator measures it as the number of vehicle kilometre operated, on the basis that vehicle kilometres operated reflect service frequency (and therefore passenger waiting times) and route coverage (and therefore passengers' walking time). The passengers, on the other hand, measure the level of service primarily on the basis of how long it takes to get from origin to destination. Public transport has a good level of service if the vehicle speed and the frequency of the service are high.

Higher in-vehicle speed means a reduction in in-vehicle time, whereas higher frequency means a reduction in waiting time.

In the modelling of bus operations, the level of service is usually represented in the form of average waiting time. It can be estimated in detail or in a crude way. In the latter case the average waiting time is usually estimated on the basis of service frequency. If the arrival pattern is regular then the average waiting time will be half the headway. In the former case, however, the average waiting time is not only dependent on service frequency, but it also depends on the capacity of the service and the level of travel demand. An estimation of average waiting time can be used in detail in the modelling of bus operations if the model allows for the variations that might occur in the real world.

4.2.3.2 Costs The costs associated with the provision of a bus route service can be considered to consist of two different elements, namely capital costs and variable costs. The capital costs are usually once-only costs that are incurred in order to provide the service. Examples of capital costs include construction, the supply and installation of fixed equipment, and vehicles. Variable costs are those which depend upon the degree of system use. Examples of variable costs include drivers' wages, fuel costs, and vehicle maintenance costs.

Theoretically, variable costs can be separated into direct and indirect costs. Direct costs are those attributable to an individual operation. In a bus operation, they would include such items as drivers' wages, fuel, and bus maintenance costs. Indirect costs are not generally attributable to a specific operation. Heating and lighting for maintenance facilities and supervisory costs are example of indirect costs.

In general, for a given system, variable costs can be related to the fleet size , vehicle hours of operation and vehicle kilometres of service provided. Some of the indirect variable costs, such as bus washing, will depend upon the numbers of vehicles to be maintained, regardless of their utilization. Some of the variable costs, such as tyre costs, can be related to vehicle kilometres, whereas some other variable costs, such as labour costs, can be related to vehicle hours. The supposition that vehicle hours of operation is a primary determinant of variable operating costs derives from the fact that labour costs constitute the most significant component of bus operating costs. In general, drivers are paid on the basis of hours worked.

In the modelling of bus operations, the capital costs are usually explicitly considered as a part of variable costs. the total of operating costs then formulated on the basis of variable costs.

4.2.3.3. Fares and Revenues It is quite common in the modelling of bus operation not to consider the fare in great detail. It used to be considered in a simplified manner. This is partly due to the fact that the movement of passengers is not represented in the model in great detail, and partly because it is not easy to incorporate the fare system into the model specifically.

The most common representation of fares in the models is on the basis of the mileage or kilometerage of the trip. To some extent, this method of modelling is appropriate, but one must be aware that the common ticket system, in practice, is not only based on mileage. One must consider other fare systems such as flat-fares, stage-fares and zonal-fares in addition to fares based on mileage.

When the fare system considered in the model is based on mileage, the revenue is usually calculated on the basis of the estimated trip-length and the number of passenger who make that journey (see, for example, Glaister, 1985,1986). However, since the movement of passengers is not usually represented in great detail it can be expected that the calculation of the revenue has a potential bias.

4.3. Model of bus operation in a network system

A model of bus operations in a network is understood to include all the methods that aid in planning, design and the evaluation of the bus operation in a network system.

Using the same framework as in reviewing models of single route bus operation, we can consider bus operations in a network system as consisting of three main elements : the system, demand and supply.

4.3.1. The system

Looking at an urban bus network operation system, one would find that the system consists of a number of elements which are interrelated. In general, the system of an urban bus network can be briefly described as a system where the operator provides a bus service in order to meet the people's need. In the system, the operators provide the service by running a fleet of buses along a particular route. The routes are set planned to cover all the areas where the people need them. Usually these follow the existing road network. The travellers, on the other hand, use the services nearest to the stops available from their homes to make a journey.

Since a model is developed to represent reality, it is necessary to take into account the elements of the system which are considered to play a major role. Such elements are the network, the buses, the travellers and the operator.

4.3.1.1. The representation of bus network

An urban bus network consists of bus stops, bus routes and the area where passengers start and end their journeys. Bus stops can be represented by points where the passengers can enter and leave the network. These are the places where passengers board and alight from the bus. The bus routes are a sequence of bus stops along which a particular type of vehicle moves.

The purpose of representing this bus network in the model is essentially to permit a simulation of travellers' behaviour, the level of accuracy of which depends on the amount of detail the model represents. For a model that tries to simulate the behaviour of travellers in great detail, the description of the network in the model would include all the necessary artificial network elements, which would be more complex than the actual one.

Basically, a bus network is often represented in a model as a set of nodes and links. The nodes are the place in the system where travellers can start and terminate their journey, whereas the links are the place where the traveller can move from one node to another. In more detail, however, the nodes are sometimes represented as a place where the traveller starts and ends his journey (centroid zones), or as the place where the traveller can get on and off the bus and make a transfer (bus stops).

The way in which the bus route network is represented in the model is strongly influenced by the purpose and the characteristics of the model concerned. We can differentiate them on the basis of the type of model: models dealing with an idealised network and models dealing with an actual route network.

For models concerned with an idealised system, it is common to represent the network system in a simplified manner. In one of the approaches (see, for example, Byrne 1975, Black, 1979), the bus network was represented as a radial (hub and spoke) route structure serving a single dominant activity centre. The system consists of several links and nodes to form a 'spider web' network. The bus routes are not specified explicitly, but sometimes are specified as serving radial sections and circular sections. If the network does not specify the route(s) explicitly, it implies that the bus can move to any link within the network, and the transfer element is not taken into account. When the model has specified the route(s) explicitly, however, it means that passenger journeys have been represented in more detail, including the possibility of transferring from one route to another. The place where passengers can have access to the network is usually assumed to be a node which is located at the end of link.

This method of representation has the advantage of simplicity in the formulation of the model. As the feature of symmetrical configuration can be explored, it is possible therefore to produce a model that is computationally efficient.

Another simplified approach is by considering the urban system to based on a grid with a single dominant area or multi-centres area where the routes have equal spacing between them (see, Holroyd, 1967, Newell, 1979). The bus stops are not explicitly represented and the travellers are assumed to have access to the network at any point, so they can get on or off at any point on its route. Again, because the network has a simple configuration, the formulation of the model has the advantage of simplicity.

For the model that deals with the actual urban network, however, the representation of the network in the model depends on the level of aggregation of the model and the assignment method taken.

In general, most earlier works have tried to represent urban bus networks as closely as possible to reality in order to get an accurate simulation of traveller behaviour. However, there are some features of a bus network that seems to be difficult to simulate. First, actual bus route networks are complicated in nature, a lot of routes occupying the same street and overlapping each other, and , second, overall a bus network consists of so many stops. As a result, most authors tend to make some simplifications, which of course entails some drawbacks.

The common approach has been to treat the bus network in the same manner as any other road network, but bearing in mind the feature of transfer and parallel routes. The routes are not treated in detail. Dial

(1967) only considered bus stops at which transfers are possible. He treated a section of road which has two transfer points at its end as a network link. This link can be serviced by one, two or more routes. Last (1972) used the same approach, but with more detail in representing the bus stop. He considers several stops which are located close to each other as one node. Overall, the bus stops are not considered individually but as aggregates. The main advantage of this approach is that it can use a similar method of assigning travellers to the network as the one used in a road network.

A more detailed way of representing the bus network on the model was applied by Horowitz (1987). He represented the route individually even if two or more routes occupied the same section of the road. So, the link is represented as part of an individual route, not as a section of the road. He also introduced an artificial transfer link in the network in order to represent the process of transfer more accurately. The artificial transfer links are created on the basis of the number of routes which pass through the node concerned. For a node where a transfer is possible between two routes, two artificial transfer links are created. With this approach the network represented in the model becomes complicated, but the simulation of travellers becomes more detailed.

4.3.1.2. The representation of the buses

Unlike the model of single route bus operations, a representation of buses in the model of multi-route bus operation has never been considered in great detail. This is partly because most models used a method in which it is not possible to consider buses individually, and partly because most models consider the system in an aggregate way. For example, if at a particular section of a road a bus service runs on it with the capacity of C and frequency of f, then the model will consider that section of the road as a link which has the capacity of Cf passengers per hour.

This way of modelling has been applied to most models, particularly for those which have used the approaches derived from methods applied to road networks where the vehicle is considered in terms of flow (see, for example : Holroyd, 1967, Dial, 1967, and Scheele, 1977).

The apparent weakness of this approach is that it can not represent the features of the bus operation in detail. It can not, for example, estimate the actual waiting time of passengers at each stop, or estimate the operating costs of the service.

4.3.1.3. The representation of the travellers

Although most models consider the behaviour of travellers as the basic concept for the development of the model, travellers do not have to be considered as individuals. Most earlier works have tended to represent travellers en masse rather than as individuals. This is understandable since a network bus route model deals with a great number of travellers.

4.3.1.4. The representation of the operator

The role of the operator in the system of a network bus operation is vital. It is the element of the system which determines the operating strategies of the service, that is what level of service or level of supply should be provided. In reality, the operator determines the operating strategies on the basis of the operational objective and the real situation of the demand. Most often, the operational objective of the operators is profit maximization, and their strategies are subject to change from one period to another on the basis of their previous performance.

However, in modelling a network bus operation, the operator is not considered as an active element. He is usually considered as a passive element of the system and represented in terms of his operational objective, most of which is treated as an ideal objective, such as : minimizing travellers' total generalised cost, or minimizing the cost of providing the service and using it. This is understandable since most models are developed for the purpose of planning.

4.3.2. Demand

Theoretically, the demand for public transport is dependent upon the population distribution in different parts of the study area concerned, the degree of service offered and any existing alternative modes of travel available. In the bus network system concerned, the arrangement of bus routes and the frequencies of these routes in turn influence the trip generation, modal split, trip distribution and trip assignment.

The way in which earlier works handle trip demand on the model seem to be strongly influenced by the assumptions regarding the system under study. For a model where the system being studied is a hypothetical idealised urban bus network, trip demand is represented as a function of some variable related to the area concerned. This can be fixed over time (see, for example, Holroyd(1967) and Newell(1979)), or sensitive to the level of service being provided (Kocur and Hendrickson, 1982).

For a model where the system under study is an actual bus network, most earlier works treated the demand as a trip matrix where each cell represents the total demand for travel from a certain origin to a certain destination. It means that trip generation and modal split are not considered in the model and only the trip assignment is influenced by the level of bus services available.

The works that have included the modal split process in the model are the works of Last(1974), Last and Leak (1976) and Scheele (1977).

4.3.3. Supply

In a system of bus network operation, the supply can be briefly described as parameters that are to be set by the operator in order to meet certain operational objectives. These include the route to be operated, the type of vehicle, the frequency of each route, the system of operation, the fare system and the fare level.

Of all the supply parameters mentioned above, the frequency is often the main consideration in the modelling of a bus network operation. This is so partly because most authors consider frequencies as the main measures of the adequacy of level of service for a certain level of demand, and partly because the method developed in the model derived from the method used in road traffic where the main element of the supply side of the transport system is often represented as capacity. However, as the fare can be included in the formulation of generalised cost, the fare level began to be considered as an important element of the supply parameter, even though it is only considered in aggregate.

Since most models of bus network operations are developed for the purpose of planning, it appears that supply parameters are often treated as output variables of the model rather than input variables. This is particularly so for analytical (for example, Furth, 1975) and optimization models (for example, Holroyd, 1967 ;Scheele, 1977).

In order to make the formulation of the model manageable, most earlier works have tended to make the assumption that the route to be operated in the system is fixed, and have treated the supply parameter of frequencies as variable (see, for example Scheele 1977) except for the models that are developed with scratch and screen methods (see, Pratt and Schultz, 1972 ; Rea, 1972) where both route and frequencies are treated as variables.

4.3.4. Interaction between supply and demand

A bus network system is a complicated system where many elements interact with each other. However, in a simplified manner one can consider the interaction between elements of the system as the interaction between supply and demand, or, between travellers and the service offered by the operator(s). In general, the interaction between supply and demand can be described as the interaction between the need to minimise the traveller's disutility and the need to achieve the operator's objective. The travellers will react to the service offered by operator on the basis of minimising their disutility, whereas the operator(s) provide the service in order to meet their operational objective.

4.3.4.1. General framework

If one assumes that the demand for transport can be described as a set of trips between the zone of origin and the zone of destination, then for a given level of service the travellers will allocate themselves to the network in such a way as to minimise their disutility. In doing so they will choose a combination of bus routes which are fast in travel time, short in waiting time (or transfer time) and cheap in fare price. The obvious result of this process is that for a given supply provided by the operator, each route in the system will have an allocated demand which will depend on its attractiveness and the attractiveness of other routes. There is interdependency between one route and another. In general, the better the level of service on the route, the higher the allocated demand for that route. However, it is worth noticing that the correlation between the level of service and allocated demand are not proportional.

4.3.4.2. Demand allocation

All models of bus network operations, of course, include some method for allocating the demand to each link or route. These are known as trip assignment method. As mentioned before, this method is derived from the basic behaviour of travellers in the system i.e. the way in which passengers are assumed to choose their path from origin to destination.

However, to model the behaviour of travellers when they choose their path is more complicated than describing the assignment of cars on a road network. A bus journey consists of different parts : walking, waiting and riding the bus.

There are some common questions relating to the problem of modelling the assignment of travellers on a bus network system. The first is how should the model represent the different values put by the travellers on each part of the journey ? How should the model represent the behaviour of travellers when they are faced with a situation where they have to choose between two or more routes which are provided on the same streets for some part of the journey ? And the last one is how should the model represent the situation when a bus is filled to capacity ?

a._Generalised_cost

Generally, a bus trip consists of a number of different elements, each of which has its effect on travellers' decisions. These elements include : walking time, waiting time, time spent in vehicle, the fare paid and the number of interchanges.

The selection of journey path in most models is sometimes arbitrary. This is because of the difficulties in knowing the relative importance of different elements in the path chosen. In general, the decision to use particular a element in a model is made intuitively. In developing a model, the model will appear to fix and restrict the elements and the possibility of their arrangements. In the process of modelling, therefore, one would wish to use only the main elements of the journey as the criteria for finding the shortest path, for example : minimum travel time, or minimum travel cost.

In most models, the use of the criterion of minimum travel time for finding the shortest path is common (see, for example : Dial, 1967 ;Clercq, 1972 ; Scheele, 1977). The travel time is composed of the time spent in the vehicle, time going to and leaving the bus network system and waiting time (for entering and for transfer, if necessary). However, this approach seems to ignore the importance of the fare or monetary cost of the journey, which, in fact, represents one of the major factors in travellers' decisions while making a journey.

A better way of modelling, therefore, is to take into account the cost component. However, if one tries to incorporate fares in the model and use it as an additional criterion for finding the shortest path, one would find that it is not possible to minimise both travel time and travel cost simultaneously. A possible solution is to bring together time and cost in a function to get a generalised resistance, or generalised disutility, or generalised cost. This is an arguable basis to model the behaviour of travellers properly, as, in practice, the main criterion of the path choice in a bus route network is governed by travellers' perception of the relative merit of their available alternatives.

With the concept of generalised cost, the disparate components of travellers' journeys can be reduced to one measure through interpretation as a weighted sum of all the components. It may be represented in terms of weighted components of various elements of the journey and can conveniently be taken to have the unit time (minutes) or unit cost (pence).

In general, the formulation of generalised cost can be given as follows :

$$\textit{Generalised costs} = \sum_{i=1}^{N} \textit{(journey component)(related weight)} \qquad (4.10)$$

where N is the number of components of the journey being considered which is dependent on the level of detail of the model. The more detail the model represent the component of journey the bigger the value of N.

One of the examples for using this concept was given by Horowitz (1987). For a bus trip between centroid zone origin to centroid zone destination, the generalised cost was calculated with the following formulation :

Generalised costs = (Access walking time)(walking weight) +
initial waiting penalty + (waiting time)
(waiting time weight) + riding time +
(transfer time)(transfer time weight) +
(transfer penalty)(number of transfer)+
(egress walk time)(walking weight) +
(fare)(value of time)

(4.11)

In his formulation, the weights and penalties on the equation above vary according to the environmental conditions for the particular trip component. For example, the transfer penalty has been noted to be considerably smaller for a timed transfer than for a normal, uncoordinated transfer.

Despite most authors having tried to formulate a generalised cost with the emphasis on representing a complete picture of a journey, in practice it is difficult to find a model that incorporates the element of travel cost or fare in great detail. The common practice is to represent the travel cost as a simple single parameter, typically in the form of travel cost per journey as is shown in *Equation 4.11.*

However, if one considers the process of the choice of travel path in more detail, one finds that the fare structure has an important effect on the way travellers decide which path they will choose for their journey. If the fare structure is such that the fare is proportional to the distance (distance-based fare), the effect on the choice of path is equivalent to the distance. However, this is not the case for a fare structure where a fixed fare is to be paid on each bus route. In this system the effect of the fare on path choice is the same for any path, regardless of length.

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In deciding the weight value for each element on *Equation 4.11* the main consideration that has to be taken into account is the perception of the travellers toward the elements of the journey in comparison with that of one particular element (such as riding time). This is due to the fact that the perception of passengers toward elements of the journey are different : the perception of the passengers of 5 minutes in the vehicle, for example, will be different to that of 5 minutes waiting or walking (the passengers will feel that 5 minutes in waiting is more inconvenient, for example, because of the cold and the uncertainty associated with waiting time in travel in-vehicle). The different in passengers' perception toward each element of the journey can be established with a survey.

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If one considers again *Equation 4.11.*, one finds that the representation of travel cost is only valid for the condition that the system under study has an integrated flat fare system where changing buses is free of fare. For a system where the fare structure has the form of distanced-base fare or another fare system (for example, stage fare), however, *Equation 4.11.* will not applicable. If one still tries to implement this equation for a system which has a fare structure other than a flat fare one finds that it gives results with a potential bias.

The need to represent the travel cost in great detail in the formulation of generalised cost is obvious, particularly if the model is to be used for bus operation analysis. It is expected that a model which can represent all of the possible fare structures will be useful for analysing the effect of fare strategy on the demand, and most importantly, on the revenues.

b. Parallel routes problem

There is a feature of bus route networks that makes modelling public transport more difficult than that of private transport. Such a feature is the parallel route, where more than one bus route runs on the same section of the road. The main difficulty is in the way the model assigns travellers to the routes. This difficulty has forced transport experts to make simplification, which, in return, has produced some potential bias.

Let us consider a part of a bus network depicted in *Fig. 4.1. Route I* and *route II* run on the same section of road between node C and E. *Route I* has a frequency of f_1 whereas *route II* has f_2.

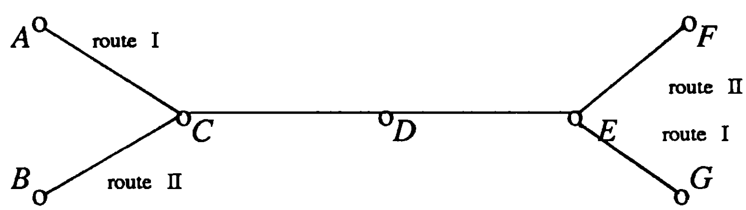

Fig. 4.1. Parallel route

To assign people from node A, B, F and G to their destination is obvious, as all of the travellers will take the one route available ; *route I* for the travellers from A and G and *route II* for the travellers from B and F. However, the problem arises when the travellers from C,D and E who want to travel to C,D or E are to be assigned to a route. To which route should they be assigned ?.

The simplest approach is to represent the road section C-D-E as a link, and assume that the travellers will split equally on both routes. This approach tends to be oversimplistic and ignores the fact that frequencies and vehicle types have a role in the popularity of a route. As a result, this approach is only valid in a case when both of the routes have the same frequency and the same vehicle type.

A more realistic approach was proposed by Dial (1967), through which he incorporated the route frequencies as one of the factors in the assignment method so that the problem of parallel routes could be tackled accordingly. In his method he assumed that the travellers would choose the route that has the highest frequency (or smallest headway). So, in our example above if f_1 greater than f_2 then all of the travellers from C, D and E who are going to go to C,D or E will be assigned to *route 1*.

Although this approach has the advantage of compatibility to the network assignment method as it has been developed for the application of the Moore algorithm (Dial, 1967), it seems, however, that the assumption it rests on is still questionable. The question remaining is whether the assumption that travellers will take the bus route which has the highest frequency is valid ? The fact is that when the travellers make the decision of which bus they want to catch, they make it not only on the basis of which route has the highest frequency, but also, more often, on the basis of which one comes first. The probability that the higher frequency buses come first when the travellers are waiting at the stop, of course, is bigger than that of the lower frequency buses. It is, however, not necessarily true that all travellers will take the one which has the highest frequency, since the travellers tend to take the first bus that arrives, which may be either the higher frequency buses or the lower frequency ones.

The approach that seems to be appropriate for tackling this problem is to consider the value of probability that each bus will be taken by the travellers. The value of the probability can be formulated on the basis of the popularity of the bus concerned. It may be frequency of the bus or other relevant factors.

If one assumes that the popularity of the bus route can be represented by its frequency, then in our example above one can assign the travellers on the basis of the value of probability of each bus to come, which can be represented in a simplistic calculation as :

$$P_i = f_i / \sum_{i=1}^{N} f_i \qquad (4.12)$$

where P_i is the probability that travellers will take route i which has the frequency of f_i, and N is number of bus routes on the link concerned. In our example, the value of N is 2.

Equation 4.12. above is appropriate if we consider that the travellers decide which bus to take only on the basis of frequency and/or availability of the bus. However, if one assumes that the travellers include other characteristics of the bus route in their decision, one comes to the conclusion that generalised cost should be used in the formulation. *Equation 4.12* therefore can be replaced by the following :

$$P_i = g_i / \sum_{i=1}^{N} g_i \qquad (4.13)$$

where g_i is the generalised cost of using bus route i on the link (or, section) concerned, and other variables are the same as before.

The potential advantage of this approach is that it is compatible with a multi-path assignment method. Furthermore, it is possible to modify the formulation of generalised cost in various ways in order to reach a certain level of accuracy (more about generalised cost can be seen in the previous section).

c. Capacity constraints

Looking back to the process of interaction between supply and demand, one finds that at a given level of service offered by operator(s) (supplier), the process of assignment will not be in an immediate way to produce a definite allocation of demand on each route. At the beginning of the process there might be an overcrowding situation (or, over capacity) on a certain link or section of the network. If this is the case then some travellers will find that the path they have taken should not be taken in the first place. In other words, they will redefine their path and re-assign themselves to the route so as to produce another allocation of demand on each route. This process will repeat itself until the travellers feel that they can not redefine their path any better, or until there is no other alternative path better than what they have, or, in other words, until the system reaches an equilibrium.

In road traffic modelling, this process is explained through Wardrop II principle (Hutchinson, 1974) and many methods have been developed to explain it (see, for example, Van Vliet, 1982). However, this feature has not been incorporated in detail and clearly in the modelling of a bus route operation. This is primarily because the modelling of bus network operations is more complicated than that of a road traffic network. As a result, some models of bus route operations represent the allocation of the travellers to the routes on the basis of the shortest path, without any consideration of capacity constraint (see, for example : Dial, 1967 ; Chriqui and Lobillard, 1975).

However, if one tries to take into account the effect of capacity constraint in the development of a bus route operation model one finds some difficulties. The main problem is in determining feedback parameters. It is well known that in road traffic modelling the speed variable is used as a feedback parameter in the process of equilibrium assignment as the speed is strongly affected by congestion. This is due to the fact that there is a clear relationship between speed and flow : when traffic is congested (over flow, or over capacity), the speed decreases to a low level.

However, in the public transport system, the overcrowding situation or over-capacity will have very little effect on the speed of vehicle. It is necessary, therefore, to consider other factors as a feedback parameter. The ones that seem relevant are waiting time and travellers' will accordingly have the same system. However, this may not be true for a distance-based fare system.

For the flat or zonal fare system, the price of a travelcard is usually determined on the basis of the standard fare, the average trip pattern of the holder within its validity period, and the discount factor to be applied. For example, if the actual fare per trip is 50pence, the average number of trips made by a weekly travelcard holder is 14, and the discount factor is 20%, then the price of a weekly travel card will be 560 pence.

The proportion of passengers who hold a travelcard will depend on the discount factor applied to the travelcard. In a monopoly one would find that the greater the discount factor the greater the proportion of passengers who will hold a travelcard. The situation is not so clear, however, under competitive conditions.

Returning to the first question, there are two possible situations to be considered : a monopoly situation and a competitive one. In both cases, it is expected that there must be a clear relationship between the proportion of travellers who are travelcard holders and the level of the level discount factor. However, it has to be recognised that its formulation will be more complicated under competitive conditions than in a monopoly.

Two possible approaches can be considered in the estimation of the proportion of the travelcard holders. The first is to use an empirical formulation, and the second is to use a logit model.

If the first approach is considered it implies that one should test its formulation before trying to use it. If one assumes that there is a direct relationship between the proportion of travelcard holders and the discount factor of the travelcard, then in general it can be formulated as :

$$Pt = f(x) \tag{4.14}$$

Where *Pt* is the proportion of travelcard holders and *x* is a discount factor applied to the travel card. The form of function *f(x)* can be in any form. It can be determined using a regression analysis based on actual data. It has to be recognised, however, that the main problem of this approach is the availability of data. It is expected that the data available would be very sparse and, therefore, the regression analysis would be very difficult. In the case of competition it is expected that *equation (4.14)* would be more complicated since more than two variables are involved. Moreover, it is difficult to determine the formulation since there is not any relevant data available.

The idea behind the logit model in the estimation of the proportion of travelcard holders is that the potential passenger uses his perception of disutility of the journey in deciding whether he will get a travelcard or not. He would have a travelcard if he felt that the disutility of using a travelcard is less than that of the standard ticket. This argument is particularly true in a monopoly where the operator introduces a travelcard. In this situation, there are two alternatives available to the potential passenger, and the logit model that can be used to estimate the proportion of travelcard holders is as follows :

$$P_t = \frac{e^{-\lambda C_t}}{e^{-\lambda C_t} + e^{-\lambda C_n}} \qquad (4.15)$$

where P_t is the proportion the market who hold the travelcard, C_t is the disutility of using the travelcard, C_n is the disutility of using the standard ticket and λ is a calibrated parameter. Ideally, the disutility parameters C_n and C_t are derived from all factors that are related to the trip-making activity. However, because the main difference between the use of the travelcard and the use of standard ticket is only in the price, it is reasonable if only that factor is considered in the formulation.

In the case of a competitive market, however, the problem will be more complicated than that described above, since there will be more than two alternatives available to the potential passengers. For example consider the condition when each operator introduces his own travelcard. In this situation potential passengers will fall into three different groups : travelcard holder 1, travelcard holder 2 and non travelcard holder.

Equation (4.15) above can still be used to estimate the proportion in each group. Two steps have to be used to calculate this. The first step is to consider the potential passengers as two groups: travelcard holders and non travelcard holders, and to calculate each proportion. The second step is to consider the travelcard holder group as two different groups : travelcard holder 1 and travelcard holder 2, with proportions calculated on the basis of the figure from the first step. This approach is known as a nested logit model.

Another way of calculating the proportion of each group is by using a multi-logit model. In general, the multi-logit model can be formulated as follows :

$$P_i = \frac{e^{-\lambda C_i}}{\sum_{i=1}^{N} e^{-\lambda C_i}} \qquad (4.16)$$

where P_i is the proportion of the market who choose the i^{th}alternative, C_i is the disutility of i^{th} alternative, λ is a calibrated parameter and N is the number of alternatives available. In the case of our problem the number of alternatives is 3 (non travelcard holders, travelcard holder 1 and travelcard holder 2).

In the second problem, two possible approaches can be considered, firstly by considering the way the operator estimates the revenue from the purchase of the travelcard, and secondly by considering the total number of travelcard holders that actually board the bus.

In the former approach, one can estimate the revenue from travelcard holders on the basis of the number of travelcard tickets which have been sold within a certain period. The assumption in the modelling process is that all of the passengers buy a travel card at the same time at the beginning of the time period concerned. Therefore, the total revenue from the travelcard holders who use a service can be calculated as a multiplication between the total number of travelcard holders and the price of the travelcard. This approach seems satisfactory but one must be aware of the fact that, in reality, not all passengers buy a travelcard at the same time.

In the latter approach, the revenue from travelcard holders is calculated on the basis of the number of passengers that are actually board the bus. This approach implies that the travelcard ticket is considered as pre-paid discount-fare rather than a season ticket. This simplification is particularly true if the travelcard holders considered in the system are passengers who have a regular pattern of journeys. If this is the case then the revenue from the travelcard holders can be calculated in the same manner as from the standard fares, except that the travelcard holder has a discount price.

Referring to the third problem, there are two situations to be considered : a monopoly condition and a competitive one. In the first case one would expect that in a monopoly, the introduction of a travelcard will increase the level of travel demand. This is obvious since, in general, the introduction of a travelcard has the same effect as a decrease in the level of fares. However, the problem is that for a certain level of travel demand this approach is over simple since not all potential passengers have the same perception of the travelcard. Potential passengers who travel only occasionally by public transport would feel that the use of a standard ticket is cheaper and more practical since the travelcard is usually designed for more than one trip and for a certain time period. As a result, one needs to know exactly the structure of travel demand before trying to predict the change in the level of travel demand.

The problem of estimating the responsiveness of the demand to the change in travelcard price in a competitive market seems to be more complicated than in a monopoly market described above. In a competitive market there is a wide range of possibilities that might occur concerning the travelcard. Take, for example, a condition where two operators introduce a travelcard, but with different a strategy : one of the operator decreases the discount factor of travelcard, whilst his rival increases it. In this situation there will be some possible conditions concerning the level of travel demand : some existing passengers may switch to the competitor who increases the level of discount factor of the travelcard; some existing passengers will disappear because they are worse off; and some new passengers may be generated by the operator who increases the discount factor of his travelcard. The main problem that arises is how to estimate the number of those new passengers who will be generated, and how to estimate the number of those passengers who will go to the competitor.

The simplified approach to overcome this problem is to consider the average fare paid. When the operator introduces the travelcard, mathematically it means that overall the average price is decreased since the travelcard usually has a discount factor. Using this figure one can then predict the change in the level of travel demand based on the elasticity concept.

The potential advantage of this approach is that one can predict the change in the level of travel demand for any possible situation concerned with the travelcard price. It is easy, for example, to predict the change in the level of travel demand in a monopoly condition when the operator increases the travelcard price whilst keeping the standard fare price constant, or, to predict the responsiveness of the travel demand in a competitive market when one of the operators increases the discount factor of the travelcard whilst his rival decreases it.

CHAPTER 5

COMBO.1 : A SIMULATION MODEL OF SINGLE BUS ROUTE FOR THE ANALYSIS OF BUS OPERATION AND COMPETITION

5.1. Introduction

In this chapter a simulation model that has been developed for the analysis of bus operation and competition, called *COMBO.1 (COMpetitive Bus Operation)*, is described. The purpose of this simulation model, in general, is for the investigation of bus operation on a self-contained route, under a monopoly regime as well as in competition. The core of the model lies in the representation of the system being studied. The behaviour of passengers is represented endogenously using the concept of disutility whereas the behaviour of the operator is represented exogenously. The model is an interactive one, that is, allowing the interaction between users and the model.

In general, the formulation of the model is based on the consideration of three different aspects : the system, the supply and the demand. Each of these aspects is considered separately on the basis of its characteristics. The system is modelled on the basis of its physical conditions. These include the characteristics of each component of the system. The second aspect being modelled represents the supply side of the bus route operation, and is concerned with fares, revenues and operating costs. The third aspect is modelled to represent how demand responds to the supply side of the operation.

5.2. Modelling of the system

The system being considered in this model is a self-contained single bus route where a number of buses move along to pick up and distribute the passengers. In general, we can consider the system as consisting of four main physical components which are interrelated. These components are : the route, the buses, the passengers and the operator. The following sections contain the description of each component.

5.2.1. The route In this model the route under consideration is a single fixed route on which buses can run from one terminal to another in both directions (see, *Fig.5.1*). There is no intermediate terminal between the two ends. It consists of *n* stops on each direction where the buses can load and unload the passengers.

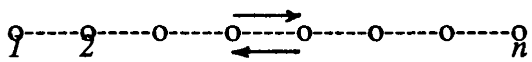

Fig. 5.1 Single fixed route

To make the problem easier to handle, yet still trying to replicate the real world, the route is represented in the model as a closed loop. It is taken to be a circular route where the terminal at the end of the route is treated as a dummy link between two stops (*Fig. 5.2*). The length of dummy link is determined on the basis of the assumption about the average time that buses layover. With this approach the flow of the buses can be considered as one-directional flow which is moving along a circular route continuously so that the travel pattern can be presented in the model as it is the real world.

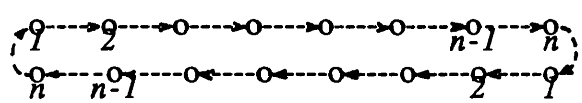

Fig. 5.2. The route in the model

5.2.2. The buses There are two possible situations which can be considered in this model. The first is when only one bus fleet is operating the route and the second is when there are two fleets of buses operating the route. The buses in the fleet have a specified speed, capacity, operating system, and system of fares. In the case of two fleets of buses operated the route, there will be a competition between operators to pick up the passengers. The buses are represented as having two characteristics : a fixed part and a variable part. The fixed part is an identifier for the buses in the system, this includes a unique number, capacity, speed, fare system and operating system. The variable part represents the condition of the buses at any time. This includes their position in the system and the number and destination of the passengers on board.

a. Bus movement

The nature of bus behaviour when moving along the route is represented in the model as follows. In the case of two fleets of buses operating on the route, the buses can overtake other buses which have a lower speed or be overtaken by others which have a higher speed.

When a bus is approaching a stop there are two cases which can be considered separately. The first is when there is another bus at the stop. In this case, the bus will stop if, and only if, there are some passengers on the bus wishing to alight. When it stops passengers are allowed to alight, but none of the potential passengers at the stop are allowed to board it. The assumption is that the potential passengers at the stop board the first bus, not the second one. Of course this is not necessarily true, since in reality some potential passengers might catch the second bus instead of the first one.

The second case is where there is no other bus at the stop. In this case the bus will stop if, and only if, there is a queue of potential passengers at the stop, or if there are some passengers wishing to alight. When the bus has stopped, some passengers get off and some potential passengers get on. It remains at the stop until no more potential passengers in the queue wish to board, or until there is no more spare capacity on the bus.

In this model, a record is kept of the destination of each passenger on each bus, so it is known whether or not a bus has to stop when approaching the stop, and it is known exactly how many passengers wish to alight at each particular stop.

b. Time between stops

In this model the movement of buses between stops is represented without any consideration of the effect of traffic flow, congestion, traffic lights or other aspects of traffic in detail. But it is modelled in such a way as to allow some variation.

The movement of buses between stops is considered to consist of two parts : a deterministic part and a random part. The former is represented as the average journey time and the latter as the variation in delay.

It is assumed that the variation in travel time between stops follows a random pattern. If v is the average journey speed of bus, d_{ij} is length of a link between stop i and stop j, then the travel time Sij between two stops can be calculated as follows,

$$S_{ij} = d_{ij}/v \quad [\ 1 + \quad X^*(0.5 - r)] \qquad (5.1)$$

where r is a random number which has a value between 0 and 1 and X is a given parameter which represent the standard deviation.

c. Time spent at the stop

The time spent by the bus at the stop is calculated on the basis of the assumption that marginal boarding/alighting time is independent of the number of passengers boarding/alighting, and the amount of time spent at the stop is a linear function of the number of passengers boarding/alighting. Since the vehicle considered in this model is to be assumed to have two doors, the total time spent at the stop ,T , is therefore calculated in the same manner as *equation (4.4)*, that is :

$$T = \ C + max\{A.n_1 \ , \ B.n_2\} \qquad (5.2)$$

where,

C = deadtime

A = marginal alighting time

B = marginal boarding time

n_1 = the number of passengers alighting

n_2 = the number of passengers boarding

The value of parameters considered on the equation above depend on the operating system of the bus concerned.

5.2.3. The passengers In this model we differentiate between potential passengers and passengers. The potential passengers are the people who come to the stop and intend to catch the bus, whereas the passengers are the people who actually get onto the bus to make a journey.

The passengers or potential passengers considered in this model are differentiated into three income groups who have a different value of time.

a. Arrival of potential passengers

The arrival of potential passengers at the stop is generated in the model on the assumption that in the route there is a fixed pattern of passenger movement between stops.

The approach applied in this model is by using stop-to-stop origin-destination data as an input to generate the arrival of potential passengers. The potential advantage of this approach is that it represents the movement of passengers between stops realistically and the number of passengers who travel in the system is treated in detail.

In this model the total potential passengers who arrive at stop i and intend to catch the bus to travel to stop j during a particular time period of, say, two hours, are assumed to be given as a trip matrix T_{ij}. These data are used to generate the arrival of potential passengers at each stop. The potential passengers generated by the model are distinguished into types according to their destination and income group.

The arrival of potential passengers at each stop in the route is generated in a sequence. It is generated for each time interval, typically every one minute or less.

The number of potential passengers who arrive at stop i during interval period Δt and intend to catch the bus to travel to stop j, P_{ij} , is generated by the model on the basis of the value of the relevant cell in the trip matrix T_{ij}. It is generated with the assumption that the potential passengers, P_{ij}, who arrive within that particular interval time have a random pattern with the constraint that the total number of those who arrive within 2 hours is about the same with the data cell trip matrix concerned. Mathematically it is given by :

$$T_{ij} = \sum_{t=0}^{T} P_{ijt} \qquad (5.3)$$

where T is the total time period and t is the arrival time. With this approach, the model generates the arrival of potential passengers in great detail.

It is necessary to note that at the process of generating the arrival of potential passengers at the stop, the model sometimes will not produce any arrival within a time interval, particularly for those potential passengers who are a small number in total in the cell trip-matrix T_{ij} concerned. For example, consider a cell of trip-matrix T_{ij} which has a value, say, 10, which implies that within two hours there will be 10 potential passengers who arrive at stop i and wish to go to stop j. If the model generates the arrival of potential passengers with the interval time of one minute, mathematically, it means that at stop i there will be 0.166 potential passenger per minute who wish to go to stop j. Of course the model will not produce this number, since the arrival of potential passengers has to be represented as an integer number. In this case, the model will produce the arrival of potential passengers for each time interval in such a way as to make the total number within two hours about the same as 10.

For every potential passenger who has been generated the model keeps a record of the time they arrive at the stop and accordingly places them at the back of the existing queue. This makes it easy for the model to represent them in the boarding process and to calculate the waiting time for each potential passenger.

b. Boarding

Since the model keeps a record of the time the potential passengers arrive at the stop and places them in the queue, the model therefore can represent the boarding process fairly realistically. It can choose which of the potential passengers board the bus first, which of them later and which of them have to wait for another bus to come in the case of the bus having already filled up. All of these processes are based on the position of potential passengers in the queue.

When a bus has stopped at a stop, the model will carry out the alighting process first (as described in *Section 5.3.2.c.*) to determine exactly how many seats are available on the bus, and then, in sequence, will give a chance for each of potential passengers, starting from the head of the queue, to board the bus. If there is only one fleet of buses operating the route, every potential passenger who has a turn will accept the chance, but this is not the case when there are two different fleets of buses operated the route. The model allows the possibility that a potential passenger may refuse to board and wait for another bus to come. This feature will be discussed in more detail in the passengers' decision section (*Section 5.3.2.*).

For each potential passenger who has boarded the bus the model keeps a record of his or her destination, this is to make the model easy in representing the alighting process for the bus concerned.

The boarding process will finish if the bus has filled up, or the queue has emptied, or the bus has not filled but all the remaining potential passengers in the queue refuse to board.

When the boarding process has finished the potential passengers who are still in the queue will be rearranged on the basis of the time they arrive at the stop.

c. Alighting

In the model the alighting process is represented in such a way as to ensure that the number of passengers alighting at stop j is dependent on the number boarding at the earlier stops who intend to do so as it is in the actual conditions. This is, however, not too difficult to represent in the model since a record is kept of the destination of each passenger who is on board.

When a bus has arrived at a stop, the model will check whether or not any passengers wish to alight. This is based on the record of the destination of each passenger. The number of passengers who wish to alight at the stop is the number of passengers on the bus who have a destination at that stop. If a bus has a set of passengers p_{ij} on board, then the number of passengers who wish to alight at stop j is given by,

$$A_i = \sum_{i=1}^{i=j} p_{ij} \qquad (5.4)$$

For every passenger who alights from the bus the model will reduce the total number of passengers on board by one. After the alighting process has finished the model knows exactly how many passengers remain on board.

5.2.4. The operators As mentioned in *section 4.2.1.4.*, the behaviour of the operator is difficult to formulate endogenously within the model. This is because it is so complicated and there are too many relevant variables involved. Therefore it is necessary to consider the operator as an active component of the system, that is, a component which is not formulated within the model but treated exogenously.

The potential advantage of this approach is that the model can be used to investigate several possible behaviour patterns of bus operators, and to examine the likely outcome of bus operation with those patterns of behaviour.

In this model the operators are considered in a way that makes it possible to represent their behaviour endogenously, by choosing alternative values of input parameters. The alternative input parameters available are the parameters that represent the main components of the system which are under the full control of the operators. These include : the type of vehicle, the system of operating the bus, the fare system, the level of fare and the number of buses operated on the route.

With this approach the behaviour of the operators in the bus route can be briefly described as how do they manage these parameters in order to achieve their operational objectives ?.

5.3. Modelling of demand

Demand for public transport in this model is represented in such a way as to replicate realistic conditions. The main assumption concerning demand is that the route being studied is a self-contained route where the overall level of travel demand is only sensitive to the change of service provision such as : level of fare and level of service frequency. It does not take into consideration any other factors. Moreover, it is assumed that for any particular route the passenger movement between stops has a specific pattern.

The demand is represented as potential passengers and passengers. The way they are represented in the model has been mentioned in *Section 5.2.3*.

5.3.1. Demand elasticity In this model the causal relationship between total supply and total demand is represented using an elasticity model. It is assumed that the factor which has the central role in this causal relationship is the 'level of service' of the journey.

Aspects of level of service that are considered in this model are : the average headway and the average fare level. It is true that this assumption may be rather misleading since, in general, generalised cost would be more appropriate to consider as the factor that has a central role in the relationship between supply and demand. However, since the average fare level and the average headway are part of generalised cost that people are most concerned about in the long term, it is reasonable to consider them as the supply parameter that affects the overall level of travel demand rather than generalised cost itself. If T^{o}_{ij} and x^{o} are the level of demand and the aspect of level of service at time period o, then the introduction of the new level of service x^{t} will make the level of demand T^{o}_{ij} :

$$T^{t}_{ij} = T^{o}_{ij} \left(\frac{x^{t}}{x^{o}}\right)^{\xi} \qquad (5.5)$$

where ξ is the level of service elasticity of demand. The value of ξ for each aspect level of service can be seen on *Table 5.1.*

Table 5.1. Elasticity value

Aspect considered	ξ
Fare	- 0.3
Headway	- 0.50

Source: Webster, F.V. and P.H. Bly, 'The demand for Public Transport', Transport and Road Research Laboratory, Crowthrone, U.K.,1980.

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Aspects of level of service that are considered in this model are : the average headway and the average fare level. It could be argued that it would be more appropriate to consider generalised cost since it represents the aggregation of all the elements (i.e., access walking time, waiting time, fare, in-vehicle travel time and egress walking time). However, passengers may perceive fare levels and the average headway (which is the converse of frequency and affects waiting time) separately in their decision making process. They also have the advantage of being easy to measure ojectively, unlike reliability for example. If T^{o}_{ij} and x^{o} are the level of demand and the aspect of level of service at time period o, then by using log elasticity formulae the introduction of the new level of service x^{t} will make the level of demand T^{o}_{ij} :

$$T^{t}_{ij} = T^{o}_{ij} \left(\frac{x^{t}}{x^{o}}\right)^{\xi} \qquad (5.6)$$

where ξ is the level of service elasticity of demand. The value of ξ for each aspect level of service can be seen on *Table 5.1.*

Table 5.1. Elasticity value

Aspect considered	ξ
Fare	- 0.30
Headway	- 0.50

Source: Webster, F.V. and P.H. Bly, 'The demand for Public Transport', Transport and Road Research Laboratory, Crowthrone, U.K.,1980.

It should be recognised here that the demand considered in *equation (5.6)* is the demand for a specific O-D pair. This is because demand is considered in the model in the form of a stop-to-stop trip matrix.

Although *equation (5.5)* above derives from the condition of a monopoly market, it is assumed that the formulation is still valid under the conditions of a competitive market. This simplification is necessary as the behaviour of a competitive market for buses has not, as yet, been studied fully.

5.3.2. Passengers' decisions In a case when there are two operators

In the equation above, the money fare F_{ij} for the red bus is different from that the blue bus : it depends on the length of the journey and the fare system for each fleet of buses. Moreover, the travel time S_{ij} for the red bus may, or may not, be different compared to that of the blue bus. It depends whether or not they are the same type of vehicle.

In these equations it is assumed that the travel time S_{ij} is an expected travel time. It is not the actual one. The assumption is that the potential passenger does not know exactly how long the bus will stop at each particular stop. In the model S_{ij} is therefore calculated on the basis of the average speed and the trip distance of the passenger.

The expected waiting time W is calculated on the assumption that the potential passenger has good information about the frequency of both services. It is also assumed that the arrival time of a red bus is independent of the arrival time of a blue bus. A potential passenger arriving at the stop expects that the average waiting time for each bus will be about half of the headway. When the red bus arrives, the potential passenger who has been waiting *t* minutes for the bus would expect that the waiting time for the next bus of the other fleet will be half of its headway, less *t* minutes.

In this model the decision making process of each potential passenger is represented as a choice probability which takes a logit form with the decision based on the difference in the generalised costs described above. The choice probability has the form of

$$P = Y / [1 + exp (-CZ)] \qquad (5.9)$$

where *Y* represents the preference value of potential passengers for the bus concerned, *Z* is the difference in generalised cost as given in *equation (5.8)* and *C* is a constant parameter.

The coefficient of *C* applied to *Z* in the equation above determines the propensity to discriminate against a vehicle which is slower or more expensive.

The preference value Y is represented in equation *(5.9)* to model how the potential passengers behave when they are faced with the condition of waiting for the bus. It is determined on the basis of the psychological condition of the potential passenger concerned, that is how many previous buses have been refused. The more refusal, the bigger the value of Y (see *Table 5.1*).

Table 5.1 THE VALUE OF *Y*

The number of buses have been refused in the previous time period	*Y*
0	*1.0*
1	*1.5*
2	*2.0*

A potential passenger who has refused two buses would almost certainly board the next bus to come since the value of the choice probability would be very high. It can be argued that a potential passenger in this situation would feel frustrated and would instantly board the next bus to come without considering all the factors. In this model it is assumed that the potential passenger's criterion for deciding whether or not to board the bus is based on the value of the choice probability. He or she would do so if the value of choice probability was greater than or equal 0.5, and would refuse and wait for the next bus to come if its value was less than 0.5.

5.4. Modelling of supply

The supply side of the bus operation considered in this model covers all of the aspects that are concerned with the financial side of the operation. These include operating costs, fares and revenues.

5.4.1 Costs In this model the costs associated with the provision of the bus route service are considered to consist of two different costs, namely variable costs and capital costs.

a._Variable_costs

The variable costs are treated as operating costs and calculated on the basis of time-related and kilometer-related costs. The former category includes labour costs, overhead and maintenance, while the latter includes fuel, tyres and maintenance. The general formulation for the calculation of operating costs is given by :

$$OC = x.(VH) + y.(VM) \qquad (5.10)$$

where :

OC = total operating costs
VH = total vehicle hours of operation
VM = total vehicle kilometres of operation
x = cost related to an hour of vehicle operation
y = cost related to a kilometre of vehicle operation

In this model the total operating cost of the bus operation for a certain time period is calculated on the basis of the figures from a two-hour simulation process which represents the morning peak hour.

b._Capital_costs

For simplification, the element of capital costs considered in this model is the cost of providing the vehicle. It does not consider other elements, such as the provision of the bus station or administration offices.

Since this cost is incurred at one time, and in the model the total costs are considered for a certain period of operation (typically 3 value of Y. Unfortunately, there is little empirical evidence in the influence of waiting on passenger behaviour under conditions of competition. Hence, it has been necessary to use personal judgement to determine the value of Y. The values selected, as shown in *Table 5.2,* imply that when one bus has been refused the probabality of taking the next bus increases by 50 %, all other factors being equal, and doubles when two buses have been refused.

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a. Variable costs

The variable costs are treated as operating costs and calculated on the basis of time-related and kilometer-related costs. The former category includes labour costs, overhead and maintenance, while the latter includes fuel, tyres and maintenance. The general formulation for the calculation of operating costs is given by :

$$OC = x.(VH) + y.(VM) \qquad (5.11)$$

where :

OC = total operating costs
VH = total vehicle hours of operation
VM = total vehicle kilometres of operation
x = cost related to an hour of vehicle operation
y = cost related to a kilometre of vehicle operation

In this model the total operating cost of the bus operation for a certain time period is calculated on the basis of the figures from a two-hour simulation process which represents the morning peak hour.

b. Capital costs

For simplification, the element of capital costs considered in this model is the cost of providing the vehicle. It does not consider other elements, such as the provision of the bus station or administration offices.

Since this cost is incurred at one time, and in the model the total costs are considered for a certain period of operation (typically 3 months), a discounting technique is used to express this cost over a period of time in terms of equivalent recurring costs. In the calculation, the following relationship is used :

$$A = P \frac{i(1 + i)^n}{(1 + i)^n - 1} \qquad (5.12)$$

where :

A = Equivalent annual cost

P = Initial capital costs

i = Annual rate of interest

n = Service life of the vehicle in year

5.4.2._Fares_and_revenues For most bus operators the money fare from passengers is an important part of revenue sources since more than 90 % of true revenue (excluding subsidy) is usually attributable to the fare (other sources can be revenue from advertising and other related bussiness).

Theoretically, there are many possible fare systems that are applicable for bus route operation, however, the most common fare systems that are found in practice are : flat fare, distance-based fare, stage fare and zonal fare. Flat fares are characterised by a single fares area, within which there is only one price for the ticket offered for the journey. This system has the advantage of simplicity. The passengers require no special knowledge of the system. Distance-based fares, on the other hand, offer appropriately differentiated fares for journeys of different lengths. For the passenger, distance-based fares are more difficult to grasp than flat fares. Stage fares, in fact, have the same concept with the distance-based fare; the difference is in the way the fare is differentiated for journeys of different length. In this system the differentiation of the fares is coarse. Zonal fares are the fare system that combine the flat fare system and the stage fare system. Thus delineate different areas in such a way that, within the areas, there is the flat fare, but the crossing of a boundary between two areas results in higher fares.

3. The revenue from the travelcard holder is calculated in the same manner as from the passenger who uses an ordinary ticket. The difference is that the travelcard holder pays less (at a discount price level).

4. The travelcard holder passengers are assumed to choose whether to catch the first bus to come along or to wait for the next one with the decision based on *Equation(5.8)* and *(5.9)*, but with some modification. It is assumed that he or she would pay nothing if he or she catches the bus for which the travelcard is valid. Mathematically the fare will be zero. This means that the traveller is more likely to take the bus for which the travelcard is held. The greater the travelcard discount the greater the chance the bus is taken. Thus, by offering a travelcard, the operator will attract more passengers but at a lower fare.

5.5 Simulation process

In a simulation model it is necessary to ensure that all events are dealt in chronological order since a change at one point in time can affect changes at a later point in time. In the model the simulated time period is divided into smaller time cells, typically one or two minutes ; the model then works through the time periods taking each successive time cell in turn representing the events that occur within that time cell.

The simulation process begins after the values of each operator's parameters have been input. Initially the model will distribute all the buses being operated along the route and will generate the arrival of potential passengers at the stops. So, at the beginning of the simulation process there are already queues of potential passengers at the stops, and some passengers on the buses. This way of modelling does not simulate the condition that the buses have just left the garage, but represents the conditions when buses have already been operating on the route.

As time passes, during each time cell the model examines the position of all the buses. If a bus can reach the next stop before the end of the time cell being considered and there are no other buses at the stop when it arrives, the model will represent the boarding and alighting process. However, if there is another bus at the stop when it arrives then the model represents only the alighting process. At the same time the model generates the arrival of potential passengers at each stop. This is based on the data from the stop-to-stop origin-destination trip matrix. The potential passengers wishing to travel during a particular time cell generated by the model have an attribute of an income group, a destination, a time when they arrive at the stop and a type of fare they use (travelcard or ordinary ticket). For stop i at time t the model generates the potential passengers P_{ijqth} of income group q who use ticket system h and intend to catch the bus travel to stop j.

In the boarding process the model will consider each potential passenger at the stop, starting from the head of the queue. In the case of two fleets of buses operating on the route the model calculates the generalised cost of using the bus available, relative to that of the next bus to come. Using this value the model then calculates the choice probabilities and considers whether or not the passenger will board the bus. This is not the case when only one fleet of buses is being operated on the route. It is assumed that each potential passenger will board the bus. This process applies to every potential passenger sequentially, and it will stop when the bus has no spare capacity or no more potential passengers wish to board (in the case of competition), or no more passengers are standing in the queue. For each potential passenger boarding the bus the model calculates the revenue received by the bus on the basis of the level of the fare and the fare system applying to that bus.

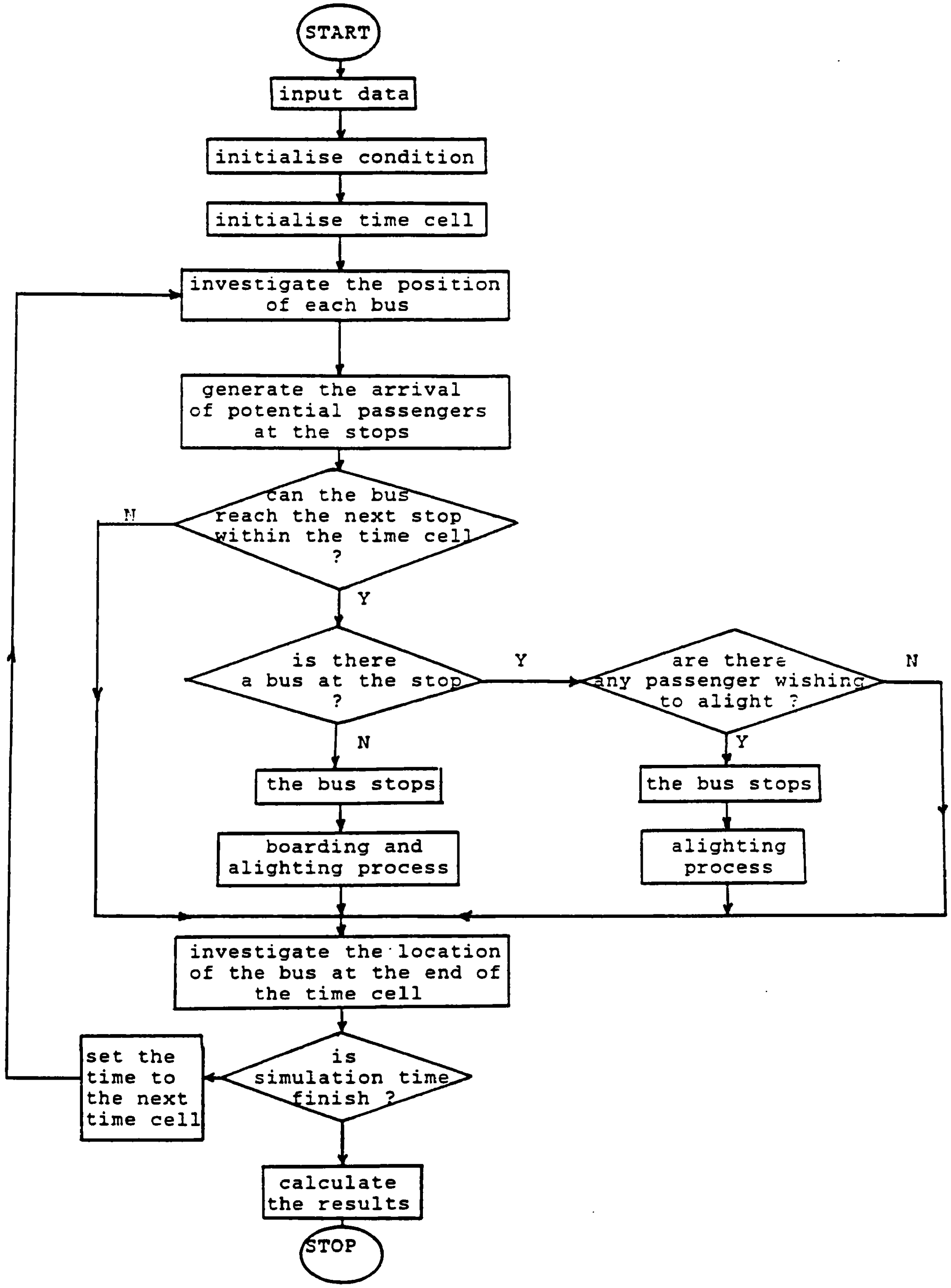


Fig. 5.3. The framework of simulation

After the boarding process the model examines the position of the bus at the end of the time cell. The whole process will be considered again for each particular bus for each time cell until the simulation period has finished. The framework of the process can be seen in *Fig. 5.3*.

After the simulation period has finished the model calculates all the outcomes of the operation of the buses. It is then scaled up to give the outcome of three months of bus operations.

5.6. Interactive process

After the model has produced the outcome of a three month period of operation, it is possible for it to be run to produce results for the next period of operation by introducing new values for the input parameters or by using the existing ones.

This feature allows an interactive process between the model and the user which may be regarded as a representation of the interaction between the operator and the system of bus route operation.

In general, the interaction between the user and the model can be described as follows : the user, acting as an operator, represents his strategy of bus operation by setting the values of the input parameters, and the model responds by simulating the system based on the input parameters given and produces the output produced by the model. The user, however, responds to it by setting the new values of the input parameters. Again, the model responds by simulating the system to produce another outcome from the operation.

When only one fleet of buses is being considered in the model, the interactive process between the user and the model is a replication of the interaction between the operator and the system of bus route operation under a monopoly. However, when two fleets of buses are being considered in the model, the features of the model will be more complicated. There will be an interaction between users in addition to the interaction between the model and the users. This is a representation of the conditions on the route in a competitive market.

5.7. *COMBO.1* as a gaming-simulation model

From the features of the model described in the previous section, it can be seen that the model provides the user with an artificial environment of bus operation where some of the characteristics of a real situation are replicated. It enables the 'players' (or, operators) to follow up the consequences of their decision with a rapid response. Because of these features, it can be concluded that the model can be classified as a gaming-simulation model.

The term 'game' is applied to this type of simulation model because the environment and activities of the participant have the characteristics of games. There are the conditions that users may have : goals, sets of activities to reform, constraints under which these can be carried out, and 'payoff' as consequences of the actions. In the application of the model, those characteristics of the game are as follows :

- *Goals* :
  Since the users act as operators, the goals of the users will be the objectives of the operators when they run the services. It can be profit maximization or patronage maximization.

- *Activities* :
  These are the sets of alternative activities available in the model that can be reformed by the users in order to represent their strategies in order to achieve their goals. In the model these are represented in the form of a set of input parameters that can be chosen by the users.

- *Constraints* :
  The constraints considered in this model are those

that are concerned with the capacity of the computer and those that are concerned with the operation of the bus route. The latter are mainly financial matters.

- *Payoff* :

  The payoff is consequences of actions that are represented in the model as a set of outputs. It shows the performance of the operation of the service for a particular period of time. It may be good or bad.

Using the model, the individual is involved in an 'engineered' situations of bus operation where a number of outcomes is possible. Decisions by the users when they set the values of the input parameters generally have a bearing on the state of the simulated environment. Each set of results is influenced not only the players' own decisions but by those of other players.

Consider a bus route which has a certain level of travel demand. Suppose there are two operators each of which is running a fleet of buses. They compete with each other to pick up the passengers. Artificially, one can investigate various possible outcomes of this situation by using the model. In this case the users (one or two persons) act as two operators who run the fleet of buses on the route. In using the model, the 'game' situation will be as follows :

> The strategies of the users can be presented by setting the values of the input parameters. These values are determined by the users on the basis of their goals. Using these values the model then simulates the system and produces the output representing the outcome of the bus operation for each user. From the outputs given by the model which are represented as the payoff of their actions, each user

can analyse the performance of his or her operation. If the performance is satisfactory he or she may enter the same values to represent the same strategy for the next time period of operation ; if not, he or she will change the operating strategy by introducing new values for the input parameters. Again, after the user has input the value of the parameter the model simulates the system to give another set of results. This process can be repeated until the end of a pre-determined period.

The framework of the game can be seen in *Fig. 5.4*.

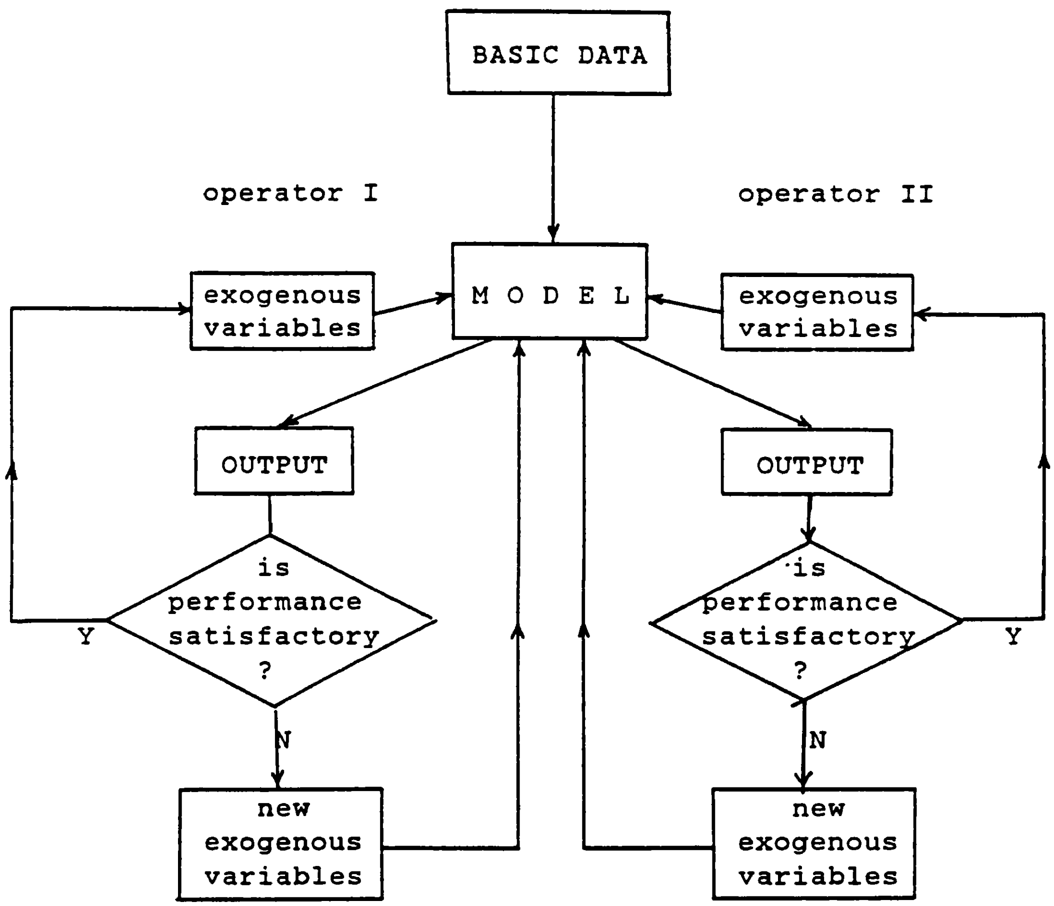


Fig. 5.4. The framework of the game

CHAPTER 6

COMBO.1 : DATA AND MODEL VALIDATION

6.1. Introduction

Having developed a model, there are two main considerations remaining in the modelling process, which are related to data taking and validation. It is necessary to describe clearly the data needed to run the model and to highlight their accuracy. Furthermore, it is clear that one should validate a model before running it. This is to ensure that the representation of all aspects of the model agree sufficiently with reality.

This chapter will deal in turn with these aspects.

6.2. Data

The data needed for the model are in three main sets : data for the route being studied, data of the travel demand and data that are related to the supply side of the bus operation.

The first set of data represents the condition of the route under consideration. These include : the location of each stop and the average layover time at the terminal. The data for the location of each stop are the distance between two successive stops in both directions on the assumption that the route under consideration has the form of two parallel lines. These can be obtained from a detailed map of the route under consideration, or, more accurately, by direct observation of the route concerned.

In the preparation of these data it is sometimes necessary to make some modifications. This is because not all actual routes have a geometrical form of two parallel lines, and the number of stops in one direction is sometimes not the same as the other. The data of the location of the stops are represented in the model as a set of coordinates where one of the terminals is taken to have a coordinate of 0.0 and the next stop is referred to it.

The second set of data represents demand. This is mainly concerned with the travel demand data for a certain time period (for example, peak hour) in the form of stop-to-stop origin-destination matrix T_{ij}, each cell of which is expressed as the mean arrival rate of potential passengers who arrive at stop *i* and wish to travel to stop *j*. These data can be obtained in two ways : first, from the modelling process and the second, from observation.

In the former method, the stop-to-stop origin-destination matrices are usually produced as a result of an assignment process in a public transport model (see *Chapter 8*). In the latter method, on the other hand, the stop-to-stop origin-destination matrices are obtained from a survey.

Of both methods it appears that the former has a potential advantage. The first method is easier to carry out and appropriate for a route that does not yet exist in reality. However, it has to be recognised that the accuracy of the data produced from this method is still questionable. They depend on the assignment method used and other factors attached to it.

In the case of the data obtained through observation, one may need to make some modifications in the preparation of these data, particularly for those routes where the number of stops in both directions is not the same. This is because the model represents the route as having two parallel lines, both of them are assumed to have the same number of stops.

The data associated with the supply side of the bus operation are mainly related to the provision of the service. These include the physical characteristics of buses (speed and capacity) as well as the financial ones (price and operating cost). Since the model allows more than one type of bus to be considered, data of this type have to be provided in the model for each type of bus.

6.3. Model validation

Since a model, analysis or simulation, is developed to represent some aspects of the real world, it is obvious that one needs to check whether the model has replicated real conditions well. This process is called validation.

There are no general rules about how validation should be carried out. However, the validation process is usually carried out in terms of : the aims of the model, aspects of the system involved, the availability of the parameters to be observed, and the features of the system under study.

It is a common practice to use information from the existing system being studied to validate the model. When a model is developed to represent a simple relationship between two aspects of a system, there will not be a problem in the validation process since the data would be easy to observe. However, this will not be the case for models involving quite a number of aspects of the system. One may find that it is difficult to find the parameter of the model that is appropriate for the validation process.

A good validation process will need to compare as many aspects of the system being studied as possible, especially those that are though to be of importance, and those that are closely associated with the sort of factors which are to be investigated by the model. Unfortunately, if one follows this validation criterion closely, one finds that very few models have been validated properly since it is very difficult to meet all the requirements mentioned above.

In the field of modelling bus route operation, there is one typical example of this difficulty. This is concerned with one of the main outputs of the model, namely average passengers' waiting time. Ideally, one should use this parameter for validation purposes. However, because of the difficulties of measuring it accurately in the real world, no model of this nature has been validated using this parameter. The main difficulties in measuring average waiting time are caused by the behaviour of the passengers. Consider, for example, the behaviour of passengers at a bus stop. At a bus stop one would find that not all the passengers join the queue as it is represented in the model. There is also the problem of representation when some passengers do not join the queue before the bus arrives.

Bus route models have a specific problem in the validation process. The study by Jenkins (1976) reported that only one out of seven models has been validated. Not even in one of them was average passenger waiting time used for the purpose of validation. The following are some reasons why bus route models are difficult to validate :

1. Bus route models usually represent operations on a single route system, In fact, it is rare to find a single route system where only one fleet of bus operates. One usually finds that a bus route shares a road section with other routes.

2. The amount of data required to validate a bus route model is considerable and, moreover, the accuracy of the observed data may be questionable.

This model has more problems than those described above. This is because this model was developed to investigate bus operations in a competitive market where this feature has only recently begun in this country. However, there is another feature of the model that makes it possible to validate. That is the fact that the model can also be considered as a model of a single route bus operation in a monopoly. In this study the model was therefore validated on the basis of single route operation.

In deciding on the parameter of bus operation to be used as a validation parameter, the main emphasis was to find one that suits the following :

- closely associated with the purpose of the model
- easily available from bus operators or from direct observation.
- representing the main feature of bus operation.

The parameter that was considered to be relevant with these criterion was bus loadings.

6.3.1. The route

The route under consideration for the purpose of validation was Route no 24 of London Buses Ltd. This route runs from its suburban terminus at South End Green, southward through many busy high streets (Camden High Street, Tottenham Court Road and Charing Cross Road), then further south to Parliament Street (Westminster); here the route turns south-west and runs along Victoria Street to Wilton Road where it then turns south-east to Pimlico, where the second terminus is. The length of the route (South End Green - Pimlico - South End Green) is about 12.0 Km, and the route has 37 stops in the southbound direction and 36 stops in the northbound direction (for more detail, see *Figure 6.1*).

6.3.2. Data for the validation process

The data employed in the validation process were of five sets. These include the map of the route, the travel demand, the type of bus operated, the service frequency and the average loading of bus along the route. The demand data were stop-to-stop trip matrices for each two hours time period, from 07.00 a.m to 17.00 p.m. The total number of travel demand for each time period and its trip length pattern can be seen in *Table 6.1.*

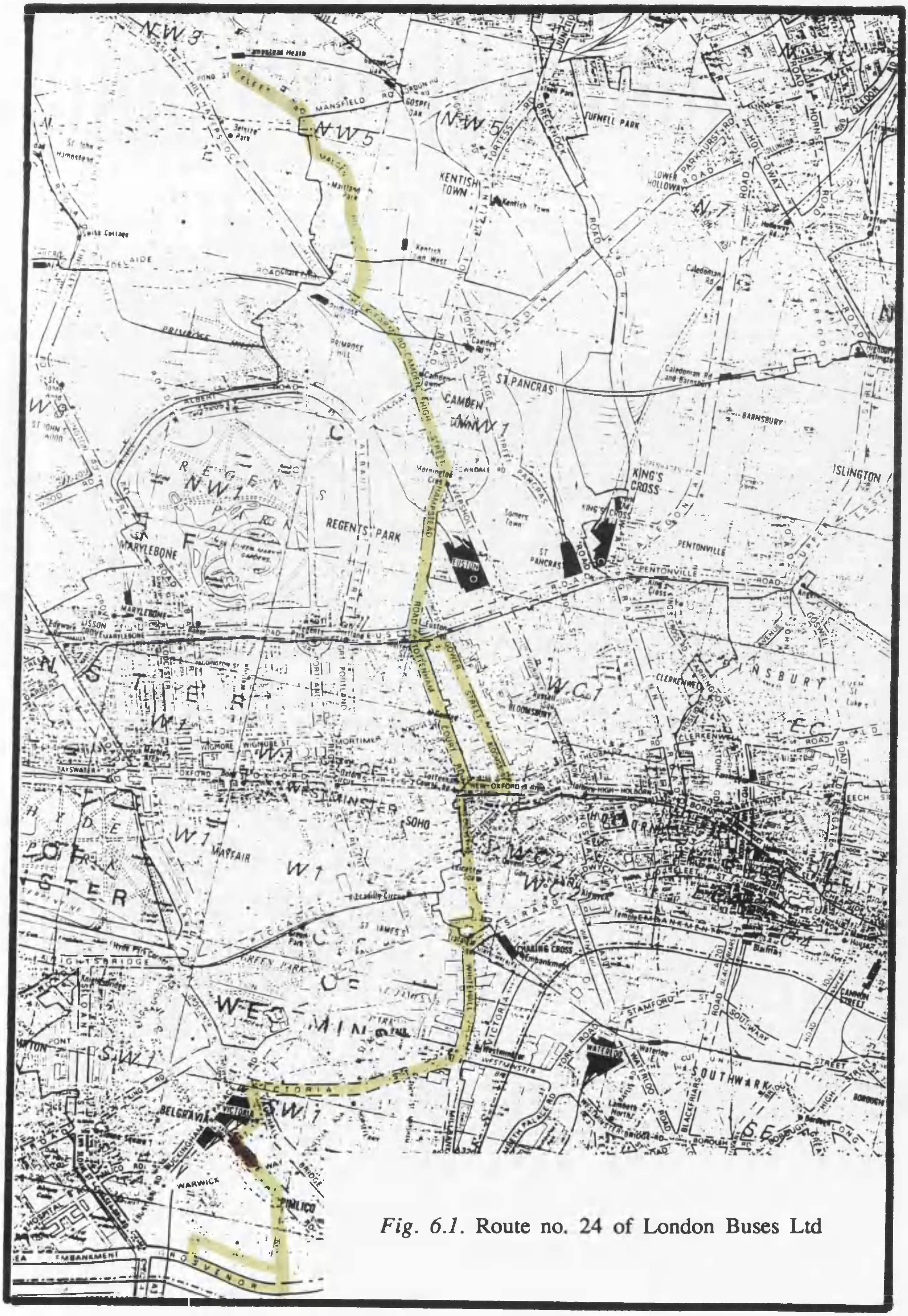


Fig. 6.1. Route no. 24 of London Buses Ltd

check whether the model represents adequately the situation to which it is going to be applied, so that the prediction it makes will be a reliable estimate of what will actually happen in other circumstances.

b. Data and parameters for validation

As mentioned before, the process of validation can be achieved by comparing the variables predicted in the model to the equivalent ones in the real life situation. This means that it is important to determine the right parameters for use in the validation process.

However, before one decides what sort of parameters are going to be used for the validation process, there are some issues to be considered. The first and the most important is the availability and validity of the input data that are needed for the model. The amount of input data depends on the nature and the complexity of the system being modelled and also on the level of detail of the model. When the nature of the system being considered is simple, it should not be a great problem to obtain complete input data. A simple survey may be sufficient to collect the data. However, this is not likely to be the case when the scale and the nature of the system are complicated.

In the case of *COMBO.1* model, it has been found that although the system is complicated, the data needed for the model are not too difficult to assemble. Of the three sets of data needed for the model (i.e, data for the route being studied, data representing the travel demand and data that are related to the supply side of the bus operation), only the last set is difficult to obtain. It is difficult, for example, to obtain complete information on the day-to-day operating costs of bus operation (the one that are easily available are rough figures on annual operating costs from Annual Report or directly from the operator). This is understandable since most operators tend to conceal the information relating to actual operating costs, particularly in the deregulated environment. Hence, in this study it was necessary to use the figures from other people's work (the data on bus operating costs, for example, was taken from Glaister's work (Glaister, 1987)).

The second issue that need to be considered in the validation process involves the problem of deciding the aspects of the system that will be needed for the purpose of validation. This is an important issue, as the quality of validation process are greatly affected by the way the parameters are chosen.

Ideally, a good validation process involves as many aspects as possible, particularly those that are thought to be important (in representing the feature of the systems), and those that are closely related to the sort of factors which are to be predicted by the model. This is obvious since the purpose of a model is to represent the reality as well as possible. Hence, the more aspects to be involved in the validation process the better the quality of the validation process will be. However, it has to be borne in mind that in deciding the aspects to be considered in the validation process one should consider the availability of such data.

In the case of *COMBO.1* model, regardless of their availability, there are many aspects that can be considered as important (in representing the feature of the systems) and relevant for the purpose of validation. They are related to the features of the bus route and the performance of the bus operation. The following are some aspects (or parameters) which are relevant to the validation process :

a. Related to the features of the bus route system

1. Average waiting time of passengers at each stop.
2. Average waiting time of passengers in the system.
3. Average travel distance in the system.
4. Average travel time of passengers in the system.
5. Average time spent by buses at each stop.
6. Average fare paid.
7. Average generalised cost.

b. Related to the performance of bus operation

1. Bus loading profile in the system.
2. Market share of each operator in the competitive situation.
3. Operating costs of bus operation in the system (for each operator,

if there is competition).

4. Revenue of bus operation in the system (for each operator, if there is competition).
5. Profitability of bus operations (for each operator, if there is competition).

Of the parameters depicted on the list above, the data on the aspects of the feature of bus route can be collected from the survey, whereas the data on the aspects of bus operation performance can be collected from the operator.

c. Criterion for selecting parameters for validation

Ideally, all the aspects mentioned above should be considered in the process of validation. However, due to the fact that the level of availability and accuracy of the data varies from one aspect to another, it is very difficult to make a complete validation process. It was therefore decided that the parameter that are going to be used in the validation process are the ones that meet the following criteria, namely the parameters that are :

1.- closely associated with the purpose of the model
2.- easily available from bus operators or from direct observation.
3.- representing the main feature of bus operation.

Looking at the aspects (or, parameters) mentioned in the list in the previous page, it is clear that in terms of the first criteria (i.e, parameters that are closely associated with the purpose of the model), only the ones that are directly related to the performance of bus operation apply. This is because the purpose of this model is to predict the implications of particular strategy on operational performance, not to estimate the technical features of the bus route system. This means that the parameters in the first list can be considered as not too important in the validation process, although it would be better if they can be included. However, if one tries to include the parameters in the first list (i.e, related to the features of the bus route system), one finds that the data needed would be numerous, and needs a comprehensive survey. Take for eaxmple, the data on the average waiting time of passengers at each particular stop. To collect these data one would need to make a survey on all the stops in the route simultaneously.

It can be argued, therefore, that the remaining parameters that have to be considered are those that are related to bus operational performance. All the parameters mentioned in the second list are very important, because they also represent the main features of bus operation. However, not all the parameters are easily available: it is very difficult to obtain the data on these aspects. This is because these data are usually strictly confidential to the operators, particularly in a deregulatory environment. The only data that were easy to obtain in the course of this were those on bus loadings.

Given that bus loading data were all that were available, these were used for validation. However, before drawing such a conclusion it is useful to check whether the third criteria is met by bus loading profiles. In order to examine this criteria, it is is necessary to consider the role of bus loadings in bus operations. It can be argued that bus loading profile plays a major role in the measurement of the success of bus operation. This is due to the fact that it represents the number of passengers in the bus as it moves along the route. Using this parameter one can find out how well the resources are being used in different parts of the model, for example, the location where the bus has no spare capacity, or the location where the bus is empty. Also the average level of bus loading of the service can be found, and when appropriate, be compared for different routes.

d. Statistical tests

In order to measure how well the model can reproduce the validation parameters compared with those observed from the survey, the following goodness-of-fit (GOF) statistical measures have been used :

1. Root Mean Square Error (RMSE and %RMSE)

a. $$\mathrm{RMSE} = \sqrt{\frac{\Sigma_i [O_i - E_i]^2}{(N-1)N}} \qquad (6.1)$$

b. $$\%\mathrm{RMSE} = \left\{\frac{\mathrm{RMSE}}{C}\right\} \times 100\ \% \qquad (6.2)$$

2. Mean Absolute Error (MAE and NMAE)

a. $$\mathrm{MAE} = \frac{\Sigma_i \ [O_i - E_i]}{N(N - 1)} \qquad (6.3)$$

b. $$\mathrm{NMAE} = \left\{\frac{\mathrm{MAE}}{C}\right\} \times 100\ \% \qquad (6.4)$$

3. Coefficient of Determination (R^2)

a. $$R^2 = 1 - \frac{\Sigma_i (O_i - E_i)^2}{\Sigma_i (O_i - C)^2} \qquad (6.5)$$

where O_i and E_i are Observed and Estimated bus loading on the bus when leaving stop i, N the number of stop and

$$C = \frac{\Sigma_i O_i}{N(N-1)} \qquad (6.6)$$

e. Criterion for validation

It has been decided that the criterion for validation is on the basis of the performance of the Goodness Of Fit (GOF) measures.

6.3.3. Validation process using route 24 data

The route under consideration for the purpose of validation was Route no 24 of London Buses Ltd. This route runs from its suburban terminus at South End Green, southward through many busy streets (Camden High Street, Tottenham Court Road and Charing Cross Road), then further south to Parliament Street (Westminster); here the route turns south-west and runs along Victoria Street to Wilton Road where it then turns south-east to Pimlico, where the second terminus is. The length of the route (South End Green - Pimlico - South End Green) is about 12.0 Km, and the route has 37 stops in the southbound direction and 36 stops in the northbound direction (see *Figure 6.1*).

The data employed in the validation process were of five sets. These include the map of the route, the travel demand, the type of bus operated, the service frequency and the average loading of bus along the route. The demand data were stop-to-stop trip matrices for each two hours time period, from 07.00 a.m to 17.00 p.m. The total number of travel demand for each time period and its trip length pattern can be seen in *Table 6.1*.

The same as the demand data, the data on bus loadings were for each two hours period, each of which represents the average bus loadings at each stop along the route on both directions.

The stop-to-stop trip matrix and bus loadings data were given by London Buses Ltd. These are survey data produced from the survey carried out by London Buses Ltd on 8 April 1987.

The buses operated in this corridor were of the typical London buses, double decker, with the capacity of 72 passengers (including standing). Their conditions when the survey were carried out are depicted by *Tables 6.2* and *6.3*.

Table 6.1.

TRAVEL DEMAND IN THE CORRIDOR OF ROUTE 24

TIME	*short trip (< 2 Km)*	*medium trip (2 - 5 Km)*	*long trip (> 5 Km)*	*TOTAL*
07.00-08.59	*1885*	*1105*	*840*	*3830*
09.00-10.59	*1454*	*836*	*526*	*2818*
11.00-12.59	*1658*	*846*	*285*	*2789*
13.00-14.59	*1732*	*754*	*303*	*2789*
15.00-16.59	*2649*	*1573*	*745*	*4967*

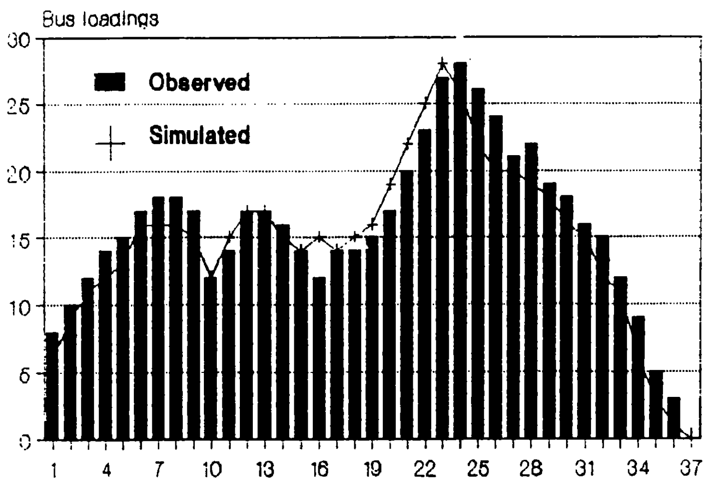


Fig. 6.5
Bus loadings on Route 24
Southbound 01.00 - 03.00 PM

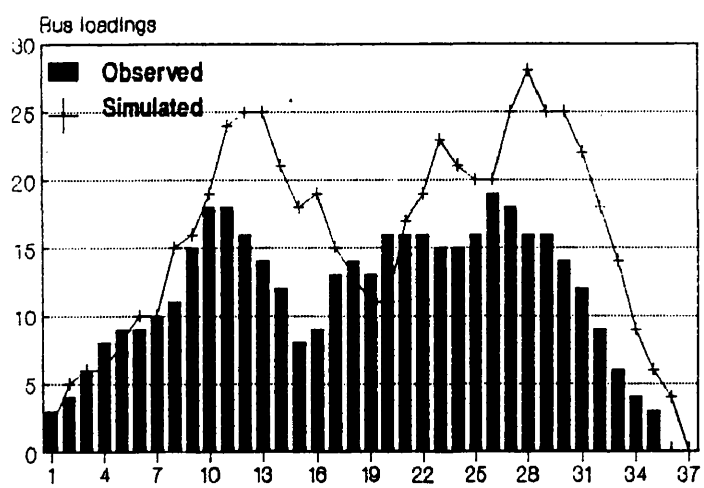


Fig. 6.5.a
Bus loadings on Route 24
Northbound 01.00 - 03.00 PM

6.3.4. Results of validation

In order to have the best representation of the true system from the model output, the model was run 10 times for each set of input (*i.e,* type of bus, headway, fare system and fare level) and the average of the outputs were used as the basis of the validation process. The comparison between bus loadings predicted by the model and from observations can be seen in *Figures 6.2* to *6.6*, each of which represents the situation at different time periods. Some GOF statistics to compare the estimated bus loadings and the observed one, for each time period, are given in *Table 6.2*.

Table 6.2

The Goodness Of Fit statistics of estimated bus loadings compared with the observed one for each time period

TIME PERIOD		RMSE	% RMSE (%)	MAE	NMAE (%)	R^2
7.00-8.59	Southbound	0.663	122.1	0.086	15.9	0.969
	Northbound	1.119	267.6	0.162	38.8	0.847
9.00-10.59	Southbound	0.324	59.2	0.041	7.4	0.992
	Northbound	0.727	205.2	0.092	25.8	0.907
11.00-12.59	Southbound	0.419	104.7	0.057	14.3	0.972
	Northbound	1.084	301.4	0.164	45.7	0.771
1.00-3.59	Southbound	0.315	72.4	0.044	10.0	0.987
	Northbound	1.024	323.9	0.134	42.3	0.748
3.00-4.59	Southbound	1.226	227.1	0.167	30.9	0.884
	Northbound	1.189	169.1	0.149	21.1	0.937

note : RMSE, %RMSE : Root Mean Square Error
MAE : Mean Absolute Error
NMAE : Normalised Mean Absolute Error
R^2 : Coefficent of determination

6.4. Conclusions

The description of data for COMBO.1 model and the validation process were given in this chapter. The data of the bus operation of route 24 of London Buses were used for the validation process. It was found from the validation process that the model predicts the bus loading sufficiently well.

CHAPTER 7
THE USE OF THE *COMBO.I* MODEL FOR ANALYSING SINGLE-ROUTE BUS OPERATION AND COMPETITION

7.1. Introduction

From the previous chapter it is clear that the *COMBO.I* model can be used to investigate some features of bus operations in a monopoly as well as in a competitive market.

In the case of a monopoly, the model can be used to investigate and analyse various operational strategies of the bus service. For example, to find out the implications of a particular operator's strategy on the performance of bus operations ; in terms of profit as well as the level of service. More specifically, the model can be used to find out the best strategy to apply to a corridor route for a particular operational objective.

In a competitive regime, however, the model can be used to investigate the various strategies of new entrants when they enter the market to compete with the existing operator. Furthermore, the model can be used to conduct experiments of competitive behaviour. An experiment can be done when two people use the model to play 'the game' where each user acts as an operator competing with the other on the same route.

The application of the model using real data will be described in this chapter. Two routes which have different patterns of travel demand were considered. For each route the model was used to investigate two situations of bus operation : first, a monopoly where only one operator runs the service, and, second, a competitive market where two operators compete with each other to win passengers.

7.2. The routes

Two different route corridors have been considered in these exercises. Each represents a variation in the pattern of travel demand that exists in a typical urban area. They are situated in two different areas of London (see, *Fig. 7.1.*). The first route, from Kingston Station to Putney Bridge Station, is bus number 85 of London Bus Ltd which runs through the Kingston and Putney area (South West of London), and where the pattern of travel demand of public transport predominantly consists of medium and long distance journeys. The second route, from South Green End to Pimlico, is a travel corridor which runs through the central London area and whose pattern of travel demand consists mainly of short and medium distance journeys. The bus which runs the service on this route is bus number 24 of London Bus Ltd. The details of the two routes can be seen in *Figs. 7.2* and *7.3*. Their characteristics and the conditions of their existing service can be seen in *Table 7.1*.

Data employed in these exercises were stop-to-stop trip matrices which were given by London Bus Ltd. These data are survey data taken by London Bus Ltd as part of a routine survey.

Before we go further, it is important to mention some of the assumptions taken regarding the two routes. The first assumption was that, the routes under consideration were treated as two self-contained single routes where travel demand was only influenced by a change in the level of service (represented by frequency or headway and average fare level). Consequently, no other factors were considered. Indeed, in reality this may or may not be the case, since most of the routes that exist in an urban area are not a self-contained single route. Ideally, care should be taken when dealing with a single route, since its travel demand not only depends on its level of service, but is also strongly influenced by the level of service of other routes in the system (this issue will be discussed in *Chapter 8* and forward).

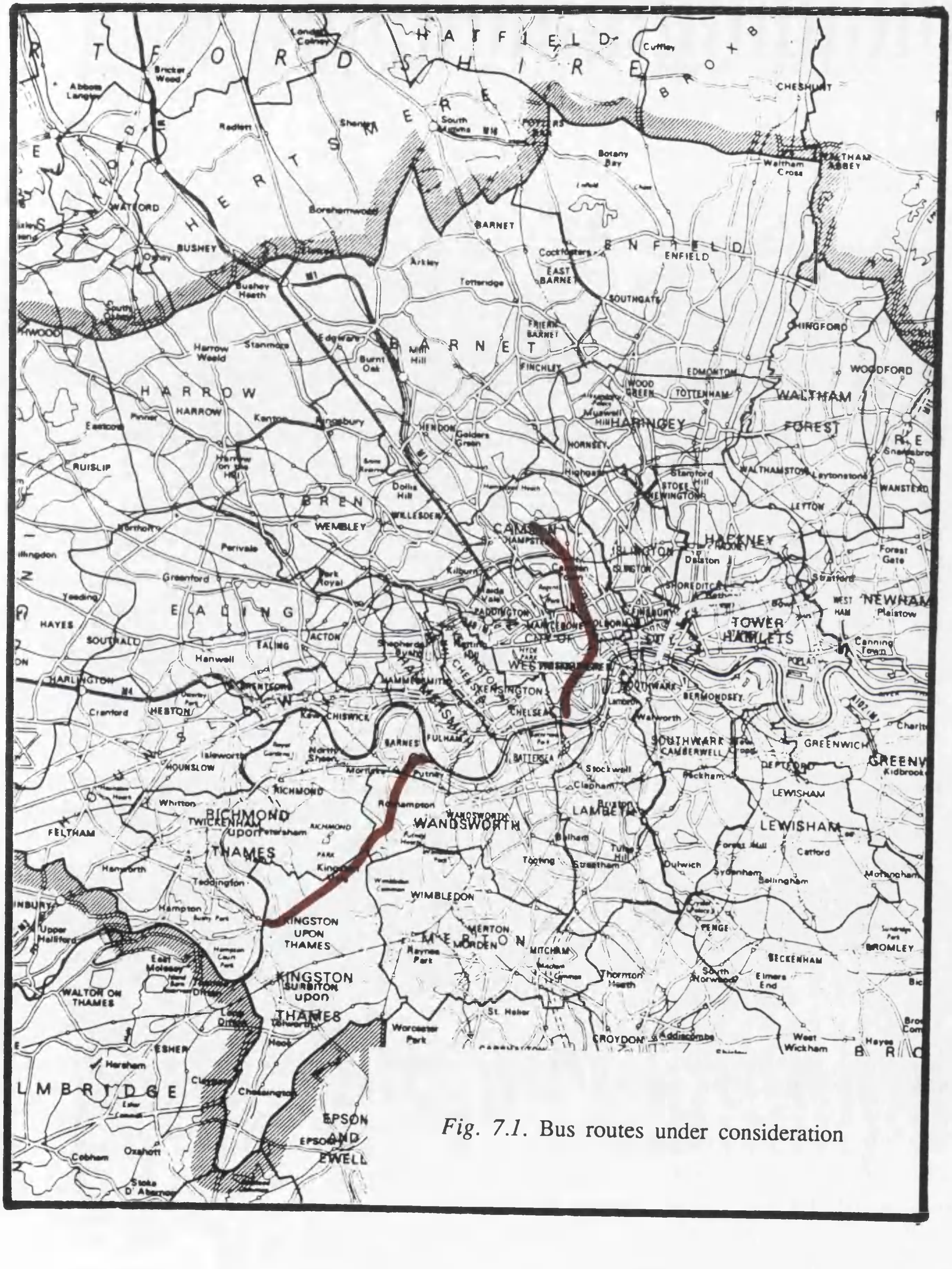


Fig. 7.1. Bus routes under consideration

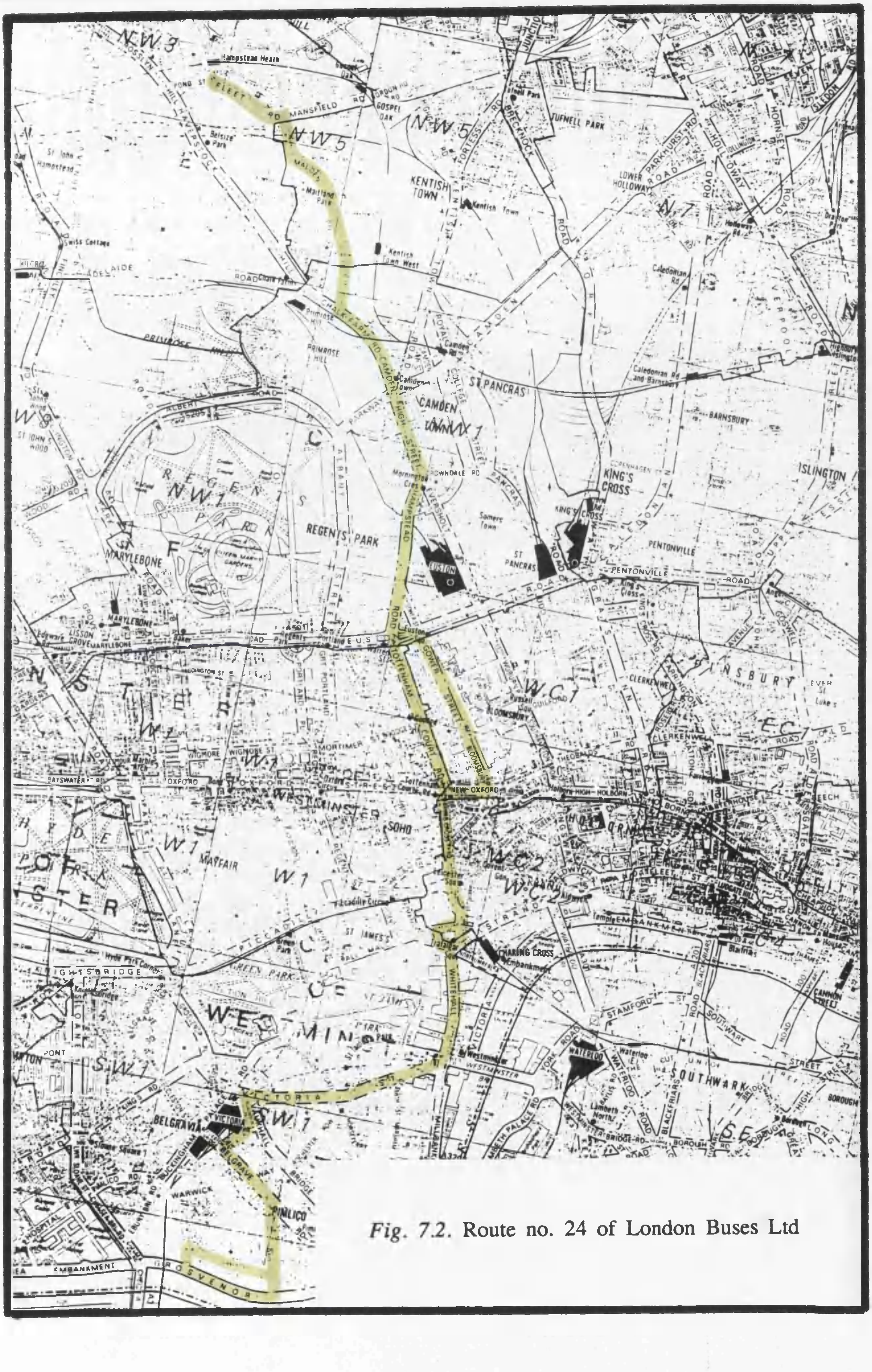


Fig. 7.2. Route no. 24 of London Buses Ltd

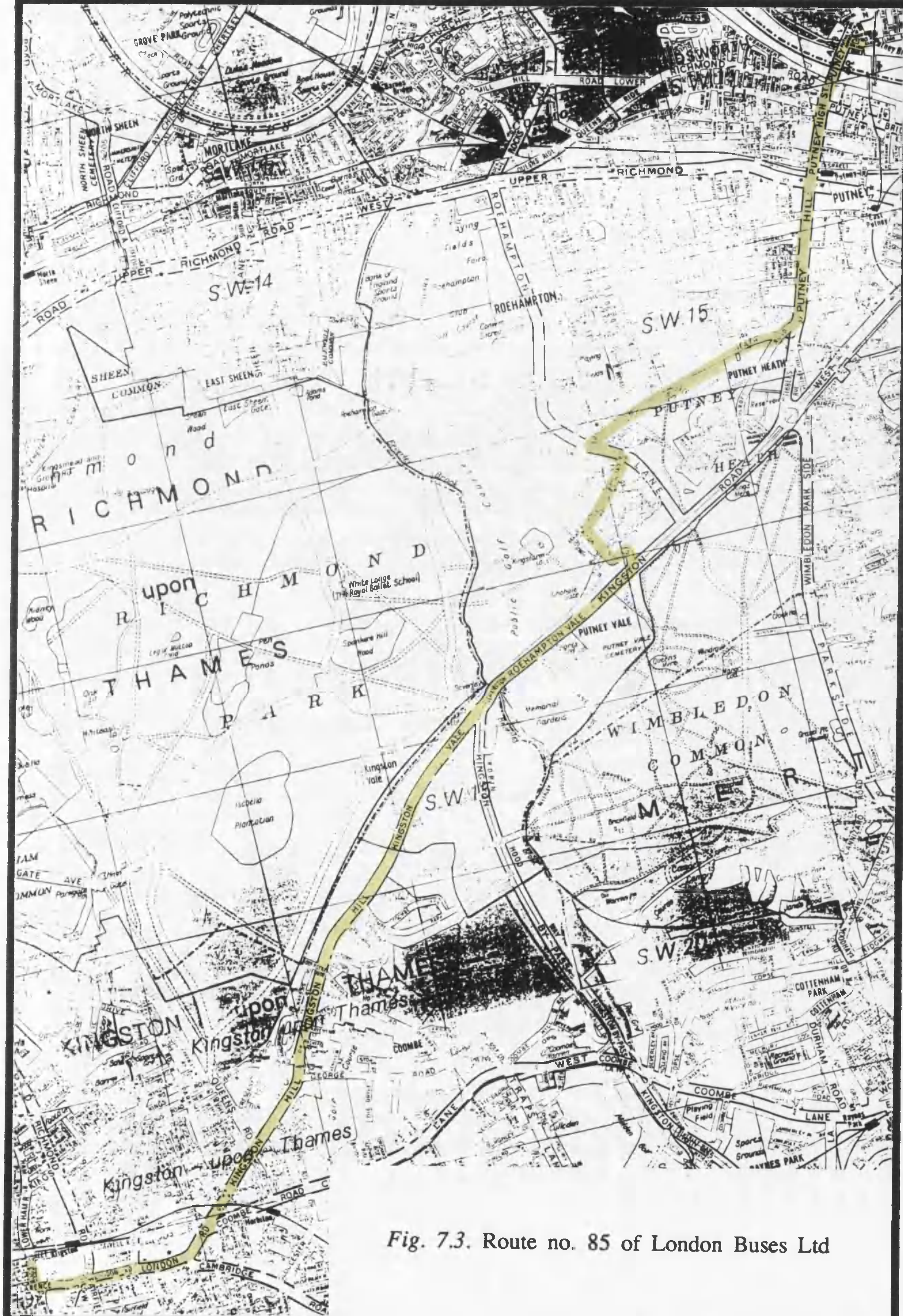


Fig. 7.3. Route no. 85 of London Buses Ltd

From Figures *6.2* to *6.6*, it can be observed that in general, the bus loadings predicted by the model are similar to those observed. Statistically, these vary from one time period to another. As can be seen on *Table 6.2*, their variation (NMAE) range from the smallest value of 7.4 % (for Southbound, 9.00 - 10.59) to the highest of 45.7 % (for Northbound 11.00 - 12.59). It is worth mentioning, however, that although the differences between the level of bus loadings predicted by the model and those observed are sometimes quite large (for example, Northbound direction, 11.00 - 12.59, with the value of NMAE of 45.7 %), their patterns are very similar.

If one looks at *Table 6.2* in more detail, one finds that the value of NMAE for Northbound direction from time period 07.00 to 15.59 (morning-peak and off-peak) are relatively small compared to those of the Northbound direction for the same time period. However, this is not the case for time period 15.00 - 16.59 (evening peak). The value of NMAE is smaller in the Nortbound direction than that of the Southbound direction. These indicate that distortions occured in the data for the direction where fewer people use the bus, for example for northbound direction in the morning and mid-day period (when most people tend to go the the city centre in the southbound direction), or for southbound direction in the evening peak (when most people tend to go home to the north).

There are two reasons for these distorsions : first, the service condition of the route when the survey was taken, and second, the accuracy of the trip matrix data. As mentioned in the previous chapter, the operation of the bus service along the route is represented as the continuous movement of a fleet of buses along two parallel routes. This means that the number of buses operated on the route is assumed to be the same along the route, and the number of buses that pass through each particular stop during a particular time will also be the same. However, in the real world this is not always true. There are some instances when the buses are not operated to cover the full length of the route, but are turned back before reaching the end of the route.

If one observes Table 6.2 in more detail, one finds that the other measures of GOF statistics will support the argument that the model produced the better fit for the Southbound direction in the morning and mid-day period and for the Northbound direction for evening-peak period (for example, the value of RMSE and %RMSE time period 07.00-08.59 for the Southbound direction is less than that of the Northbound direction, and conversely for time period 15.00 - 17.59)

If the measures of GOF statistics are used to judge the validation of the model, then it can be argued that, in general, the model produced the estimated bus loadings reasonably well, as it reveals from GOF statistics on *Table 6.2* (for example, the value of R^2 on most cases is close to 1.0.)

6.3.5. Comparison with other routes

In order to find out more on the validity of the model for other conditions of travel demand, the data on route 85 of London Buses Ltd was used. The location of route 85 can be seen in *Figure 6.7.*

Unlike route 24, the data used for route 85 was only for morning peak-hour period, between 07.00 and 09.00. The comparison between bus loadings predicted by the model and from observations can be seen in *Figure 6.8.*

It is clear from *Figure 6.8* that the model can predict the profile of bus loading very similar to those of observed. This is shown by the fact that on each stops in the route the level of bus loadings predicted by the model is very similar to that of observed. It can be seen from the chart, either for southbound direction or northbound direction, that the pattern of bus loading predicted by the model follows the pattern of that of observed. Of course there are a different between the two (between what have been predicted and what have been observed), but in general the differents are not too significant, as the value of variation measure (NMAE) is 20.5 % for Southbound direction and 12.9 % for Northbound direction (see, *Table 6.3*).

7.5. Monopoly situation

When a route corridor is served by one company, it is obvious that its operator will have absolute freedom to run the service as he wants. Generally, the way the service is operated depends upon its constraints as well as its objectives. For example, the operator may run the service, say, with a zero fare if no financial constraints are to be considered. On the contrary, the operator may also run the service with a high fare level if his operational objective is to maximise profit.

In reality, however, the practices mentioned above are seldom found as many other considerations have to be taken into account. For example, one should also consider government regulation and public awareness in addition to operational objectives. It is well known that public awareness of the provision of a bus service is mainly to get a good level of service. This is usually measured in terms of average waiting time or average generalised cost.

In general, it can be argued that the main factor behind the formulation of operational objectives is the financial background of the operator. Those operators who have financial resources from public funds will probably consider a good level of service as one of their objectives. However, this is not the case for private operators who treat the service as a commercial business. It seems that they will consider profit maximization as their main objective rather than the provision of a good level of service.

For a given level of travel demand and for given constraints, the main task of a bus operator on a day to day basis is to formulate and implement its strategies in order to meet its objectives. Among other factors, it seems that the pattern and level of travel demand are the most significant factors to be considered. They are important because they are the ones that strongly influence the performance of the bus operation. The level of travel demand represents the number of potential passengers who are in need of the service, whereas the pattern of travel demand determines the distribution of trip length. On the basis of these factors, it is possible for the operator to determine the best strategy to be adopted, in terms of : fare system, fare level, service frequency and vehicle size.

In what follows, a series of operational strategies of the service under a monopoly will be reviewed.

7.5.1. Setting the service frequency

In deciding the level of service frequency for a fleet of buses, it is necessary to examine how significantly service frequency can affect the performance of bus operation, in terms of profit as well as in terms of the level of service. If the level of service as perceived by the travellers is measured in terms of the average waiting time, and if the service frequency is represented by the average headway, then it is obvious that there will be a direct relationship between service frequency and the level of service. Theoretically, the higher the frequency of the service, or the lower the average headway, the better the level of service that will be perceived by the travellers. This is so, because in a situation where people do not know the time-table the average waiting time will be roughly half the average headway. However, it should be recognised that this is only valid when the capacity of the service is above the level of travel demand. Because when the capacity of the service is lower than the level of travel demand, some passengers will suffer an excessive waiting time as many buses will be full when they come to the stop. Hence, the average waiting time will be considerably higher than half the headway.

The relationship between the service frequency and the level of profit, however, is not as simple as the relationship between service frequency and the level of service. Many additional factors are involved. Among all the factors it seems that revenues and operating costs play a key

Table 6.3

The comparison of Goodness Of Fit statistics of the validation results using data routes 24 and 85

ROUTE		RMSE	% RMSE (%)	MAE	NMAE (%)	R^2
Route 24	Southbound	0.663	122.1	0.086	15.9	0.969
	Northbound	1.119	267.6	0.162	38.8	0.847
Route 85	Southbound	1.110	134.4	0.170	20.5	0.961
	Northbound	0.924	105.0	0.113	12.9	0.970

Note: RMSE, %RMSE: Root Mean Square Error
MAE : Mean Absolute Error
NMAE : Normalised Mean Absolute Error
R^2 : Coefficient of determination

Moreover, if one looks at the GOF statistics of the results (see, *Table 6.3*), one finds that the results of test statistics will support the argument above (i.e, that the model can predict the profile of bus loading very similar to those of observed). This is due to the fact that the value of Coefficient of determination R^2 for the two direction are very close to 1, and also because the RMSE and %RMSE statistics reveal that the model produced a good fit.

If the criteria of GOF statistics are used to judge the validity of the model, then it can be argued that the model can predict the profile of bus loading on route 85 reasonably well.

Table 6.3 also shows the comparison of GOF statistics between routes 24 and 85, both for morning peak-hour time periods. The RMSE and %RMSE GOF statistics in the *Table 6.3* reveals that on both routes the model produced a good fit for each route. However, if one compares the value of R^2 GOF statistics of the two routes, one finds that the model produced the better results for route 85 as its value greater than that of route 24.

In order to give more insight on other validation parameters, *table 6.4.* shows the list of parameters value that have been produced from the model using data on routes 24 and 85, both for morning time period.

Table 6.4

Parameters that have been produced by the model for routes 24 and 85

PARAMETER	ROUTE 24	ROUTE 85
Average fare paid (pence)	48.97	53.10
Av. waiting time (minutes)	3.12	3.41
Av. gen. cost (pence)	74.50	85.69
Operating costs *)	752341.40	566497.48
Revenue *)	827412.7	654324.06
Profitability (%)	9.98	15.5

*) For three months period of operation (after scaling up)

6.4. Conclusions

The description of data for *COMBO.1* model and the validation process were given in this chapter. In deciding parameter for validation, three criteria have been set up, namely : *1).* the parameter should be closely associated with the purpose of the model, *2).* the parameter should be easily available from bus operators or from direct observation, and *3).* the parameter should be representing the main features of bus operation. On the basis of these criteria it has been decided that bus loading profile are used as validation parameter.

The data of the bus operation of routes 24 and 85 of London Buses have been used for the validation process. Using the criteria of GOF statistics measures as the vriteria, it was found from the validation process that the model predicts the bus loading reasonably well, both for routes 24 and 85.

From the results of validation process using routes 85 and 24, it can be argued that the model can be applied in any route, provided that the data needed are available and reliable.

level of profit start to fall significantly. Route 24 has a peak profit with an average headway of 11 minutes, whereas route 85 peaks at about 13 minutes. The concavity of the profit curve indicates that, when the headway of the service is changed, the percentage of change in revenues is not proportional to the percentage of change in operating costs. There is a situation where the level of profit is at a maximum. This is an optimal headway.

It is worth mentioning, however, that the level of the two profit curves is different. Route 24 tends to have a higher curve at any given point than route 85. This condition indicates that the operation of bus services on route 24 produces more profit than route 85. This is not surprising as the existing level of demand on route 24 is higher than that of route 85. Therefore, it can be argued that for any service frequency, or for any headway, the operator will get more profit from route 24 than from route 85. To some extent, it can be concluded that, for a particular route, the higher the level of demand , the higher the level of the profit curve will be, and the smaller the value of its optimal headway.

From the graph shown in *Fig. 7.4.*, it can be suggested that if the operator has no awareness whatsoever of the travellers perception, the service frequency on both routes should be changed to a level where the bus operation gets most profit; in this situation the average headways of the bus operation should be changed to 11 minutes on route 24, and to 13 minutes on route 85. However, if the operator still considers the level of service as one of his criteria, then the service should be operated with average headways on which a break-even can be reached, namely ; 4 minutes for route 24 and 4.5 minutes for route 85.

7.5.2. Fare strategy

Since the fare from the passengers is the main contributor to revenue, it is not surprising that a proper strategy on fares plays a key role in the operation of bus services. It can be argued that operators need to adopt a good fare strategy, that is, a fare system that will match the condition of the route concerned and produce the best possible performance, in terms of profit as well as in terms of level of service.

There are two relevant issues when dealing with the problemof fare strategy : the level of fares to be charged and the system of fares. For a particular fare system adopted, there are two obvious implications that can be expected from a change in the level of fares : first, the number of passengers, and second, the revenues. The first premise derives from the fact that the perception of potential passengers of the bus service is strongly influenced by the level of fares. For example, when the level of fares is low, the service becomes more attractive so that some new potential passengers will be encouraged to use it. As a result, the market expands and the number of passengers can be expected to rise. In terms of revenues, the effect of a change in fare levels is predictable. The level of revenue generated from fares will increase as the level of fares increases. However, it should be recognised that this situation is likely to pertain only if the value of fare elasticity to demand is not significant, or if the number of missing passengers caused by an increase in fares is not too great.

There are two factors that need to be considered in determining the appropriate fare system : first, in the context of technical operations, and second, in terms of revenues. In the context of technical operation, it can be argued that a system of fares that is thought to be appropriate for a bus operation is one that is practical, easy and inexpensive to apply and, of course, most preferable to the passengers. These criteria would lead one to the conclusion that the most appropriate fare system is a flat fare where each trip is charged at the same rate regardless of the distance. It has the advantage of simplicity and the passengers requiring no special knowledge of the system.

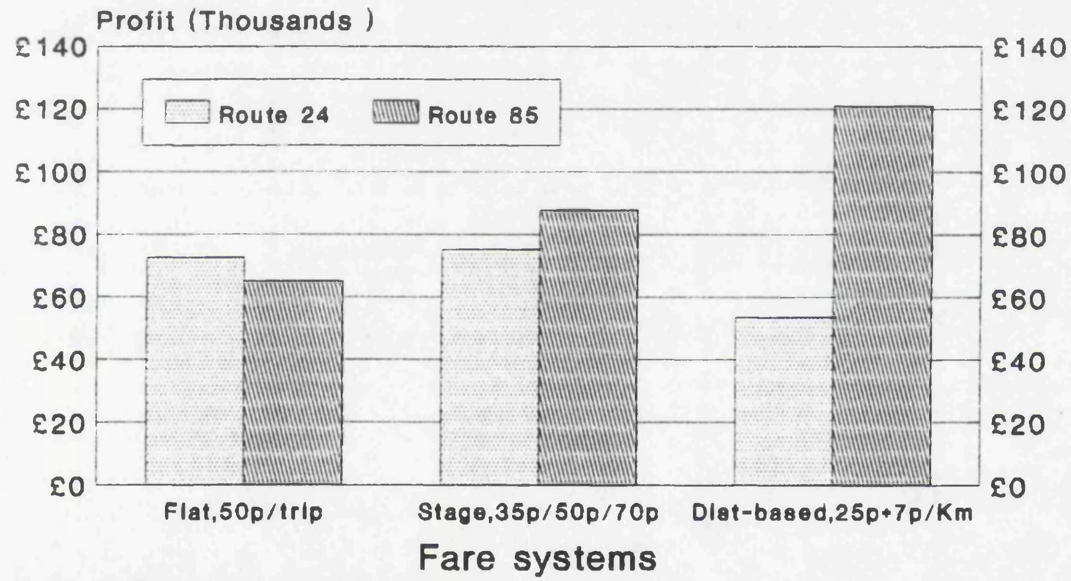
In terms of revenue, however, the problem of determining the appropriate fare system has to include a consideration of the pattern of travel demand for the route concerned. For example, if the demand is predominantly for short journeys, the adoption of a flat fare system with a fare of 50p per trip will produce a different level of revenues compared with the adoption of, say, a stage (zonal) fare system, even though both have the same average fare. Since the pattern of travel demand for each particular route is unique, it can be argued that a good fare system for one route is not necessarily good for another.

The problems of choosing the appropriate fare system and adjusting the right fare level for the two routes under consideration are described in the following paragraphs. In order to do this the model has been used to explore various fare strategies. It was assumed that the operating costs of a bus operation are not affected by the fare system. For a given level of supply, the total operating costs were calculated as the same, whatever the fare system.

The first problem was the question of whether the existing fare system was the best one, particularly in terms of profit. To investigate this the model was run in a situation where various fare systems with an approximate average fare of 50 pence per trip were applied on both routes. These included : a flat fare system with fare of 50 pence per trip and a distance-based fare system with initial fare of 25 pence and an additional fare of 7 pence per kilometre. In these exercises the other operating conditions of the bus service were kept the same as existing conditions (see, *Table 7.1*). *Fig.7.5.* shows the level of revenues of the bus operator on routes 24 and 85 when various fare systems were adopted.

From the chart depicted in *Fig. 7.5.* it can be observed that, in terms of revenues, the performance of the bus operation is strongly influenced by the fare system adopted and the pattern of demand that exists on the route under consideration. It is found that the operation of the bus

Fig.7.5 Bus Operations on Routes 24 & 85 : Fare Systems



Route 24 : D/Dckr, headway 4.7 mnts
Route 85 : D/Dckr, headway 6.0 mnts

service on route 24 performs best when stage fares at 35, 50 and 70 pence per trip were adopted, whilst on route 85, bus service got more revenue when it introduced a distance-based fare with an initial fare of 25p and with an additional fare of 7p/Km. These results are not surprising as the pattern of travel demand on route 85 is dominated by long and medium trip journeys, whereas route 24 has more short journey travellers.

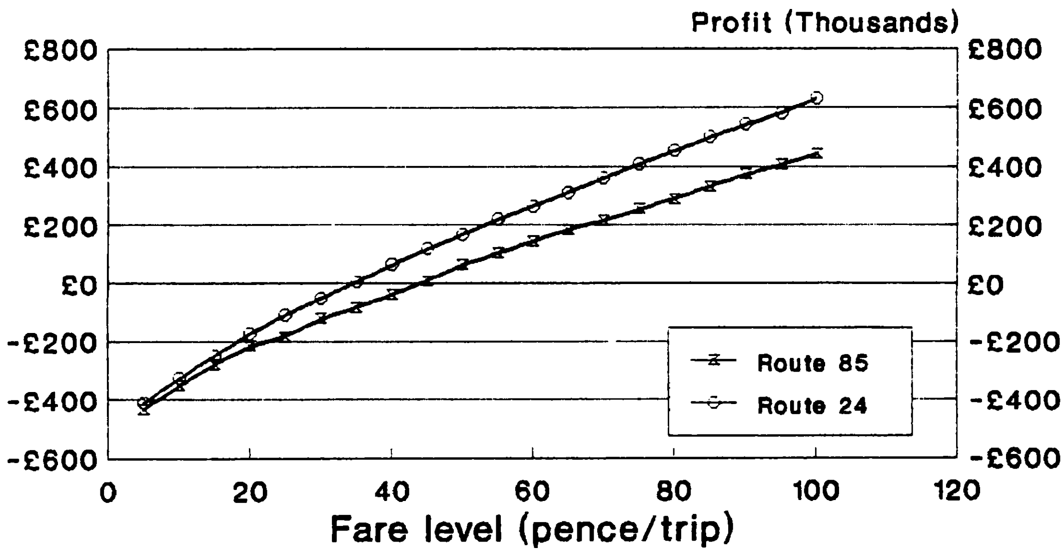
If other operational conditions are the same as existing ones, it can be suggested that to maximise revenues, each route should introduce a different fare system. The service on route 24 should keep the same fare system and fare level as before, whereas the service on route 85 should change its fare system to a distance-based fare with an initial fare of 25 pence and with an additional fare of 7 pence per kilometre.

Figs. 7.6. and *7.7.* illustrate in more detail the performance of the service when a flat fare and distance-based fare were adopted at various price level. In order to make the results of the two routes comparable with each other, the operational conditions have been taken as the same: each service operating double decker buses with average headways of 6 minutes.

From the two figures shown in *Figs. 7.6.* and *7.7.* it is clear that despite the decline in the level of demand, the operator will always get more profit when a higher fare is introduced. These conditions apply on both routes, for a stage fare system as well as a distance-based fare system. These results are predictable, since the percentage change in the level of demand is always less than the percentage change in the level of fares.

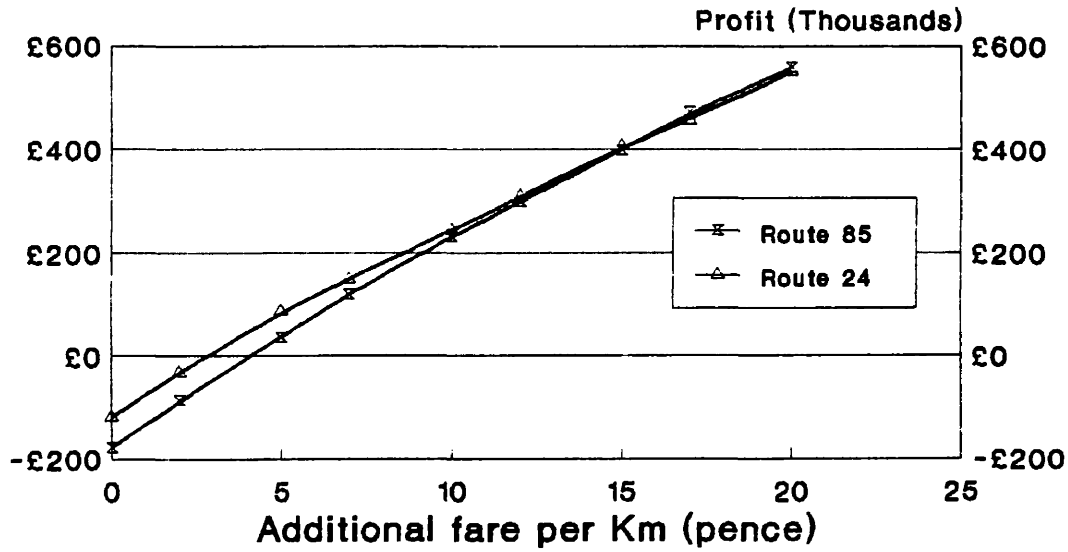
It is worthwhile noting that the two fare systems have different features. When a flat fare was introduced on both routes, it can be observed from *Fig. 7.6.* that the two revenue curves were quite similar. The difference is in their slopes. These indicate that the percentage

Fig.7.6 Bus Operations on Routes 24 & 85 : Flat fare system



D/Dckr buses were operated on both routes with the average headways of 6.0 minutes.

Fig.7.7 Bus Operations on Routes 24 & 85 : Distance-based fare



D/Dckrs were operated on both routes
with the average headways of 6.0 mnts.
Initial fare to be charged was 25 pence.

change in revenues is different between the two routes. The percentage change in revenues as the result of the change in fare on route 24 tends to be higher than that on route 85 whatever the level of fare. This is not only due to the fact that the level of demand on route 24 is higher than that of route 85, but also because with a flat fare system the level of revenue is directly proportional to the level of demand.

Distance-based fare system, however, has one feature different from that of a flat fare system. As can be seen in *Fig.7.7.*, the level of revenue of the service does not only depend on the level of demand as in the case of a flat fare system, but is also strongly influenced by the pattern of travel demand. For example, when the additional fare per kilometre is not too significant in determining the fare price, the level of revenue is primarily affected by the level of demand. The higher the level of demand the higher the level of revenue. However, as the additional fare per kilometre becomes a more important factor in determining the fare price, the level of revenue is not only affected by the overall level of demand but, more significantly, is influenced by the pattern of travel demand. In our example, the level of revenue on route 85 becomes higher than that on route 24 when the additional fare per kilometre is greater than 15 pence. This can be explained because the proportion of long journeys on route 85 is greater than that on route 24.

7.5.3. Choosing the right vehicle size

Another issue to mention concerning the strategy of a bus operation is the issue of vehicle type or vehicle size. This issue relates to the question of what is the appropriate type of vehicle to operate on a particular route and for a given level of demand. This is quite an important issue, since in the deregulated environment most operators are faced with a situation that with limited financial resources available they have to operate a service using an appropriate vehicle type so that it can become an unsubsidized, and, if possible, a profitable service.

There are some factors that need to be considered in deciding the type of vehicle to be operated on a particular route : first, the level of demand, second, the characteristics of the vehicle and third, the perception and responsiveness of potential passengers to the type of vehicle concerned.

The level of demand is important in determining the capacity of the service to be provided. If a route has a very high travel demand, theoretically big buses are more appropriate than smaller ones, since a service with big buses has more capacity per bus and therefore gives a more efficient service per vehicle. However, if the level of demand is very low, it might be more appropriate to use medium or small vehicles.

The characteristics of vehicle type are also important. It has been argued that small buses have advantages in terms of speed (see, for example, Glaister, 1986). This argument derives from the fact that the smaller the bus the higher the ability to manoeuvre and also the total time needed for the passengers to board and alight is much less. It implies that small buses will have a faster end-to-end running speed than that of big buses. However, it should be recognised that this argument is only strong when the effect of congestion is not taken into account, or when the level of congestion is not significant. On the basis of these characteristics, one may come to a rough conclusion that the use of small buses will be more attractive for passengers than using big buses. It can be expected therefore that the service will generate more revenue, since more new potential passengers are encouraged to use it.

However, it is important to recognise that, because small buses can carry fewer passengers, whilst the number of staff needed to operate them is quite similar to that of big buses, they tend to have a lower passenger capacity to staff ratio. Operating costs per passenger on small buses, therefore, will be higher than those on big buses.

For a given level of resources available the operators have to decide on the type of vehicle to be operated on a particular route. If big buses are chosen, the number of vehicles that can be provided and operated are not too many, which means that the operator will have small operating costs to cover and a low frequency service to offer to the travellers. However, if small buses are chosen, the number of vehicles that can be provided and operated becomes greater. Therefore, the operator will be able to provide a high frequency service, but at the same time have to provide a considerable amount of extra money to cover the operating costs.

For all types of vehicle, the question arises whether the service can generate enough revenue to cover its operating costs. Since the choice of vehicle size will affect the level of service frequency on offer, whilst the level of revenue depends upon the number of passengers that can be carried by the service, it is therefore important to know the extent to which a good service can attract passengers, or, how significant the responsiveness of travellers is to various service frequencies.

In order to investigate this problem, a scenario of a bus operation problem was set up and the model was used to examine it. The scenario was a problem of choosing a vehicle type for given available financial resources. In the scenario it was assumed that the operator had financial resources of £1,000,000 available. It was assumed that the operator wished to know which type of vehicle he should spend his resources on so that his bus operation would be profitable. It was also assumed that the fare system to be adopted was a stage fare system with fares of 35p, 50p and 70p per trip for short, medium and long trips respectively.

For the £ 1,000,000 available, the operator had four alternatives to choose from, each providing a service capacity of about 1000 seats. These included : a fleet of 15 double/decker buses, 27 standard buses, 31 midibuses, and 53 minibuses (see, *Table 7.3*). *Figs 7.8.* and *7.9.* summarise the results on routes 24 and 85 for each available alternative, each with various levels of passenger response. It has been assumed that passenger response is represented by headway elasticities.

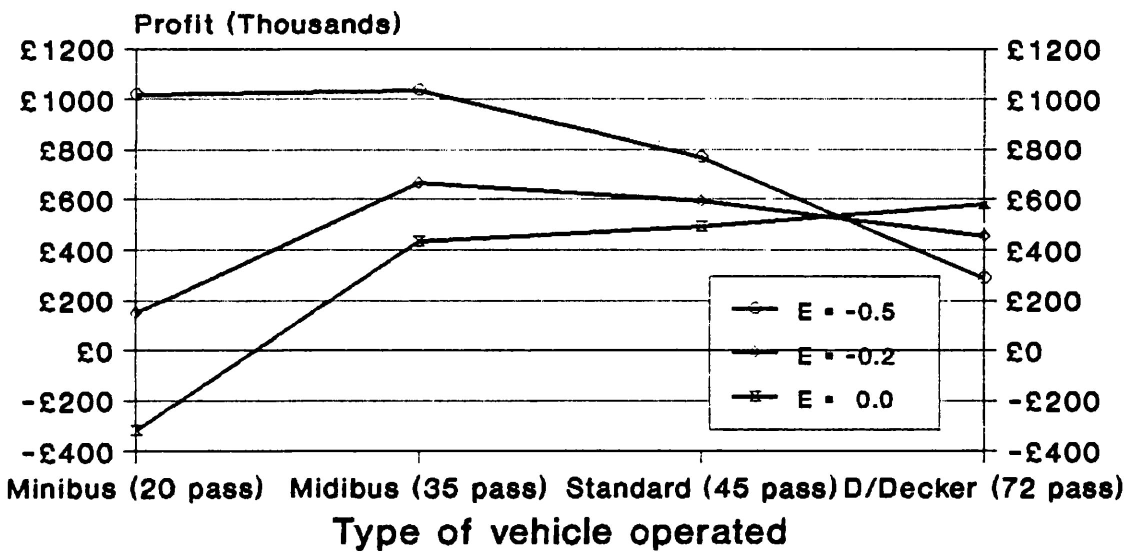
Table 7.3. ALTERNATIVES AVAILABLE

Alternative	Type of vehicle	Fleet size	Service capacity (pass.)	Headway (mnts)	Freq bus/hr
A	D/Decker	15	1080	6.6	9
B	Standard	27	1215	3.3	18
C	Midi bus	31	1085	2.6	23
D	Mini bus	53	1060	1.4	43

Of the four alternatives available, it is clear that there is a trade-off between service frequency and total operating costs. If the operator chooses small vehicles, he can offer a high frequency service to his travellers, but at the same time he has to recover a considerable amount of operating costs. However, if big buses were chosen then the service on offer would not be very attractive, since it would be a low frequency service, but with the advantage that not too many resources are needed to cover its operating costs.

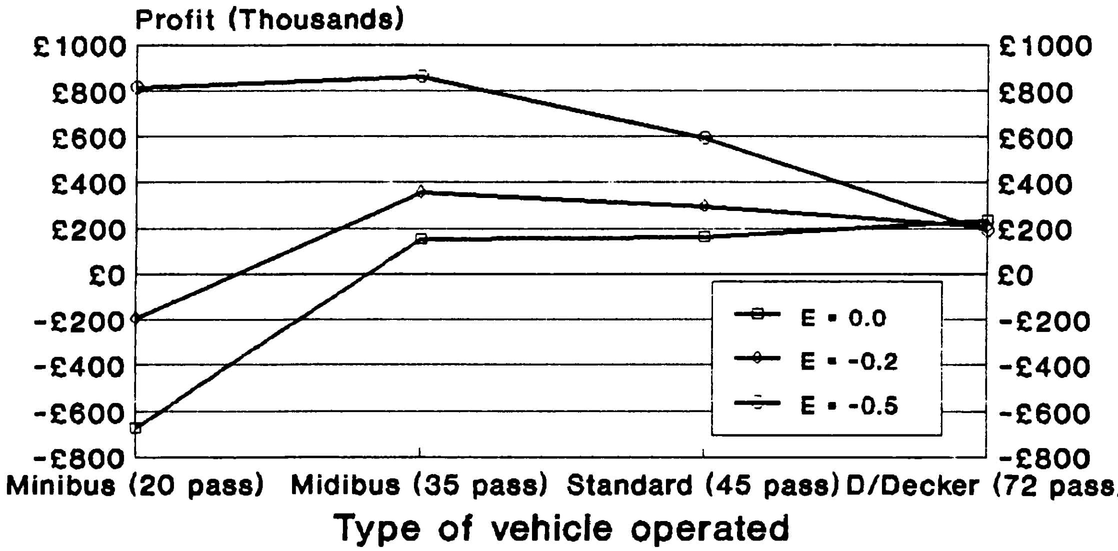
Given the fact that the smaller the vehicle chosen, the bigger the total operating costs, it is clear that the key factor in determining the level of profits is the ability of the service to generate revenue, or to encourage new potential passengers to use the service. If the response of passengers toward the service is the same regardless of the type of vehicle offered and the level of service frequency, it seems

Fig. 7.8 Bus Operations on Route 24 : Vehicle types



The operator has £1,000,000 to spend
on the provision of vehicles.
E = Headway elasticity of demand

Fig. 7.9 Bus Operations on Route 85 : Vehicle types



The operator has £1,000,000 to spend
on the provision of vehicles.
E = Headway elasticity to demand

likely that the use of big vehicles is the most profitable choice. This is true because the revenues collected from passengers will be the same regardless of the vehicle size, whilst total operating cost using a big vehicle is smaller.

However, if passenger response to the frequency of the service is quite significant, then the choice of big buses no longer becomes advantageous, since smaller vehicles will attract more new potential passengers than big ones. From the chart depicted in *Figs 7.8. and 7.9.*, it can be observed that, the greater the response of the passengers to the frequency of the service, or the higher the value of demand elasticity to frequency, the more profitable the operation of small vehicles will be. From the two figures it was found that when the value of demand elasticity to frequency was -0.2 and -0.5, the choice of midibuses on the two routes produced the most profitable service. These findings agree with those suggested by most authors (see, for example, Bly, 1981) as from the empirical evidence the value of headway elasticity to demand in urban areas is about -0.4 to -0.5 (Webster,1980).

7.5.4. Travelcard

When a travelcard system is introduced, the obvious advantage is gained by the travellers, particularly those who are captives to the bus service. This is true partly because the price of the travelcard usually a discount price where, on average, the price per trip per passenger becomes lower than the standard rate, and partly because the holders can use it any time while it is valid and anywhere within its zonal boundary.

Since travelcards can be used on any journey within the zonal boundary, where on the other hand a fare system sometimes differentiates fares on the basis of travel distance, it appears that the benefit to the passenger from using a travelcard will depend upon the fare system applied.

For a bus service that adopts a flat fare, for example, the introduction of a travelcard gives the opportunity to all potential passengers to get a bargain fare. Every potential passenger who is captive to the service will feel that it is worth having a travelcard. However, for a bus service which adopts a distance-based fare or a stage fare, the introduction of a travelcard will only benefit some potential passengers, namely those travellers who make medium or long journeys where the normal fare for their journey is more expensive than using a travelcard. The travellers who make short journeys, however, will only benefit if they make lots of trips.

To some extent, this scheme also provide some advantages for the operator : the boarding process will be much faster, the number of passengers carried will increase, and the company can generate more cash in advance. However, despite the fact that this scheme promotes customer loyalty, it is still questionable whether it has the advantage in terms of profit. This question arises because the level of profit that can be generated by this scheme will depend mainly on how much revenue can be generated, and how great a reduction in operating costs can be made.

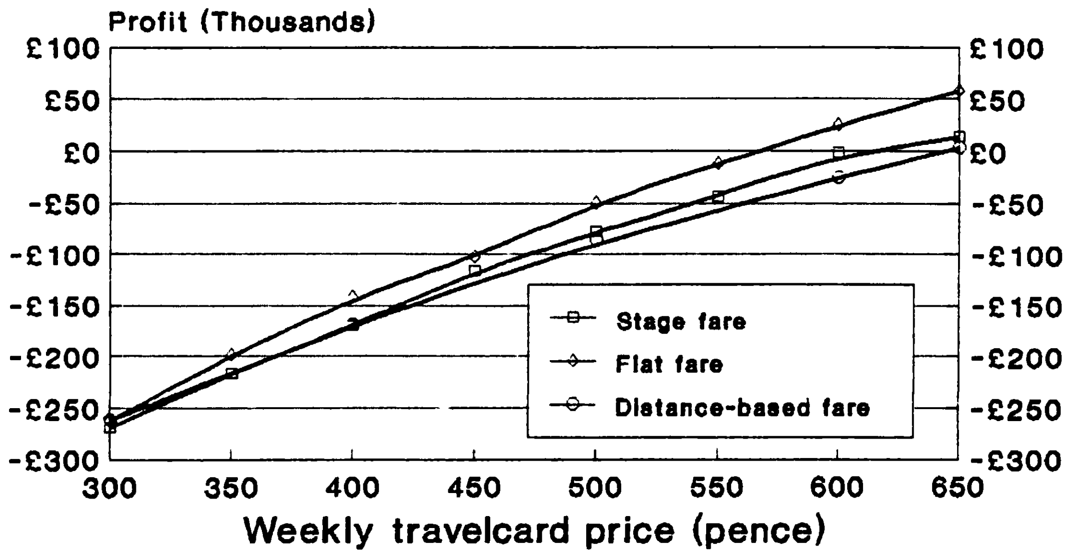
Since the increase in the level of demand is not likely to be too significant, whilst the average fare per trip per passenger collected becomes cheaper, it seems likely that this scheme will slightly reduce the level of revenue. These mean that the level of profit will also decline since the reduction in operating costs is expected to be very marginal.

In this exercise, the model was used to investigate the performance of bus operations when a travelcard was introduced. It has been assumed that the type of travelcard to be introduced is a weekly travelcard and the average number of trip per week was assumed to be 14. The possibility that the passengers tended to have more trips per week as the travelcard price decreased was not taken into consideration. The operational condition of the service was assumed to be the same as the existing one (see, *Table 7.1*). Three different fare systems were considered : *1)* a flat fare system with a fare of 50 pence per trip ;*2)* a stage fare system with a fare of 35, 50 and 70 pence per trip for short, medium and long trips respectively, and *3)* a distance-based fare system with an initial fare of 25 pence and an additional fare of 7 pence per kilometre. The results of these exercises can be seen in *Figs 7.10.* and *7.11.*

As can be expected, the results indicate that the introduction of a travelcard at any price level causes a decline in the level of revenue and, therefore, a reduction on the level of profit. In general, the lower the price of the weekly travelcard the lower the level of revenue. This is also true in terms of profit since in this model the operating cost was assumed to be the same regardless of the introduction of travelcard. In this exercise, these features apply for both routes. There are two reasons for these. Firstly, as the operator decreases the price level of the weekly travelcard, the travelcard becomes more attractive and , as a result, more people wish to have it. Secondly, the cheaper the price of the weekly travelcard the less the level of revenue will be, since the increase in the number of passengers is not very significant, whilst the average fare charged per trip decreases.

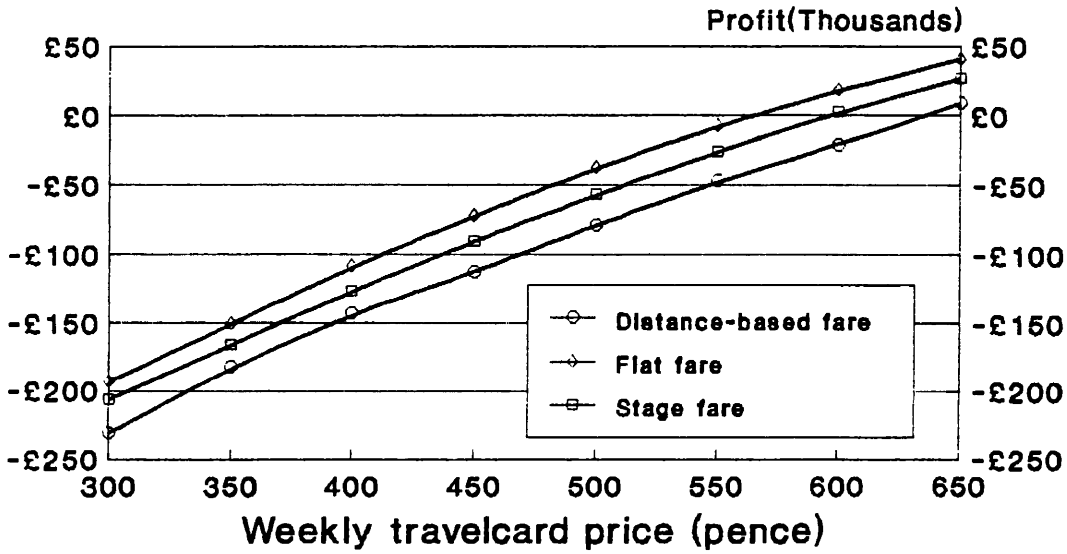
Of the three fare systems considered, it is clear that the introduction of a travelcard on a service which differentiates the price on the basis of travel distance makes the level of profit decline considerably as the price of the travelcard decreases. This is true because the introduction of the travelcard only encourages those travellers with long journeys to use it. As a result, the money generated from normal fares comes from short distance travellers and is relatively small in value.

Fig.7.10. Bus Operations on Route 24 : Travelcard



Flat fare : 50 p/trip
Stage fare: 35p,50p and 70p per trip
Distance-based fare : 25p + 7p/Km

Fig.7.11. Bus Operations on Route 85 : Travelcard



flat fare : 50 p/trip
stage fare: 35p, 50p and 70p per trip
Distance-based fare : 25p + 7p/Km

7.6. Competitive market

It can be argued that in a competitive market there will be a strong interdependence between the action of the operators. The action of any one operator will affect the others, provoking a response leading to competitive strategies being developed in terms of fare, frequency and other operational factors. Each of the operators will try to adopt the best operational strategy to achieve his objective which can be either profit maximization or patronage maximization. In this situation, the problem of the operators is that their interests are partly similar and partly conflicting. They are similar in the sense that both operators try to give the best service to the travellers, and conflict in the sense that both of them try to catch as much of the market as possible. As a result, the pattern of competition will be unpredictable and a whole range of outcomes can emerge.

The implications of competition to the travellers are numerous and are all dependent on the behaviour of the operators. However, regardless of the competitive situation, one thing seems certain ; the overall frequency of the bus service on the route will be much higher compared with that in a monopoly and, most importantly, the travellers have alternatives to choose from. These also mean that competition makes better off, particularly in terms of average perceived waiting time.

As a better frequency service tends to attract more potential passengers, it seems likely that competition makes the level of travel demand increase significantly, particularly if the average level of fares is not too different compared with that in a monopoly. Consequently, there is always a chance for a new entrant to catch the market when it is in competition with an existing operator, regardless of the level of demand. The problem facing each operator is how operational strategy should be formulated so that his service can survive, or, if possible, be profitable.

In general, the main idea behind the formulation of the operational strategy is how to make the service on offer more attractive than the competitor's. Ideally, in doing so one has to consider the strategy of the competitor in addition to the structure of the market. However, this situation is not likely to be possible, since in a competitive market, it is very difficult to know exactly the competitor's strategies. Therefore, it appears that the operator will be inclined to take decisions on the basis of the structure of the demand and his competitor's existing operational condition rather than his competitor's strategies.

In these exercises the issue of competitive strategies has been investigated. It was carried out in order to examine the best strategy to be adopted for a new entrant when entering the market, in terms of : service frequencies, fare systems and fare level, and type of vehicle. The market here means route 24 and route 85 in London.

It was assumed that the market has an oligopoly structure rather than perfect competition. This was based on the fact that the market is generally too small to sustain a large number of operators. Competition therefore is expected to be between the few (oligopoly) rather than the many (perfect competition).

Consider again routes 24 and 85. Suppose that before deregulation they have been served by a single bus operator, each with the service condition as mentioned in *Table 7.1*. After deregulation the market is open for other bus companies to enter and compete with the existing one. Ideally, the new entrants can adopt any operational strategy when entering the market. However, before entering the market, one normally needs to know the best strategy to be adopted to meet one's operational objectives.

The following are some of the possible competitor's strategies in terms of fare system, frequency and vehicle type.

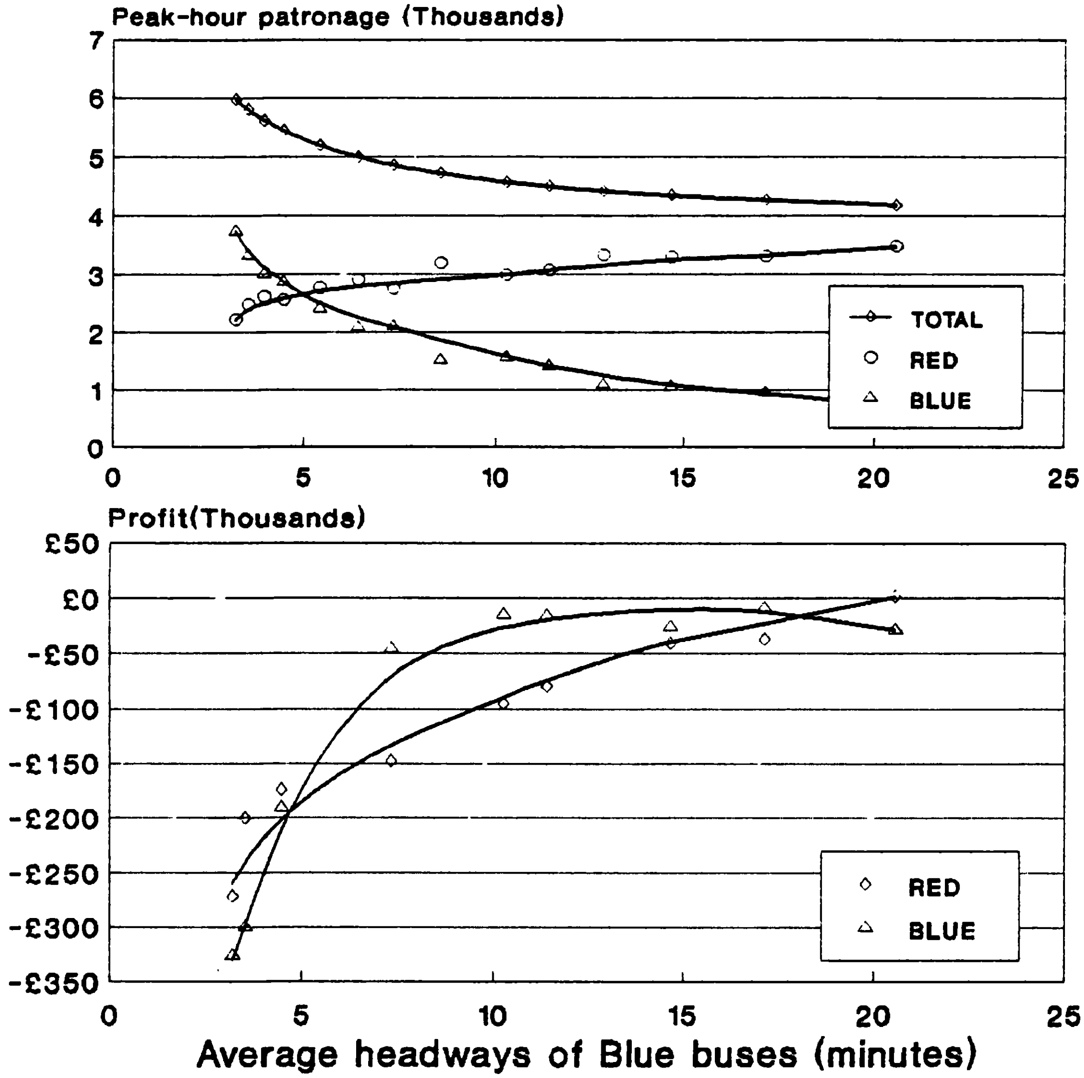
7.6.1. Setting the service frequency

Suppose that the new entrant (blue bus) has decided to enter the market with the same vehicle type, fare system and fare level as the existing operator (red bus). The problem to be investigated was at what frequency, or, at what headway, the blue bus should run in the market. *Figs. 7.12.* and *7.13.* show the outcomes of competition when the blue bus enters the market with various headways, whilst red bus makes no response.

Given that all factors were equal for both services except their service frequency, it is clear that the attractiveness of the two services will otherwise be the same. Passengers will not differentiate between the two services. They will take any bus that comes first, either red or blue, as long as there is still spare capacity. Under these conditions each operator will catch a market share in proportion to its buses operated on the corridor. If the blue bus improves its service frequency, or increases the number of buses operated, it is most likely that its market share will increase, but at the same time, the market share of its competitor (red bus) will decrease. Thus, the entry of the blue bus operator makes the overall level of travel demand increase, and the existing operator will suffer, since the number of its passengers will decline.

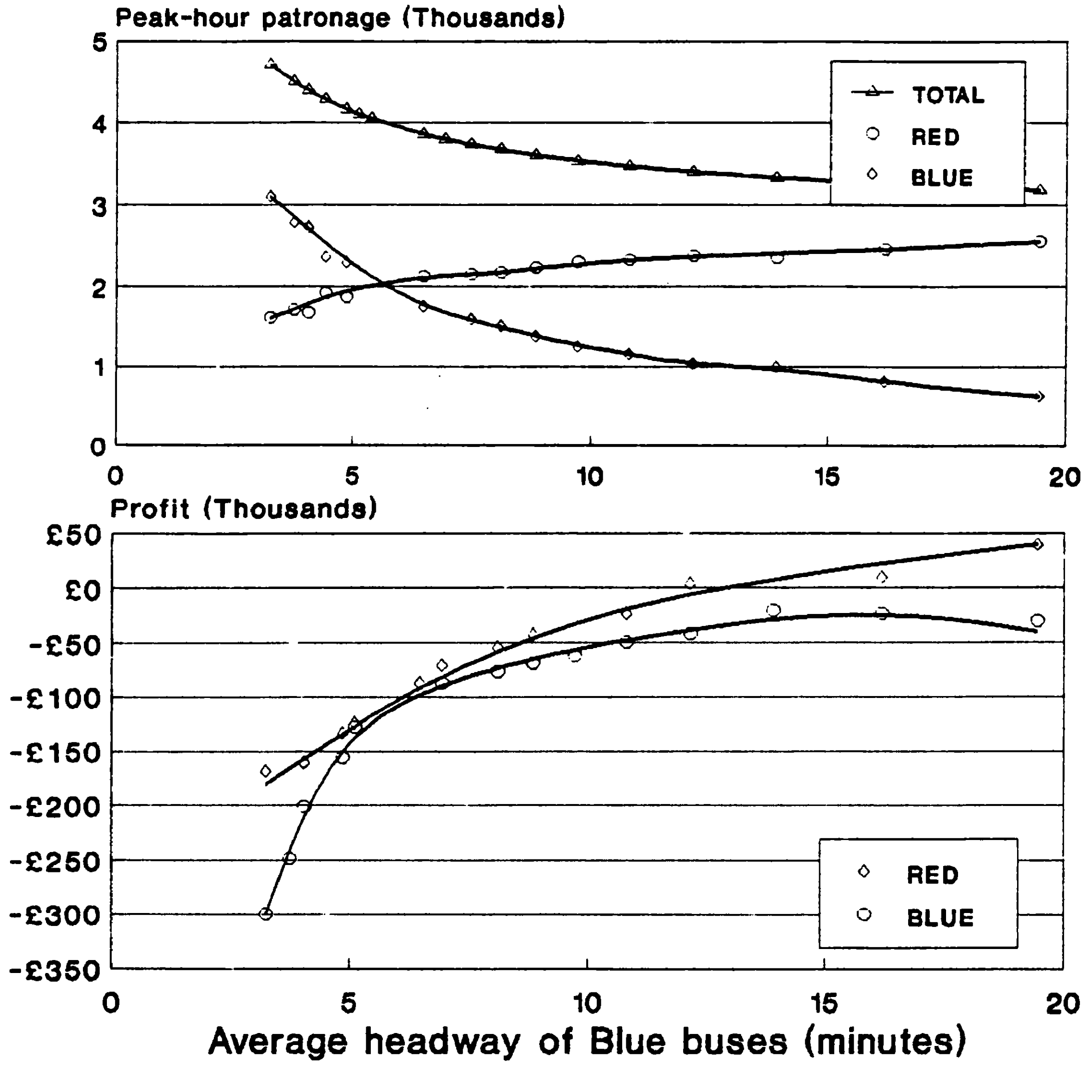
Since the total operating cost of the red bus was the same regardless of the level of patronage, whilst its patronage (and revenues) varies and depends on the competitor's frequency, it appears that its profit will worsen whenever the blue bus enters the market. Therefore, it is not surprising that the curve shape of the red bus's profit is similar and proportional to that of its patronage curve. On the two routes the trend of profit curve of the red bus is the same, the differences is in the level. The level of profit of the red bus on route 85 is higher than that of route 24. This is primarily because the red bus operator has already served route 24 with a higher service frequency (with 4

Fig. 7.12. Competition on Route 24 : New entrant with various headways



RED : D/Dckr, headway 4.7 mnts, stage fr
BLUE: D/Dckr, headways vary, stage fare

Fig. 7.13. Competition on Route 85 : New entrant with various headways



RED : D/Dckr, headway 6.0 mnts, stage fr
BLUE : D/Dckr, headway vary, stage fare

minutes headways) compared to that of route 85 (with 6 minutes headways).

For the blue bus operator, it is apparent that whenever it enters the corridor, either on route 24 or 85, with any level of service frequency, it will never be profitable. The main reason is that the level of travel demand on the two routes is not high enough to sustain competition. It might be argued that if the level of travel demand on the two routes was much higher, the blue bus would, under certain conditions, become profitable.

It is worthwhile mentioning that, the profit curve of the blue bus depicted in *Figs. 7.12.* and *7.13.* has a similarity with that in *Fig. 7.4* . The curves have a concave shape. This indicates that, regardless of the level of travel demand, and the condition of the existing operator, there is always a situation in which a new entrant (blue bus) can get a maximum profit (or minimum deficit). This point is an optimal headway, the value of which depends on the condition of the existing operator and on the level of travel demand.

For the travellers, it is obvious that they will get most benefit whenever blue bus enters the market, since for every additional bus operated in the corridor, the total headway of the two services becomes lower, which means there will be a reduction in the expected waiting time.

7.6.2. Fare strategy

If competition is manifested in a situation where operators have absolute freedom to set the operational factors, then it can be expected that the fare level and the fare system will be the ones that most operators will be inclined to adjust during their operation. This is partly because it is very easy to do, and partly because only very few resources are needed to implement them.

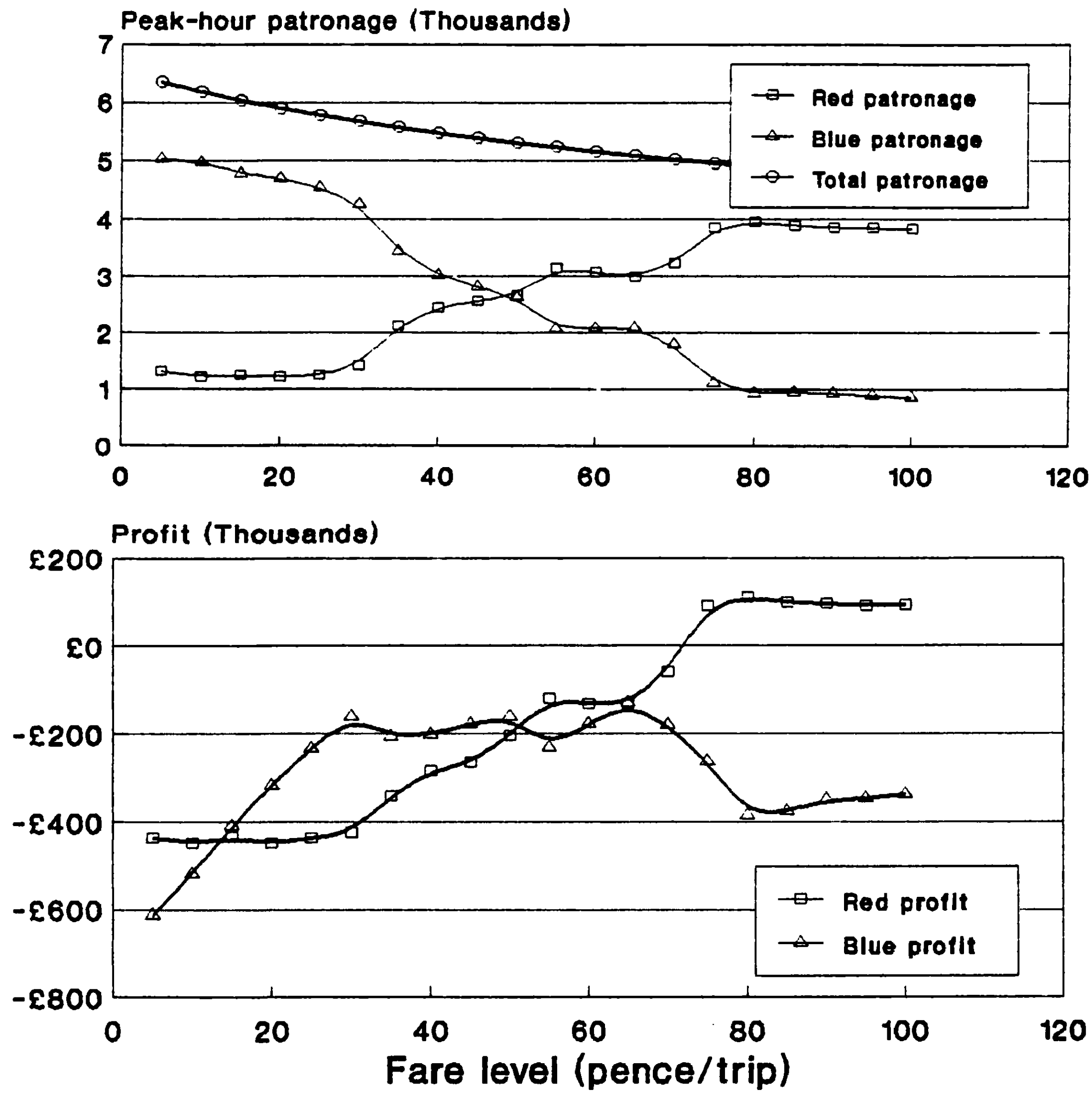
In adjusting the fare strategy it appears that each of the competing operators will set the fares in such a way that his service becomes more attractive than that of his competitor. This can be done by adjusting the level of fares below of that of his competitor. When the fare system adopted is the same as the competitor's, it is apparent that this strategy is not very difficult to apply. Reducing the level of fares below the competitor's will enable the service to catch as significant share as the market. However, if the fare system to be adopted is not the same as the competitor's, then the problem of adjusting fare levels becomes a tricky one. In this case, one has to consider the pattern and the segmentation of the market in more detail and with greater care. one has to examine, for example, the part of the market which one is trying to catch.

The next condition to be analysed is strategies of fare systems and fare levels in a competitive market. The routes to be analysed are the same as before, routes 24 and 85, each of which has the same operational conditions as the base case (see, *Table 7.1*). It has been assumed that the new entrant intends to enter the market with the same operational conditions as the ones of the existing operator except for the fare system and the fare level. He enters the market with various fare systems and fare levels, whereas the red bus keeps the same operational conditions and does not make any response.

The results of competition in terms of patronage and profit are shown in *Figs 7.14.* to *7.17.* The first two charts demonstrate applying a flat fare system at various levels, whereas the last two are demonstrate adopting a distance-based fare system with an initial fare of 25 pence and with an additional fare per kilometre varying from 0 to 20 pence.

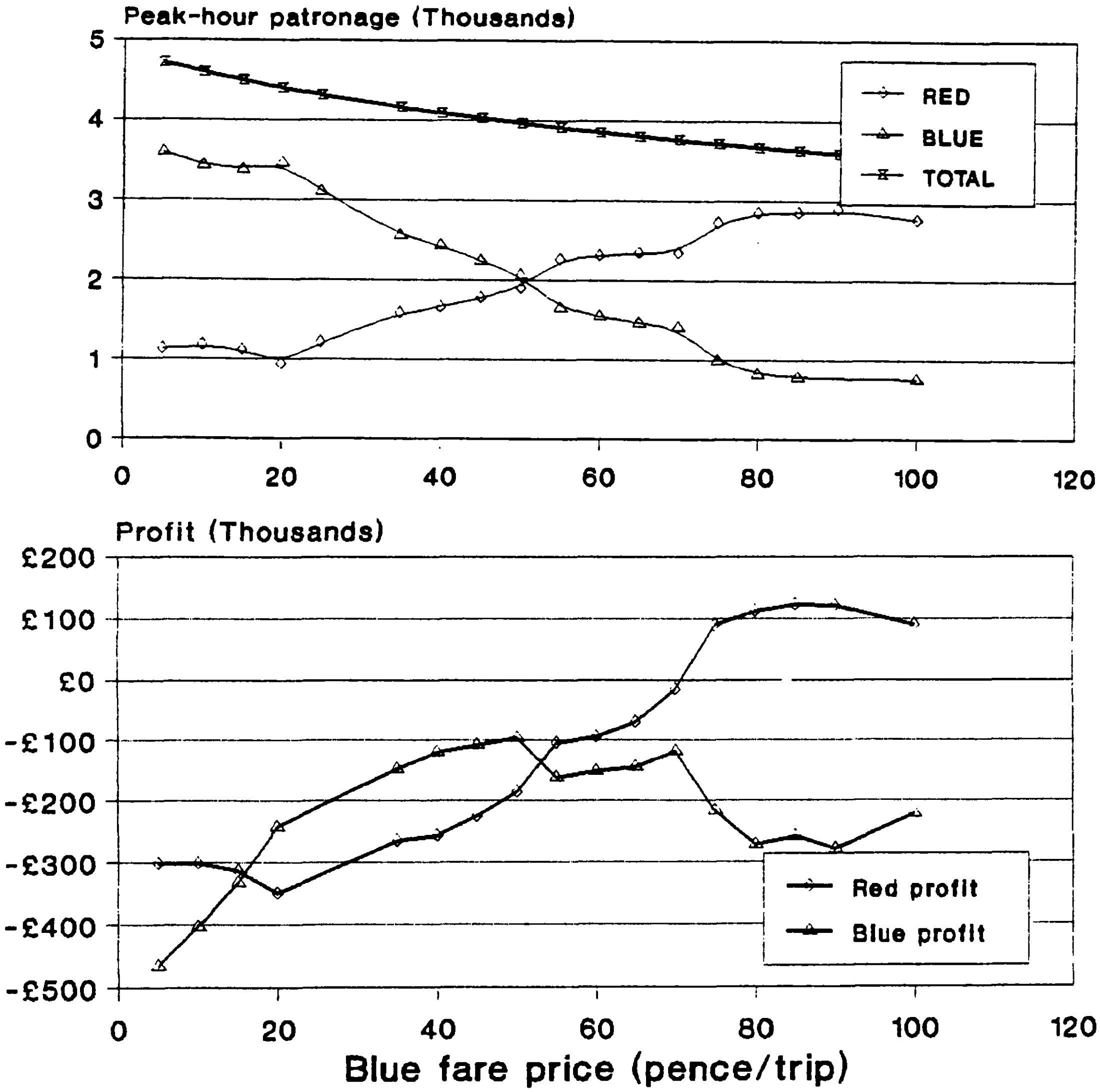
From the graphs depicted in *Figs. 7.14.* to *7.17.*, it is clear that the outcomes of competition between the two operators on the two routes were strongly influenced by the fare system adopted by the blue bus operator (the new entrant). In general, the trends of the outcomes are obvious.

Fig. 7.14. Competition on Route 24 : New entrant with flat fare



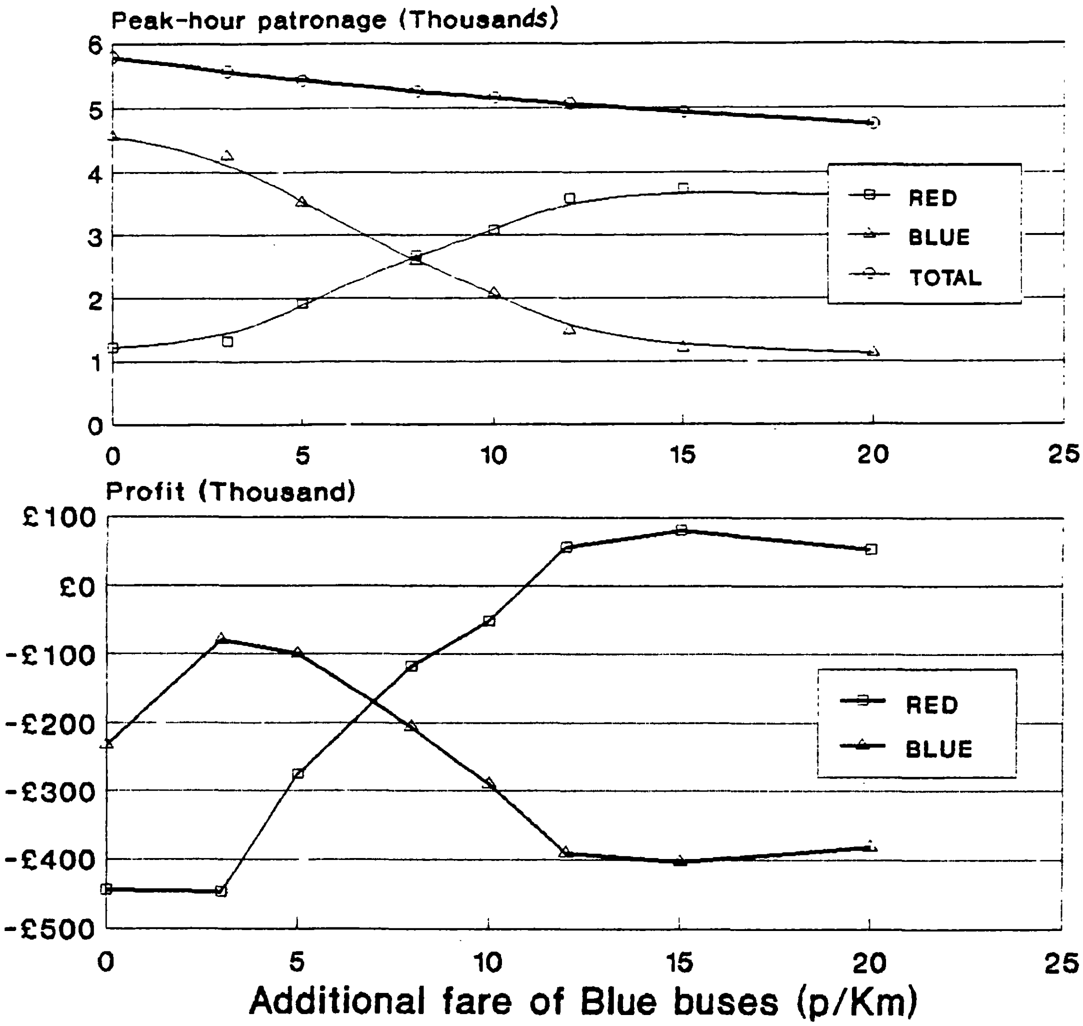
RED : D/Dckr, headway 4.7 mnts, stage fr
BLUE : D/Dckr, headway 4.7 mnts, flat fr

Fig.7.15. Competition on Route 85 : New entrant with flat fare



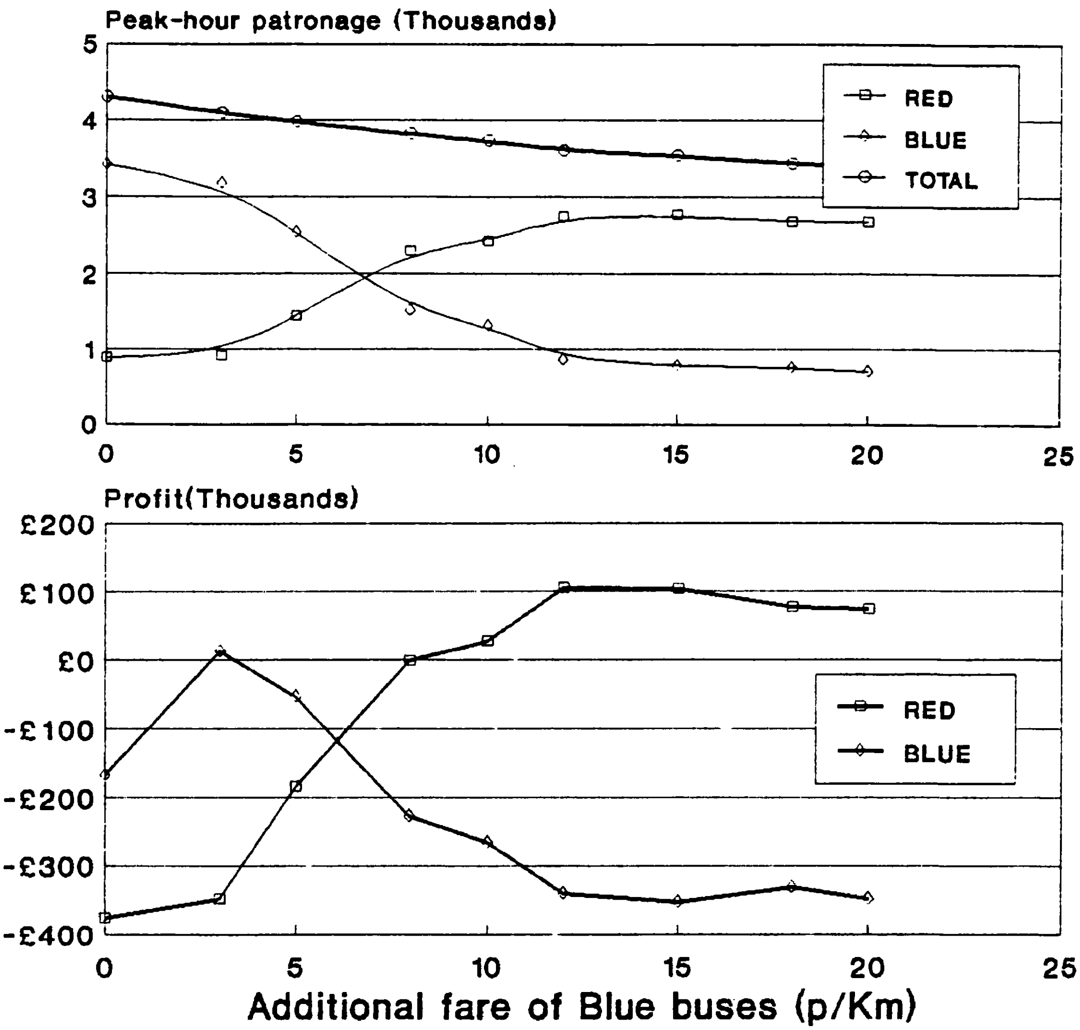
RED : D/Dckr, headway 6.0 mnts, stage fr
BLUE : D/Dckr, headway 6.0 mnts, flat fr

Fig.7.16. Competition on Route 24 : New entrant with distance-based fare



RED: D/Dckr, headway 4.7 mnts, stage fr
BLUE : D/Dckr, headway 4.7 mnts,distance -based fare with initial fare of 25p.

Fig.7.17. Competition on Route 85 : New entrant with distance-based fare



RED : D/Dckr, headway 6.0 mnts, stage fr
BLUE : D/Dckr, headway 6.0 mnts,distance
-based fare with initial fare of 25p

The blue bus operator only catches those passengers who feel that by using the service, their disutility becomes lower than by using the red bus service. For example, the introduction of a 5 pence flat fare has similar results to that of 30 pence per trip, but has a different outcome on the introduction of a 40 pence flat fare. This is partly because of the segmentation of the market and partly because the red bus operator adopts a stage fare system : in the first two cases all groups of potential passengers feel that blue buses are more attractive than red, whereas in the third case only those passengers who have medium, or long distance journeys, who have to pay 50 pence and 70 pence if using red buses, do so. However, it is apparent for the blue bus that the higher its fare price the fewer the number of its passengers, and the lower its fare level the greater its market share. The two operators split the market equally when the blue bus operator set the fare at the level where on average its price is the same as the average fare of the red bus.

In terms of the profit that can be gained by the blue bus operator, however, the results show a different trend. It seems that whatever the level of fares the blue bus operator never goes into profit. These conditions apply on both routes , either when blue bus operator introduces a flat fare or a distance-based fare. The reasons for this outcome is that when the blue bus introduces a fare system with a high fare price, its level of patronage is very low, whilst when the number of passengers carried was high the level of fares is too small, both failing to generate enough revenue.

Since the percentage change in fare level is not proportional to the percentage change in patronage, and because of the segmentation of the market, the curve of blue bus profits has a different shape from that of its patronage. When the level of fares is low, the increase in fare level makes the level of profit go up steadily.

However, when the change in the level of patronage is more than the travelcard at any price level causes a decline in the level of revenue and, therefore, a reduction on the level of profit. The lower the price of the weekly travelcard the lower the level of revenue, given the assumption that the relationship between patronage and mean fare per journey assuming 12 trips per week are made using the travelcard, is represented by an elasticity of -0.3. This assumption is based on evidence for fare changes and may not, in fact, be true for the discount offered by travelcards, but there is no direct evidence of the patronage generation effects of travelcards.

Hence the reduction in the weekly travelcard price (which means reduction in average fare paid) makes the number of travelcard holders increase, but at the same time the average fare paid per travelcard holder becomes lower. So, although the total number of passengers increases significantly (as the results of passengers generation), the total level of revenue decreases. These results are not surprising since the assumption taken regarding the travelcard holder is that they are captive and that they make 12 trips per week (which implies that the average fare paid per trip becomes very low compared to that of the standard). In reality this may not be the case since not all the travelcard holders are captive or make 12 trips per week. Under some conditions, some people will have a weekly travelcard and use it for less than 12 trips per week (which implies that the average fare paid per trip is sometimes higher that the standard fare).

The profit level, decreases as the price of weekly travelcards is reduced. This is due to the fact that in this model the operating cost was assumed to be the same regardless of the introduction of the travelcard. In reality, boarding times might be reduced. In this exercise, these features apply for both routes. There are two reasons for these. Firstly, as the operator decreases the price level of the weekly travelcard, the travelcard becomes more attractive and , as a result, more people wish to have it. Secondly, the cheaper the price of the weekly travelcard the less the level of revenue will be, since the increase in the number of passengers is not very significant, whilst the average fare charged per trip decreases.

Of the three fare systems considered, it is clear that the introduction of travelcards on a service which differentiates the price on the basis of travel distance reduces the level of profit considerably as the price of the travelcard decreases. This is true because the introduction of the travelcard only encourages long journey travellers. As a result, the money generated from normal fares comes from short distance travellers and is relatively small in value.

7.6. Competitive market

It can be argued that in a competitive market there will be a strong interdependence between the action of the operators. The action of any one operator will affect the others, provoking a response leading to competitive strategies being developed in terms of fare, frequency and other operational factors. Each of the operators will try to adopt the best operational strategy to achieve his objective which can be either profit maximization or patronage maximization. In this situation, the problem of the operators is that their interests are partly similar and partly conflicting. They are similar in the sense that both operators try to give the best service to the travellers, and conflict in the sense that both of them try to catch as much of the market as possible. As a result, the pattern of competition will be unpredictable and a whole range of outcomes can emerge.

The implications of competition to the travellers are numerous and are all dependent on the behaviour of the operators. However, regardless of the competitive situation, one thing seems certain ; the overall frequency of the bus service on the route will be much higher compared with that in a monopoly and, most importantly, the travellers have alternatives to choose from. These also mean that competition makes better off, particularly in terms of average perceived waiting time.

As a better frequency service tends to attract more potential passengers, it seems likely that competition makes the level of travel demand increase significantly, particularly if the average level of fares is not too different compared with that in a monopoly. Consequently, there is always a chance for a new entrant to catch the market when it is in competition with an existing operator, regardless of the level of demand. The problem facing each operator is how operational strategy should be formulated so that his service can survive, or, if possible, be profitable.

In general, the main idea behind the formulation of the operational strategy is how to make the service on offer more attractive than the competitor's. Ideally, in doing so one has to consider the strategy of the competitor in addition to the structure of the market. However, this situation is not likely to be possible, since in a competitive market, it is very difficult to know exactly the competitor's strategies. Therefore, it appears that the operator will be inclined to take decisions on the basis of the structure of the demand and his competitor's existing operational condition rather than his competitor's strategies.

In these exercises the issue of competitive strategies has been investigated. It was carried out in order to examine the best strategy to be adopted for a new entrant when entering the market, in terms of : service frequencies, fare systems and fare level, and type of vehicle. The market here means route 24 and route 85 in London.

It was assumed that the market has an oligopoly structure rather than perfect competition. This was based on the fact that the market is generally too small to sustain a large number of operators. Competition therefore is expected to be between the few (oligopoly) rather than the many (perfect competition).

Consider again routes 24 and 85. Suppose that before deregulation they have been served by a single bus operator, each with the service condition as mentioned in *Table 7.1.* After deregulation the market is open for other bus companies to enter and compete with the existing one. Ideally, the new entrants can adopt any operational strategy when entering the market. However, before entering the market, one normally needs to know the best strategy to be adopted to meet one's operational objectives.

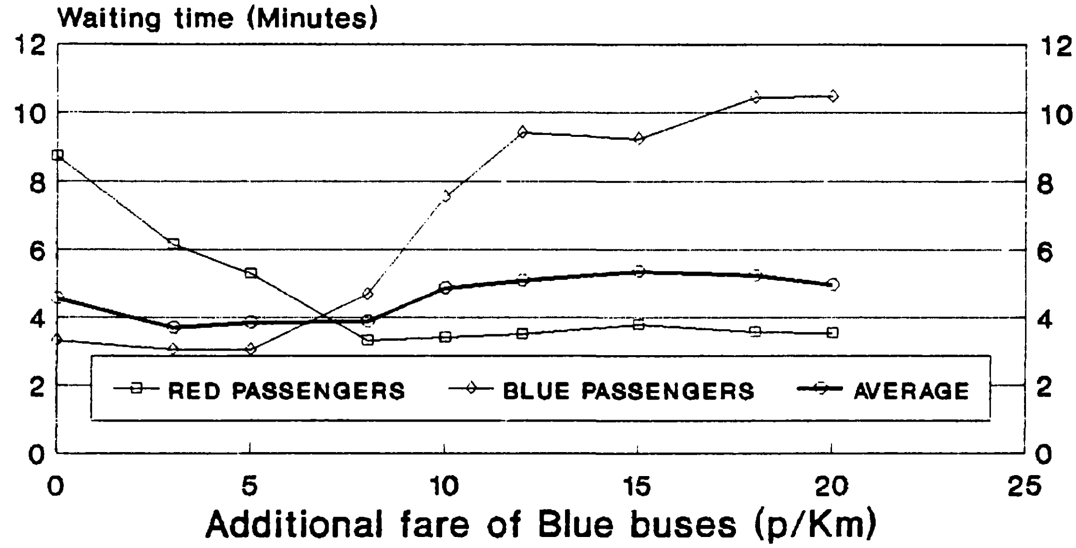
The following are some of the possible competitor's strategies in terms of fare system, frequency and vehicle type.

7.6.1. Setting the service frequency

Suppose that the new entrant (blue bus) has decided to enter the market with the same vehicle type, fare system and fare level as the existing operator (red bus). The problem to be investigated was at what frequency, or, at what headway, the blue bus should run in the market. *Figs. 7.12.* and *7.13.* show the outcomes of competition when the blue bus enters the market with various headways, whilst red bus makes no response.

Given that all factors were equal for both services except their service frequency, it is clear that the attractiveness of the two services will otherwise be the same. Passengers will not differentiate between the two services. They will take any bus that comes first, either red or blue, as long as there is still spare capacity. Under these conditions each operator will catch a market share in proportion to its buses operated on the corridor. If the blue bus improves its service frequency, or increases the number of buses operated, it is most likely that its market share will increase, but at the same time, the market share of its competitor (red bus) will decrease. Thus, the entry of the blue bus operator makes the overall level of travel demand increase, and the existing operator will suffer, since the number of its passengers will decline.

Fig.7.21. Competition on Route 85 : New entrant with distance-based fare



RED : D/Dckr, headway 6.0 mnts, stage fr
BLUE : D/Dckr, headway 6.0 mnts,distance -based fare with initial fare of 25p

Figs 7.18. to *7.21.* show clearly that the average waiting time perceived by the passengers depends upon the difference in fare level between the two services. When the blue bus operator introduces a fare which is higher on average than that of the red bus, the average waiting time of blue bus passengers is very high, whilst the average waiting time of red bus passengers is significantly low. This is primarily because most passengers tend to take any first red bus to come and reject any first blue bus, and therefore the passengers who board the blue bus are not the ones who have just arrived at the stop, but those passengers who have already waited for quite a long time, and feel frustrated. It is important to recognise that because in this case the proportion of blue bus passengers is relatively small, the total average waiting time tends to be close to the average waiting time of red bus passengers. The reverse case is also true, that is, when a blue bus applies a lower fare level than the red bus.

Moreover, it is also clear from the graph that when the two services have the same average fare, the difference between average waiting time of those who board the red bus and those who board the blue bus diminishes. Both have the same waiting time.

7.6.3. Choosing the vehicle type

After deregulation, there is a possibility that the new entrant will try to enter the market with a different type of vehicle, and there is a belief that smaller vehicles will be used. This expectation is partly derived from recent evidence which indicates that deregulation encourages innovation (Gomez-Ibanez, 1987), and comes partly from the fact that smaller vehicles are more attractive in terms of speed and operational performance than big ones. The problem to be examined in the next paragraph is the question of the vehicle size to be used by the new entrant to make a profitable service.

Since the total operating cost of the red bus was the same regardless of the level of patronage, whilst its patronage (and revenues) varies and depends on the competitor's frequency, it appears that its profit will worsen whenever the blue bus enters the market. Therefore, it is not surprising that the curve shape of the red bus's profit is similar and proportional to that of its patronage curve. On the two routes the trend of profit curve of the red bus is the same, the differences is in the level. The level of profit of the red bus on route 85 is higher than that of route 24. This is primarily because the red bus operator has already served route 24 with a higher service frequency (with 4 minutes headways) compared to that of route 85 (with 6 minutes headways).

For the blue bus operator, it is apparent that whenever it enters the corridor, either on route 24 or 85, with any level of service frequency, it will never be profitable. The main reason is that the level of travel demand on the two routes is not high enough to sustain competition. It might be argued that if the level of travel demand on the two routes was much higher, the blue bus would, under certain conditions, become profitable.

It is worthwhile mentioning that, the profit curve of the blue bus depicted in *Figs. 7.12.* and *7.13.* has a similarity with that in *Fig. 7.4.* The curves have a concave shape. This indicates that, regardless of the level of travel demand, and the condition of the existing operator, there is always a situation in which a new entrant (blue bus) can get a maximum profit (or minimum deficit). This point is an optimal headway, the value of which depends on the condition of the existing operator and on the level of travel demand.

For the travellers, it is obvious that they will get most benefit whenever blue bus enters the market, since for every additional bus operated in the corridor, the total headway of the two services becomes lower, which means there will be a reduction in the expected waiting time.

7.6.2._Fare_strategy

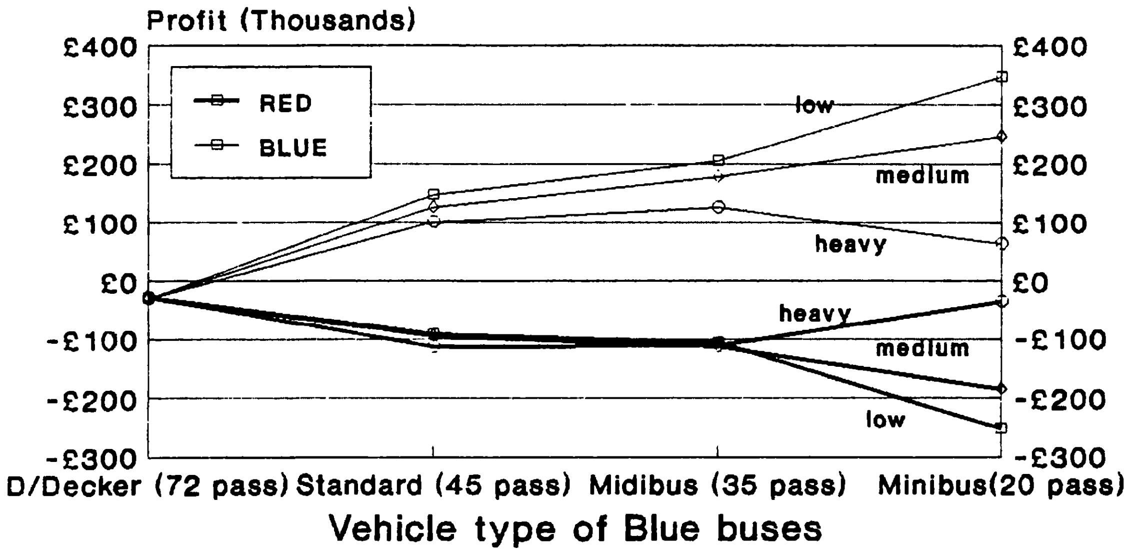
If competition is manifested in a situation where operators have absolute freedom to set the operational factors, then it can be expected that the fare level and the fare system will be the ones that most operators will be inclined to adjust during their operation. This is partly because it is very easy to do, and partly because only very few resources are needed to implement them.

In adjusting the fare strategy it appears that each of the competing operators will set the fares in such a way that his service becomes more attractive than that of his competitor. This can be done by adjusting the level of fares below of that of his competitor. When the fare system adopted is the same as the competitor's, it is apparent that this strategy is not very difficult to apply. Reducing the level of fares below the competitor's will enable the service to catch market share significantly. However, if the fare system to be adopted is not the same as the competitor's, then the problem of adjusting fare levels becomes a tricky one. In this case, one has to consider the pattern and the segmentation of the market in more detail and with greater care. one has to examine, for example, the part of the market which one is trying to catch.

The next condition to be analysed is strategies of fare systems and fare levels in a competitive market. The routes to be analysed are the same as before, routes 24 and 85, each of which has the same operational conditions as the base case (see, *Table 7.1*). It has been assumed that the new entrant intends to enter the market with the same operational conditions as the ones of the existing operator except for the fare system and the fare level. He enters the market with various fare systems and fare levels, whereas the red bus keeps the same operational conditions and does not make any response.

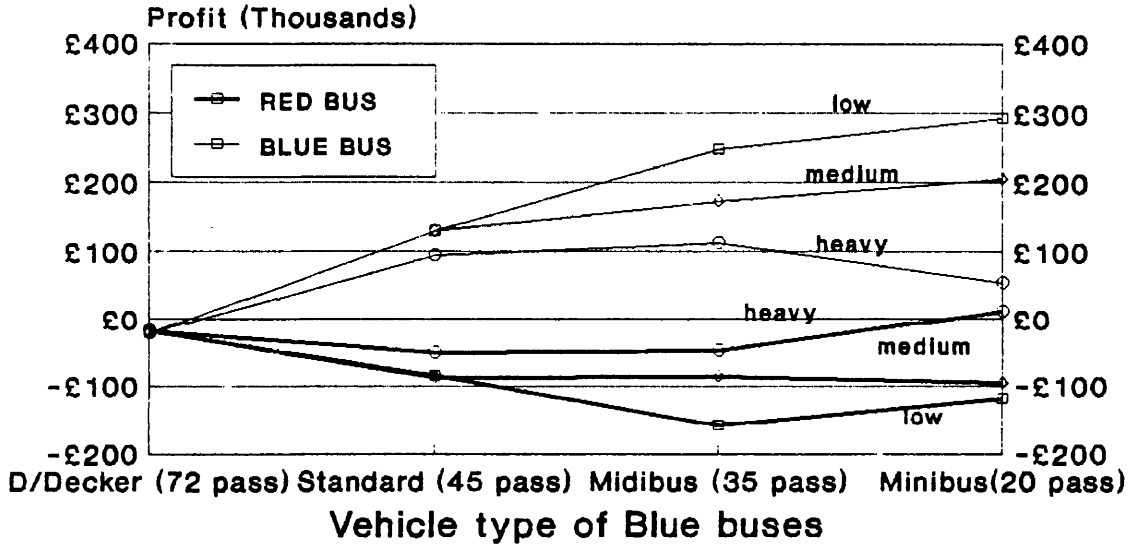
The results of competition in terms of patronage and profit are shown in *Figs 7.14.* to *7.17.* The first two charts demonstrate applying a flat

Fig. 7.22. Competition on Route 24 : New entrant with various types of vehicle



RED : D/Dckr, headway 4.7 mnts, stage fr
BLUE : operator has £500,000 to spend on providing the vehicle.

Fig. 7.23. Competition on Route 85 : New entrant with various types of vehicle



RED : D/Dckr, headway 6.0 mnts, stage fr
BLUE : operator has £500,000 to spend on providing the vehicle.

frequent service than the red one. However, because the total service becomes less frequent, the total number of potential passengers who use the services decreases, which means the number of passengers carried by the blue bus also decreases, so its revenue will not be as high as in light traffic.

The superiority of minibuses diminishes when traffic conditions are very heavy. In this situation any vehicle has the same speed regardless of type. The attractiveness of each bus on the routes will therefore be the same. Each passenger will take whatever comes first. As a result the number of passengers carried by a fleet which uses minibuses drops compared with a situation of light traffic. Consequently, the level of profit decreases.

Since most urban routes are loaded with heavy traffic, it might be argued that the choice of the use of midibuses would be the most appropriate one. However, for a small town in which traffic is not the main problem, the use of minibuses to compete with the existing operator would be strongly advised, particularly if the level of demand was high enough to sustain competition.

7.6.4. Travelcard strategy

It is very interesting to consider what would happen if a new entrant introduces a travelcard system on entering the market. The obvious expectation is that the service to be offered with a travelcard will be very attractive and, therefore, the market will be dominated. The question is whether this policy can be adopted, since one might expect that this strategy will make it very difficult for any operator to run profitably.

In the following, a competitive situation which involves the use of a travelcard is examined. The situation under consideration was the competition when generated a new entrant comes into the market with a travelcard. It was assumed that apart from travelcard, all operational factors of the two competing services were the same. *Figs.7.24. and 7.25.* show the outcomes of competition when the new entrant (Blue bus operator) come into the market at various levels of weekly travelcard price.

Given that all other factors were the same, it was obvious that the service which introduced the travelcard would be more attractive, particularly in terms of the fare, as it would generally be cheaper. This, in turn, would encourage customer loyalty, which in the longer run would ensure the stability of its market share. This situation is predictable since the introduction of a travelcard makes the service more attractive than that of its competitor.

However, it should be recognised that the introduction of a travelcard does not mean that all potential passengers will use it. Only those travellers who feel it to be beneficially will use it, namely those travellers who are travelling long distances, or those who have to pay more if using a normal fare. As a result, there are still a number of travellers who are not willing to have a travelcard. This group of passengers are those who are not captives to a particular service and, they are the ones who may take any bus, either red or blue.

In terms of patronage carried by each operator, it is clear that whenever the blue bus operator introduces travelcards, he gets most of the market share. The cheaper the price of a weekly travelcard the greater its share will be. As for the red bus operator, this situation will make him suffer most. His market share will deteriorate whenever the blue bus introduces a travelcard.

In terms of profit, however, it is apparent that although through the introduction of a travelcard the service will be able to capture the market, it does not mean that the service will be profitable. This is fare system at various levels, whereas the last two are demonstrate adopting a distance-based fare system with an initial fare of 25 pence and with an additional fare per kilometre varying from 0 to 20 pence.

From the graphs depicted in *Figs. 7.14.* to *7.17.*, it is clear that the outcomes of competition between the two operators on the two routes were strongly influenced by the fare system adopted by the blue bus operator (the new entrant). In general, the trends of the outcomes are obvious. The blue bus operator only catches those passengers who feel that by using the service, their disutility becomes lower than by using the red bus service. For example, the introduction of a 5 pence flat fare has similar results to that of 30 pence per trip, but has a different outcome on the introduction of a 40 pence flat fare. This is partly because of the segmentation of the market and partly because the red bus operator adopts a stage fare system : in the first two cases all groups of potential passengers feel that blue buses are more attractive than red, whereas in the third case only those passengers who have medium, or long distance journeys, who have to pay 50 pence and 70 pence if using red buses, do so. However, it is apparent for the blue bus that the higher its fare price the fewer the number of its passengers, and the lower its fare level the greater its market share. The two operators split the market equally when the blue bus operator set the fare at the level where on average its price is the same as the average fare of the red bus.

In terms of the profit that can be gained by the blue bus operator, however, the results show a different trend. It seems that whatever the level of fares the blue bus operator never goes into profit. These conditions apply on both routes , either when blue bus operator introduces a flat fare or a distance-based fare. The reasons for this outcome is that when the blue bus introduces a fare system with a high fare price, its level of patronage is very low, whilst when the number of passengers carried was high the level of fares is too small, both failing to generate enough revenue.

Since the percentage change in fare level is not proportional to the percentage change in patronage, and because of the segmentation of the market, the curve of blue bus profits has a different shape from that of its patronage. When the level of fares is low, the increase in fare level makes the level of profit go up steadily.

However, when the change in the level of patronage is more than the change in the fare level the curve starts to decrease slightly. It should be recognised that in these exercises it was assumed that the change in the fare system or fare level does not have any affect on the total operating costs, so the change in profit level depends mainly on the change in revenue.

The other factor to investigate is the effect of competition on passengers, particularly in terms of their perceived waiting time. Theoretically, if two competing operators introduce bus services with the same vehicle type and the same frequency then, on the assumption that there is no congestion, the average waiting time would be half the total headway of the two services. For example, if the two operators introduced a fleet of buses with an average headway of, say, 4.0 minutes each, then the average waiting time perceived by the passengers would be 1 minute, that is, half of the total headways of 2 minutes. These conditions apply only when the fare systems and fare levels of the two services are the same. In this case the passengers will not differentiate between the two services and they will take any bus that comes first, regardless of the service.

However, if the two services have different fare systems and different fare levels, the conditions mentioned above will be void. The passengers will differentiate between the two services, and tend to take the one that has the lower generalised cost, or a cheaper fare for their journey. This means that some passengers will reject the bus which has higher fare for their journey and wait for the next bus to come in the hope that it will be the one that is cheaper. As a result, the average waiting time perceived by the passengers will not be half the total because the introduction of travelcards means reduction in average fare to charge, which, in turn, will reduce the level of revenue.

For the red bus operator, it is clear that the introduction of a travelcard by its competitor makes his service less popular. Travellers who use his service are only those who have short or medium distance journeys. As a result, his market share decreases to a very low level , and most significantly, his revenue also drops considerably, which plummets his operation into a deep deficit.

From the results mentioned above, it can be concluded that the use of a travelcard as a competitive strategy is likely to be feasible if its objective is to force the competitor out of the market. However, if the operator has financial constraints, it is not reasonable to introduce travelcards, since it will only make the level of profit decrease considerably.

7.7. Conclusions

In this chapter the features of bus operation and competition on a single self-contained route were investigated using the *COMBO.1* model. The emphasis of this chapter was the investigation of operational strategies of an operator running a fleet of buses in a monopoly as well as in a competitive market.

For each particular self-contained route, it was found that there is always an optimal frequency at which the operator will get the greatest profit. This condition applies for a bus operation in a monopoly as well as under competition. Moreover, it was found that the optimal frequency of bus operations depends on the level of existing travel demand and the type of vehicle to be used (in a monopoly), and also on the operational situation of the competitor (under competition).

In terms of the type of vehicle to be used, it was found that the type of vehicles that gives the best operational performance is the midibus (35 seats). This applies to a service both in a monopoly and under competition.

As the pattern of travel demand on one particular route is unique, it is apparent that the fare system that produces maximum revenue will be the one that sufficiently matches the pattern of travel demand. It was found that for each particular route there is one fare system that gives a maximum level of revenue.

Under competition, however, the decision on the fare system to be adopted is rather difficult to make, since there will be a trade-off between the market share to be won and revenue to be generated. To win the market share, one can set the fare system or the fare level in such a way as to make one's service more attractive than the competitor's. However, it has to be recognised that winning a market share does not necessarily means running a profitable service. It was found that for each particular self-contained route, there is always one particular fare system and one particular fare level that gives the new entrant a maximum level of profit. This depends on the pattern of travel demand, the fare system applied by the competitor and the level of overall travel demand.

CHAPTER 8

COMBO.2 : A NETWORK-BASED MODEL OF BUS OPERATION AND COMPETITION

8.1. Introduction

Having investigated the features of bus operation and competition on a self-contained single route, it is time to expand the problem to a wider scale, namely a network system.

In a network system, the feature of bus operation will be more complicated than that of a self-contained single route. This is due to the fact that the travellers have a number of alternative routes for their journey. As a result, there will be more interaction and interdependency between one route and another, so the performance of bus operations on a particular route will not only depend on the level of service on the route concerned, but also on the level of service on other routes in the system.

This chapter deals with the development of a model that represents the feature described above.

8.2. Assumptions

Let us consider an urban area with a given network of bus routes, i.e : a network of streets on which certain bus routes have been set up. It is assumed that the system under consideration already has a specific demand for public transport and walking journey. The process of generating trip demand therefore will not be considered.

Moreover, let us assume that the travellers are well informed about bus services and fares, and have a choice between public transport (bus) and walking trips. The journey from one place to another can therefore be made in two ways : by walking and by a combination of walking and bus rides. When the journey is a combined one, it is possible for travellers to transfer from one route to another. In this case some additional walking trips, fare payment and waiting times will occur.

In making the journey it is assumed that travellers have two stages : first, before starting their journey a decision will be made regarding the path to be taken and second, when they are at the bus stop a decision on the specific bus to catch will also be made.

The decision regarding the path will be taken on the basis of minimising the total disutility of their journey, whereas the decision on which bus they ought to take is on the basis of the condition of the route concerned (for example, they will take the first bus to come only if one fleet of bus operates on the route).

8.3. Modelling the system

Consider the public transport system depicted in *Figure 8.1.* which gives a simple picture of its entities. A public transport system usually consists of a bus route network, buses, operators and travellers.

In a public transport system, the operators will allocate the resources they have (buses) by using an existing bus route network to provide services for the travellers. The travellers, on the other hand, will use the service in making their journeys.

The operator's task will be to allocate the resources available (buses) in order to meet the operational objective. For example, he has to decide on which routes to run his fleet, and on how many buses to be allocated to the route. On the other hand travellers will use the available service to transport themselves in as efficient a manner as possible (by minimising their disutility).

headway, but will be slightly more. It can be expected that the average waiting time perceived by passengers will depend on how different the fare price between the two services is. The greater the differences in the fare level between the two services, the longer the average waiting time will be.

Figs 7.18. to *7.21.* show clearly that the average waiting time perceived by the passengers depends upon the difference in fare level between the two services. When the blue bus operator introduces a fare which is higher on average than that of the red bus, the average waiting time of blue bus passengers is very high, whilst the average waiting time of red bus passengers is significantly low. This is primarily because most passengers tend to take any first red bus to come and reject any first blue bus, and therefore the passengers who board the blue bus are not the ones who have just arrived at the stop, but those passengers who have already waited for quite a long time, and feel frustrated. It is important to recognise that because in this case the proportion of blue bus passengers is relatively small, the total average waiting time tends to be close to the average waiting time of red bus passengers. The reverse case is also true, that is, when a blue bus applies a lower fare level than the red bus.

Moreover, it is also clear from the graph that when the two services have the same average fare, the difference between average waiting time of those who board the red bus and those who board the blue bus diminishes. Both have the same waiting time.

7.6.3. Choosing the vehicle type

After deregulation, there is a possibility that the new entrant will try to enter the market with a different type of vehicle, and there is a belief that smaller vehicles will be used. This expectation is partly derived from recent evidence which indicates that deregulation encourages innovation (Gomez-Ibanez, 1987), and comes partly from the fact that smaller vehicles are more attractive in terms of speed and operational performance than big ones. The problem to be examined in the next paragraph is the question of the vehicle size to be used by the new entrant to make a profitable service.

Consider again the two routes described in *Table 7.1*. Suppose that the new operator intends to enter the market with a new service and compete with the existing operator. Assume that the new operator has a financial constraint. He only has £ 500,000 to spend on providing vehicles. The problem is the type of vehicle he should spend his resources on.

Given the data on vehicle price depicted in *Table 7.2*, it can be calculated that with the resources available the new operator has four alternatives to choose from, each of which is a fleet of buses with a capacity of about 500 to 600 seats. The alternatives available were a fleet of : 27 minibuses, 16 midibuses, 14 standard buses, or 7 double-decker buses.

Given the alternatives available, it is clear that the differences between the four alternatives are in the size and characteristics of the fleet. The trend is that the smaller the vehicle chosen, the bigger the fleet size would be, and the more frequent and attractive the service to be offered, but at the same time, the greater the operating costs. For example, if the new operator chooses minibuses, the fleet size of the service would be 27 buses ; big enough to make a frequent and attractive service, but also difficult enough to cover the operating costs. However, if double-decker buses were chosen, the fleet size would be only 7 buses ; too small to compete with the existing operator, but with the advantage that it does not need too many resources to cover its operating costs.

Since the main concern of the new operator is usually profit, then the capability of the service to generate new potential passengers and to compete with the existing operator will be the most important factors to be considered. It is obvious that the more attractive the service on offer the more potential passengers can be generated, and also the more competitive the service will be, which means that its capability of catching a market share will be greater. Therefore, if one can offer an attractive service, it seems likely that one's revenue will be able to cover operating costs. Of the four alternatives available, theoretically, the smaller the vehicle the more attractive the service will be, and the more likely it will be to be profitable.

Since one of the factors that affects the attractiveness of the vehicles is speed, and because the average speed of a vehicle depend upon the traffic conditions, it is reasonable to take into consideration the effect of traffic conditions. In these exercises, three different traffic conditions were considered : low, medium and heavy. It has been assumed that the effect of traffic conditions on the operation of a bus service was on their average operating speed. The more congested the traffic the more difficulties they have in operating at optimum speed. In heavy traffic, for example, every vehicle will have the same average operating speed, and in light traffic they can be operated at their own average running speed. Therefore, the minibuses will be very attractive in terms of speed only in light traffic conditions. In heavy traffic, however, the minibus will not be too attractive in terms of speed since its speed will be the same as a double-decker bus.

Figs. 7.22. and *7.23.* illustrate the operational performances of the two competing operators when they compete under various traffic conditions. When the traffic is so light that every vehicle can travel at its own average speed, it appears that the use of small vehicles gives the best possible performance, in terms of the level of patronage as well as the level of profit. Of the alternatives available, it seems that minibuses gives the best performance of all. This is because the use of 27 minibuses makes the service so attractive to the passengers, that it easily captures a market share.

However, as the level of traffic increases, the superiority of minibuses

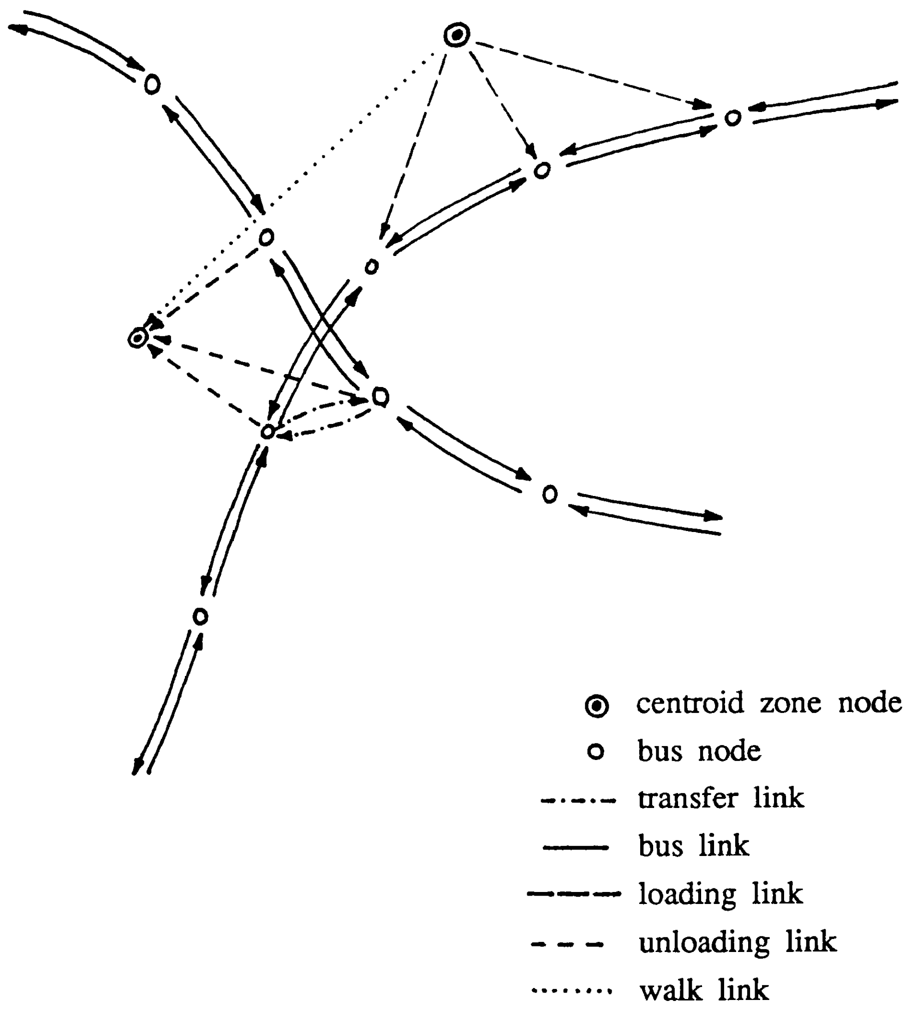


Fig. 8.2. Links in the bus network system

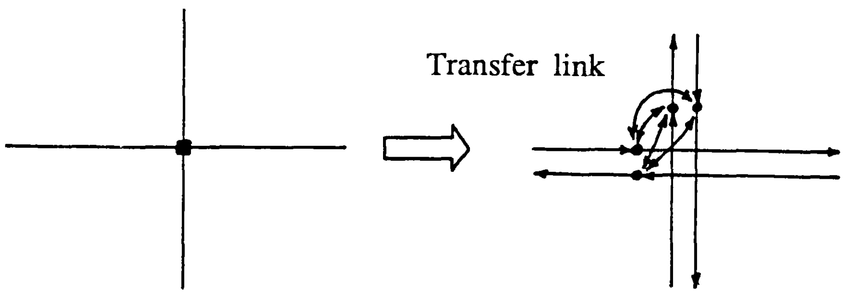


Fig. 8.3. Reconstruction of transfer links

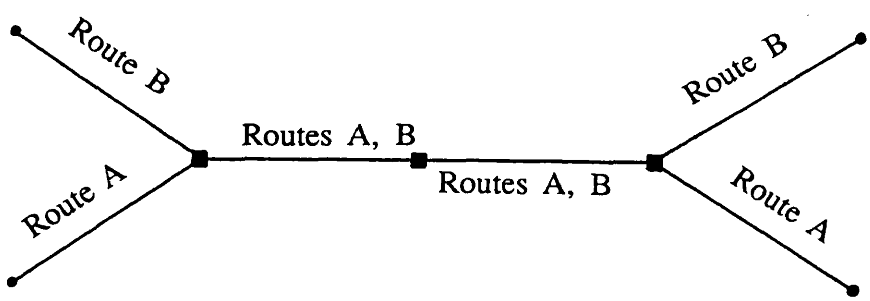


Fig. 8.4. Section of hypothetical bus network

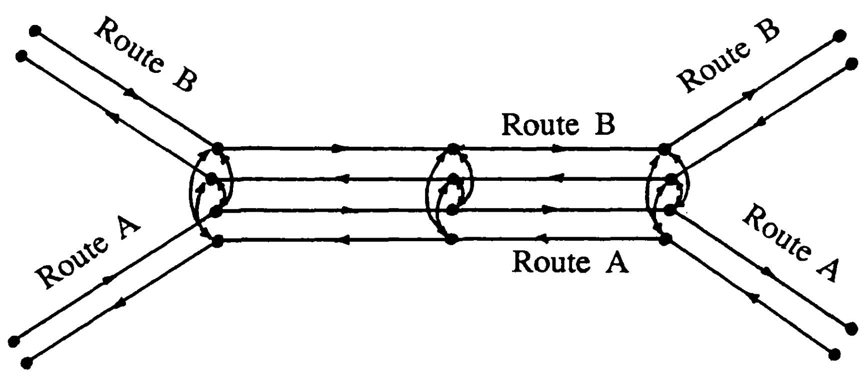


Fig. 8.5. Representation of bus network in the model

becomes less significant. The profit level decreases to the level below that when midibuses are operated. Indeed, in this situation the blue bus service with minibuses is still more attractive as it has a more frequent service than the red one. However, because the total service becomes less frequent, the total number of potential passengers who use the services decreases, which means the number of passengers carried by the blue bus also decreases, so its revenue will not be as high as in light traffic.

The superiority of minibuses diminishes when traffic conditions are very heavy. In this situation any vehicle has the same speed regardless of type. The attractiveness of each bus on the routes will therefore be the same. Each passenger will take whatever comes first. As a result the number of passengers carried by a fleet which uses minibuses drops compared with a situation of light traffic. Consequently, the level of profit decreases.

Since most urban routes are loaded with heavy traffic, it might be argued that the choice of the use of midibuses would be the most appropriate one. However, for a small town in which traffic is not the main problem, the use of minibuses to compete with the existing operator would be strongly advised, particularly if the level of demand was high enough to sustain competition.

7.6.4. Travelcard strategy

It is very interesting to consider what would happen if a new entrant introduces a travelcard system on entering the market. The obvious expectation is that the service to be offered with a travelcard will be very attractive and, therefore, the market will be dominated. The question is whether this policy can be adopted, since one might expect that this strategy will make it very difficult for any operator to run profitably.

In the following, a competitive situation which involves the use of a travelcard is examined. The situation under consideration was the competition when generated a new entrant comes into the market with a travelcard. It was assumed that apart from travelcard, all operational factors of the two competing services were the same. *Figs.7.24. and 7.25.* show the outcomes of competition when the new entrant (Blue bus operator) come into the market at various levels of weekly travelcard price.

Given that all other factors were the same, it was obvious that the service which introduced the travelcard would be more attractive, particularly in terms of the fare, as it would generally be cheaper. This, in turn, would encourage customer loyalty, which in the longer run would ensure the stability of its market share. This situation is predictable since the introduction of a travelcard makes the service more attractive than that of its competitor.

However, it should be recognised that the introduction of a travelcard does not mean that all potential passengers will use it. Only those travellers who feel it to be beneficially will use it, namely those travellers who are travelling long distances, or those who have to pay more if using a normal fare. As a result, there are still a number of travellers who are not willing to have a travelcard. This group of passengers are those who are not captives to a particular service and, they are the ones who may take any bus, either red or blue.

In terms of patronage carried by each operator, it is clear that whenever the blue bus operator introduces travelcards, he gets most of the market share. The cheaper the price of a weekly travelcard the greater its share will be. As for the red bus operator, this situation will make him suffer most. His market share will deteriorate whenever the blue bus introduces a travelcard.

In terms of profit, however, it is apparent that although through the introduction of a travelcard the service will be able to capture the market, it does not mean that the service will be profitable. This is model : flat fare, stage fare and distance-based fare. Flat fares are characterised by a single fixed fare for any journey made on a particular route concerned, regardless of the journey length. Distance-based fares, on the other hand, offer appropriately differentiated fares for journeys of different lengths. This consists of an initial fare and additional fares per unit length of journey. Stage fares have the same concept as the distance-based fare; the difference is in the way the fare is differentiated for journeys of different length. In the model the differentiation of the fares is coarse : journeys less than 2 Km (short journey) ; journeys between 2.0 and 5.0 Km (medium journey) and journeys more than 5.0 Km (long journey).

In the model the choice of fare systems and the level of fares will affect the value of the fare element of the generalised costs in the *loading link, bus link* and *transfer link.*

8.5. Modelling of demand

The total potential demand for public transport (bus) and walking trips is represented in the model in the form of the total of an origin-destination, that is the total potential demand for travel from a certain origin to a certain destination. The modal split between bus rides and walking trips is treated implicitly through the process of assignment of travellers.

Since the travellers have a choice between bus rides and walking, the actual demand for public transport will depend on the level of service. The higher the level of service the higher the demand for public transport. This also means the higher the level of service the higher the modal split for public transport.

8.5.1. Overall demand

The overall demand for public transport and walking trips is assumed to change as total supply changes. The change is represented using an elasticity model. It is assumed that the factor which plays the central role in this process is the accessibility of the trip between pairs of zones concerned. This factor is represented by a change in the generalised cost. An estimation of the change of trip demand is calculated for each pair of zones.

If T^0_{ij} is an overall trip demand for particular pairs of zone of i and j at the base time period, and Δg_{ij} represents the change in generalised cost of trip between i and j then the trip demand will change to :

$$T^t_{ij} = T^0_{ij}\left\{\frac{\Delta g_{ij}}{g_{ij}}\right\}^{-\xi} \qquad (8.1)$$

where ξ is the generalised cost elasticity of demand.

8.5.2. Travel demand for routes

The demand for a particular route is assumed to depend on the level of service of the route concerned and the level of service of the other routes in the system. Therefore, the level of demand will change as the level of service of the route concerned changes or following changes in the other routes in the system. The demand for a route is allocated in the process of assignment which will be described in the next section.

8.6. Modelling the interaction between supply and demand

Let us consider the public transport system in detail and examine the way it behaves. Each element of the system is interdependent. However, there are two main elements in the system which play a key role : the operator(s) who provide the service (supply) and the travellers (demand) who use it.

Figure 8.6 shows how the elements of the system interact with each other. The process began when the operator(s) provided the service (supply) at a certain level. These included : route to be operated, type of vehicle on each route, the frequencies and the fare systems and fare levels. These are usually set up on the basis of previous operational performance or on the basis of the condition of overall demand.

The travellers, on the other hand, respond to this by taking into consideration all of the elements supply by the operator in making their journey. In doing so the travellers will respond in two stages : *(1)* deciding which path they want to take, and *(2)* deciding which vehicle they want to catch on each particular route on the path.

The main basis for deciding which path they want to take is the criterion of minimising the disutility of the journey in general terms. On the basis of this criterion the travellers will assign themselves in the network system in such a way as to produce an allocated demand for each route. The result of this process is that the demand for a particular route will depend not only on the level of service of the route concerned but also on the level of service of the other routes.

For each particular route on the path, the travellers will have to make a decision about which vehicle they have to catch. If only one type of vehicle is operated on the route, it can be expected that the travellers will certainly take the first vehicle to come, provided that there is still spare capacity. However, if there are two types of vehicle operated on the route, the travellers will take the one that is more attractive in term of the disutility they will perceive. Again, this is measured in terms of generalised cost.

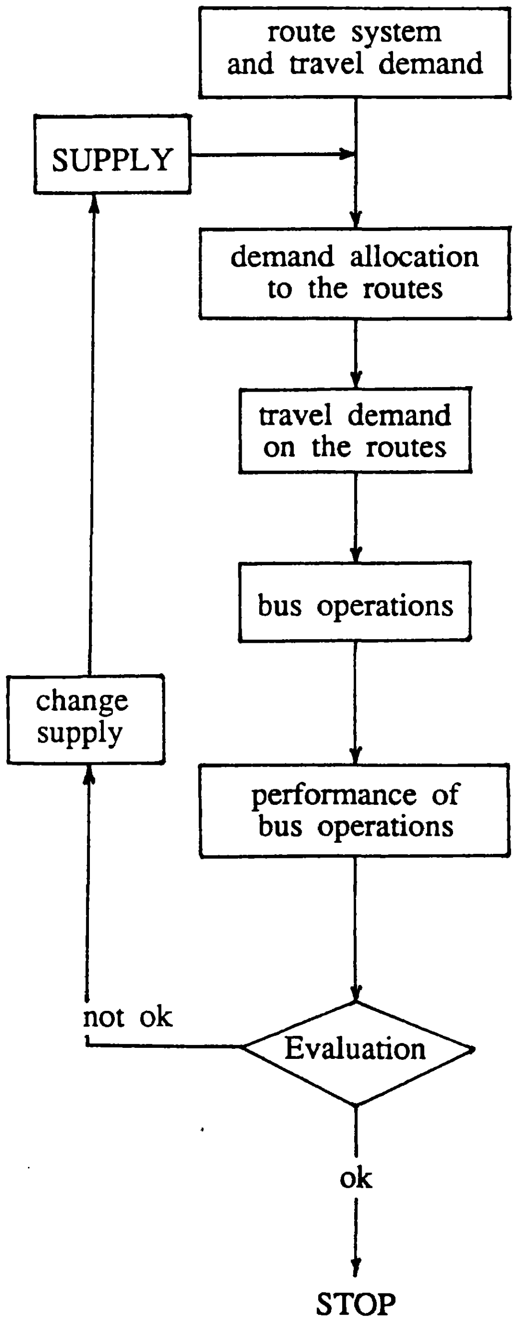


Fig. 8.6. The interactions between supply and demand

Looking at this process it can be concluded that the operational performance of a particular route will depend on two main features : first, the allocated demand produce from traveller assignment and second, the condition on the route concerned, whether or not there is competition-on-the-road.

If on a particular route there is only one type of vehicle, it is obvious that the operational performance of the route will depend on the level of allocated demand. It is most likely that the higher the allocated trip demand to the route the better the performance of bus operation of the route concerned, particularly if it is measured in terms of its revenues. However, if there is competition-on-the-road on the route concerned, the operational performance will depend not only the level of allocated demand but also on the attractiveness of the service compared to that of its competitor.

From a given operational performance produced from a particular level of service provided to the travellers, the operator will analyse and examine whether the operational objective has been met. The analyses can be on each route separately or on an overall basis. If the operational objective is met the operator will maintain the level of service as before. However, if the performance is considered not to have met the objective the operator will change the the level of supply. If this is the case then it will change the perception of the travellers about the system which,in turn, will reiterate the whole process.

Since the behaviour of the travellers is considered as an exogenous variable, it is appropriate to stress the attention of the model to the behaviour of the travellers in the system, particularly in the way they respond to the service offered by the operators.

In the model the system of bus network operation is considered to consist of two main stages : the allocation of travellers to the routes and the allocation of travellers to the vehicles. Because the detailed process of the latter is greater than the former, it is reasonable to model the system in two different approaches : approach level I for the former and approach level II for the latter.

8.7. Approach level I

In this level of approach the system considered was when the travellers decide the path they intend to take in order to make their journey. The basic assumption is that travellers decide which path they wish to take on the basis of general information about the system. Therefore, the possible situation where the travellers change path because of an immediate change such as vehicle cancellation is not taken into account.

It has been mentioned in the previous section that the response of travellers to the service offered by the operators is in the form of their decision on which path to take. As a result, their journey path will depend on the level of service on all the routes available in the system. This means that the number of travellers using a particular route does not only depend on the attractiveness of its corridor area and its level of service, but also on the condition of the other routes in the system.

The main factor affecting the allocation of demand to the routes is the behaviour of passengers in deciding which path to take for their journey. It has become a general belief that the choice of the paths taken occurs according to the disutility criteria. Each passenger selects the path from his/her origin to his/her destination which has the lowest expected disutility or generalised cost.

8.7.1. Generalised cost

In the model the generalised costs are formulated in such a way as to represent all the elements of the journey, including the consideration of some possible fare systems. In doing so the generalised costs are calculated on a link basis.

The value of generalised cost for a particular link is determined on the basis of the disutility of using it. In a walk link, for example, the value of the link cost would be the disutility of walking on it, which is the travel time by walking, whereas in a loading link the value of link cost would consist of travel time by walking, waiting time to load and the money paid when boarding the bus. In general, the generalised cost of a particular link is given by :

$$C_{ij} = \sum_{n=1}^{N} (\text{generalised cost of element } n^{th})(\text{related weight}) \qquad (8.2)$$

where C_{ij} is the generalised cost of using a link between node i and j and N is the number of elements of generalised cost to be considered on the link concerned.

Of particular concern was the representation of various fare systems in the formulation of generalised cost. The fare paid by the travellers is broken down into three different elements each of which represents the disutility perceived by travellers on each particular type of link. These include *boarding fare, riding fare* and *transfer fare. Boarding fare* is introduced when the travellers board the bus, whereas *riding fare* is applied when the travellers ride on the bus. The *transfer fare* is introduced when a traveller transfers from one route to another. The *transfer fare* is only applied if there is no integrated fare system existing between routes. The potential advantage of this approach is that one can incorporate various fare systems into the generalised cost formulation.

To clarify how the approach can be applied to various fare systems, consider a flat fare system. In this system the fare is paid only once when the travellers board the bus. An additional fare is not needed however long the journey is, as long as it still on the same route. In the model the fare paid by travellers is therefore represented by the *boarding fare* and applied to the *loading link* for the particular route concerned. The element of *riding fare* on the bus link for the route concerned therefore becomes zero.

In a distance-based fare system, however, travellers have to pay a fixed fare at the beginning of the journey and an extra fare for each additional kilometre travelled. This fare system is considered in the model as follows : the initial fare is represented by a *boarding fare* on the *loading link* for the particular route concerned whereas the additional fare is represented by a *riding fare* on the *bus link* concerned. A similar consideration also applied to the stage fare system (a description of how each type of fare system is considered can be seen in *Table 8.1*).

For each type of link considered in the model the generalised cost of using the link is given as follow :

a. *Walk link* :

$$C_{ij} = (walking\ time)(Walking\ weight) \qquad (8.3)$$

Table 8.1. REPRESENTATION OF FARE

FARE SYSTEM	FARE PRICE	*Boarding fare*	*Riding fare*	*Transfer fare* *)
Flat	p_1	p_1	0	p_1
Stage	p_1, p_2, p_3	p_1	$(p_3 - p_1)/L$	p_1
Distance-based	$p_1 + p_2$ p/Km	p_1	p_2	p_1

*) transfer fare is zero if an integrated fare system is introduced in the network

b. *Loading link* :

C_{ij} = *(walking time)(walking weight) + (waiting time) (waiting weight) + (loading fare)/(value of time)* *(8.4)*

c. *Unloading link* :

C_{ij} = *(walking time)(walking weight)* *(8.5)*

d. *Bus link* :

C_{ij} = *(riding time)(riding weight) + (riding fare)/ (value of time)* *(8.6)*

e. *Transfer link* :

C_{ij} = *(walking time)(walking weight) + (transfer fare) /(value of time) + (waiting time)(waiting weight) + transfer penalty* *(8.7)*

In the equations above the walking time and riding time are calculated on the basis of the length of the link concerned and the average speed of the vehicle passing through it. The walking time and riding time therefore can be formulated as follows :

Walking time = (length of the link)(walking speed) *(8.8)*

and,

riding time = (length of the link)(bus speed) *(8.9)*

where the value bus for speed is considered to be an average operating speed of buses between stops. These vary from one type of vehicle to another.

The waiting time element in the formulation of generalised cost described above is calculated on the assumption that the travellers have good information about the frequency of the service and they arrive at the stop at random, so they will expect the value of waiting time to be half of the headway.

It is worth mentioning that care must be taken in the formulation of generalised costs when competition is introduced on a particular route. In a competitive situation one can assume that the perception of travellers of the level of service on the route would be a combination of both services available. It is expected that the perception of travellers of the fare and speed would be the average of the two competing services. However, this is not the case for the perception of travellers about the frequency, as the travellers will considers the frequency of the route as the total frequency of both the services on the route, not separately.

8.7.2. Finding paths through the network

As mentioned in *Section 8.2.*, a key assumption made in this model is that in travelling from one zone to another, the travellers will choose the path which minimises the disutility of using it. In this case the disutility of the journey is measured in terms of the generalised cost.

Because in making a journey from one place to another the travellers may travel along more than one path, it is reasonable to incorporate a method of probabilistic multi-path trip assignment in this model. In this method N alternative bus paths are allowed to be used by travellers stochastically.

A path here means a sequence of links. Most often it consists of : *loading link, bus links, transfer links* and *unloading link.* Because each particular route is represented as a set of unique links, it is possible to know which combination of routes the travellers will take if a path has been found.

In finding the path, the method applied in the model produces two items of information for each pair of zones; a sequence of direct journey that represents the least cost path from start zone to end zone; and the generalised cost.

For each pair of zones, the generalised costs of travelling via each possible pair of start and end nodes are calculated using the least cost path between them. The first N are selected as paths between which the trip will be assigned. These paths are generated by considering the total generalised cost (zone to zone) of using different links, and selecting those for which generalised costs are the least.

8.7.3. Path choice

The travellers from one zone to another are assigned to a number of different paths. The theoretical basis for this method relies on a dissagregate approach to model formulation. It starts with the fundamental hypothesis that an individual, if faced with a travel decision, will choose that alternative which does not have a greater generalised cost than any of the others. The less the generalised cost of the path the more the number of trips along that path will be. For the purpose of representing this situation the logit model is used, that is, to estimate the proportion of travellers who use a certain path. If for a particular pair of zones there are N possible paths to be considered, then the proportion of the trips using path q^{th}, P^q_{ij} , is given by :

$$P^q_{ij} = \frac{e^{-\lambda . C^q_{ij}}}{\sum_{q=1}^{N} e^{-\lambda . C^q_{ij}}} \qquad (8.8)$$

where C^q_{ij} is the generalised cost of using path q^{th} and λ is a calibrated parameter.

8.7.4. Allocating travellers to routes

As multiplicity of choice is considered in the model, trips between any given pair of zones are assigned to more than one path between centroid.

If T_{ij} is the number of travellers from zone i to zone j then the number of travellers using path q^{th}, X^q_{ij} , is given by :

$$X^q_{ij} = P^q_{ij}.T_{ij} \qquad (8.9)$$

or with the substitution of *equation (8.8)* to *(8.9)*,

$$X^q_{ij} = \left\{ \frac{e^{-\lambda.C^q_{ij}}}{\sum_{q=1}^{N} e^{-\lambda.C^q_{ij}}} \right\}.T_{ij} \qquad (8.10)$$

where P^q_{ij} is the proportion of travellers who use path q^{th} between zone i and zone j.

If $S(i,j,q)$ denotes a path of alternative q^{th} of journey between zone i and zone j and $y(a,b,p)$ denote part of the path between stop a and stop b on route bus p, then the number of travellers who are going to ride on the bus on route p between stop a and stop b is given by :

$$t^p_{ab} = \sum_{i}\sum_{j}\sum_{q} X^q_{ij} \qquad (8.13)$$
$$y(a,b,p) \in S(i,j,q)$$

In general, the steps of calculation for allocating the travellers to the routes are as follows :

1.- Find N shortest path for each pair zones i and j
$S(i,j,q)$ $\quad q = 1,..,N$

2.- For each path q between zone i and zone j calculate the proportion of trips using path q^{th}, P^q_{ij} , and the number of travellers who use it, X^q_{ij} .

3.- Allocate all of the travellers who use path q^{th}, X^q_{ij} , to each route to give t^p_{ab} , a number of travellers who are going to make a journey between stop a and b on route p.

8.8. Approach level II

Having allocated the travellers to the routes, the next stage would be to allocate these travellers to vehicles on the route concerned to give some detailed information on the performance of the bus operation. To model this process the approach level II is adopted.

In approach level II, the model considers the process of allocation of travellers to the vehicles on the route in great detail. It considers all the entities of the route and simulates them. The basic input is the allocated demand from approach level I in the form of a stop-to-stop trip matrix and the supply side condition of the route concerned (type of vehicle, frequency, fare system).

The basic approach of the process is the same as described in *Chapter 5*. In general, the method simulates the movement of vehicles and travellers in detail. Using the stop-to-stop trip matrix given from approach level I, the model generates the arrival of travellers at the stops. The buses are assumed to move along the route continuously. They can overtake or be overtaken by the others. The bus will stop at the stop if there are some passengers in the bus wish to alight or there is a queue of travellers waiting at the stop.

The boarding process is treated sequentially based on the position of the travellers in the queue. If there is no competition, a traveller will board the first bus to come, whereas in the case of competition they will make the decision whether or not to board the bus on the basis of the relative perceived generalised cost of the bus concerned and the next one of the competing company. The choice is represented in the form of logit function *(for detail see equation 5.9).*

8.9. Structure of the model

The model has been written in PASCAL language in a microcomputer and has been structured on the basis of how travellers would react to a decision given by the operators concerning the bus service. The decisions of the operators themselves are not endogenously represented in the model, but treated as exogenous variables. The potential advantage of this approach is that the model can be used to investigate the outcome of various possible decisions of the operator concerning the supply side of public transport.

The basic framework of the model can be seen in *Figure 8.7.* The model consists of two main programs : first, a program for allocating the travellers to the routes and, second, a program for allocating the travellers to the buses.

For the first program, two types of input data are needed : the data of the system being studied and some exogenous variables which represent the supply side of public transport. The data of the system being studied include the description of the bus route network and walking links and the data of demand for public transport and walking trips. For a given set of exogenous variables the first program allocates the travellers to the routes and produces an estimated stop-to-stop trip matrix for each route in the network.

Using the allocated stop-to-stop trip matrix produced by the first program, the second program simulates the operation of buses on the

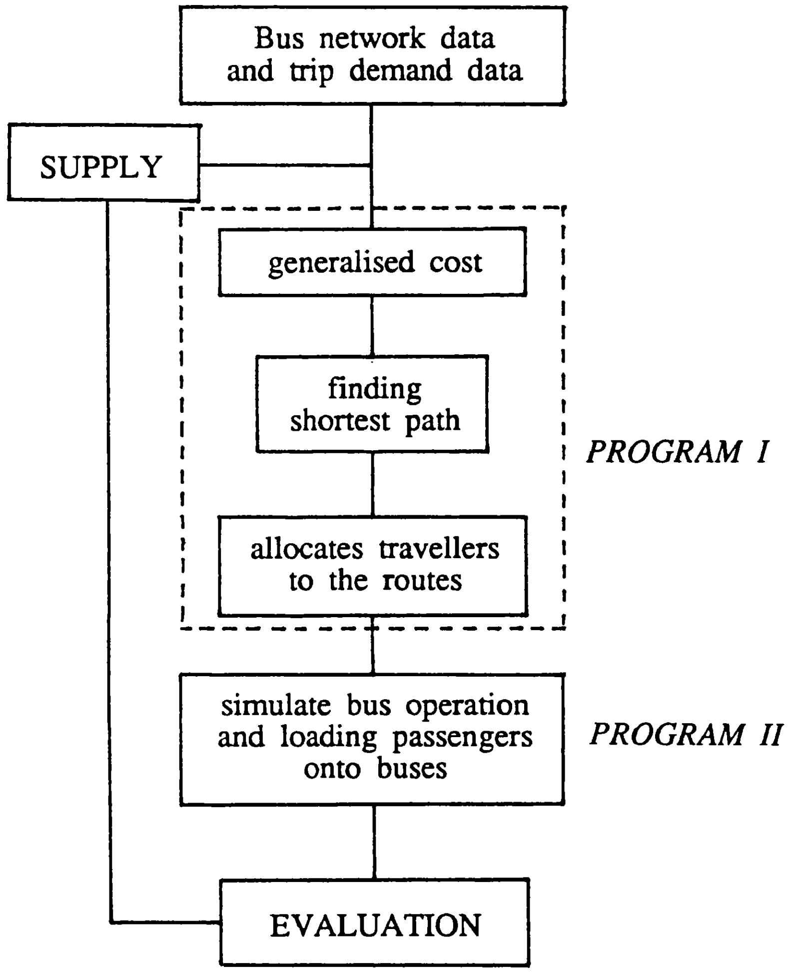


Fig. 8.7. The framework of *COMBO.2* model

routes. It simulates the detailed allocation of the travellers to buses. It represents the process of boarding and alighting and the movement of buses between stops. The results of this process are bus operation performances for each particular route in the network. It indicates how good or bad the performance of the bus operation is, both from the operators' and the travellers' point of view.

8.10. Model features

The model has been developed to make it easy, interactive and friendly to use. In doing so graphic features have been incorporated in the model. The model can be run in any IBM PC/XT/AT or IBM PC/XT/AT compatible microcomputers with MS-DOS 3.2 disk operating system. The program can be operated on a microcomputer with a minimum of 360 K RAM and two 360 KB double-density floppy disk, or system with a hard disk. However, it will be more convenient if the program is installed and used on hard disks for fast execution.

Two different sets of input are needed to run the model : endogenous and exogenous input. Endogenous inputs are those inputs that are needed to represent the situation of the study area (the description of the bus network and public transport demand), whereas exogenous inputs are those inputs which are related to the supply side of bus operation. The following is a list of the exogenous input variables of the model :

1. The route to be operated.
2. The vehicle type (size, capacity and speed).
3. The frequency of the fleet (and the number of vehicle to be operated).
4. System of operation (One Person Operated or Two Person Operated).
5. Fare system and fare price (Stage fare, Flat fare, or Distance-based fare).

The output produced by the model is those aspects which are related to the performance of bus operation as perceived by the operator as well as by the travellers. These include :

1. The number of passengers carried by the bus fleet during a peak-hour period on each route.
2. The operating cost of bus the fleet for a period of three months duration for each particular route and for the whole network.
3. The revenues of three months' operation ; for each route and for the whole network.
4. The total generalised cost perceived by the travellers on the system.
5. The occupancy rate of bus fleet on each route.
6. The average waiting time for each route, and the average waiting time for each bus stop in the network.
7. Bus loadings profile for each route in the network.

Some features of input/output of the model can be seen in **Appendix 2.**

8.11. The *BUSCOM.2* as a gaming simulation model

Another feature of the model is that it can be used as a gaming simulation. The way it can be used is the same as in the *COMBO.1* model (see *Sections 5.6* and *5.7*).

CHAPTER 9
COMBO.2 : DATA, MODEL VALIDATION AND SENSITIVITY TEST

9.1. Introduction

This chapter deals with the problems of data preparation, sensitivity test and validation process of the *COMBO.2* model. The purpose of the first part is to present the description of data needed for the model and to discuss the problem that might arise in their preparation. In the second and third parts of this chapter, matters involved in the sensitivity test and the validation process of the model will be discussed.

9.2. Data requirement

Basically, the input data required for the model consist of three different types : bus route network, travel demand, and characteristics of the vehicles used in the model.

9.2.1. Bus route network data

It is obvious that to run the model, the bus network data are needed. The first stage is to define the study area within which the system will be represented in the model. With a detailed map, one can define the boundary of the study area, draw the bus routes define the zonal system.

In defining the zonal system, ideally one would like to define the zones so that they are as homogeneous as possible with respect to the variable of interest. In practice one is often dependent upon previously collected data (e.g., census data, previous transport studies) and hence will use the zonal system associated with these data.

The bus route network is drawn up on the basis of the existing bus route network in the map. Clearly, one would find that most bus routes occupy the major road systems and some of them occupy the same link of a particular road. Each particular bus route is drawn individually, regardless of its location in the network. For each route the location of the stops is identified and the distance between two adjacent stops is measured, so that the *bus link* between two adjacent stops can be identified in terms of its location and length. *Transfer links* are created when two stops of two different routes are close to each other. *Loading links* and *unloading links* are made up for each possible link between the centroidal zone and the bus stop. A *walking link* is created between two adjacent centroidal zones.

The final definition of the study area is in the form of a set of data that consists of nodes (centroid zones and bus stops) and links (bus links, transfer links, loading links, unloading links and walking links).

9.2.2. Travel demand data

The travel demand data that are needed by the model are in the form of the total of an origin-destination trip matrix, i.e., the total demand for travel from certain origins as well as the total demand to certain destinations.

There are various sources and methods available which can be used as the basis for estimating these data. The simplest one is by using data from previous transport studies. One only needs to make some adjustments so that they represent the situation of the present study. However, it is worth noting that extra care should be taken regarding the definition of the zone system used in previous studies. Their compatibility with the present studies should be checked.

If one tries to estimate the level of travel demand using a model, one finds that there are various type of models available. However, the well established one is the urban transportation model system. This model is a well-defined package of models which have evolved over the last twenty five years. It consists of a series of models, each of which is sequentially executed, with the output of one model becoming the input for the next. Each model predicts one aspect of transportation demand (e.g., total trip leaving a zone; the proportion of these trips using each available mode; the proportion of these trips going to each possible destination; the route taken by this trip through the transport network).

Because the travel demand needed for our purpose is in the form of a trip-matrix, it is reasonable to only consider some part of the urban transportation system models with the final output in the form of a trip matrix. The parts of the urban transportation models which produce the final output of a trip matrix are trip generation, modal split and trip distribution.

a. Trip generation model

Trip generation models take their input prediction of zonal population and employment levels, densities and characteristics. These predictions typically come from various land-use and regional economics models (see, for example, Wilson,1974). The output of these models is zonal trip production and attraction.

A trip generation model is used to predict the number of trips produced by (i,e.,originating from) or, alternatively, attracted to (i.e.,destined for) a given zone. In either case, only one end of the trip is predicted. For example, a trip production model predicts the total number of trips originating from a zone, regardless of where they are destined. All such models thus assume that the trip generation rate is only a function of the spatial and socio-economic characteristics of the zone at 'the other end' of the trip, not of the level of service provided by the transportation system connecting the two zones.

A trip generation model predicts the rate of trip-making per time and space unit. A common temporal unit includes per-peak-hour and per-day. Spatially, the unit measurement may be the zones within the service area, or individual households within each zone. The zonal level in detail is usually the most useful information for planning purposes, although clearly a household trip rate model can be 'aggregated up' to make zonal predictions, providing that the number of households per zone is known.

b. Modal split model

Modal split models predict the mode used for various trips which have been predicted. Because the demands under consideration are assumed to be captive in nature, the type of mode split used to predict the demand is trip-end mode split models. The prediction of these models depend upon essentially the same set of socio-economic variables that are used by trip generation models. In other words, trip-end mode split models assume that the number of travellers who are going to use public transport and walking trips is essentially determined by the socio-economic characteristics of the trip-maker, rather than by the service characteristics of the modes available for their use.

c. Trip distribution

Trip distribution models take the zonal trip productions and attraction predicted by the trip generation and mode split models and link them together to predict the total flow between each production zone and each attraction zone. Many techniques exist for accomplishing this, but the dominant technique is the gravity model.

9.2.3. Data on vehicles

Two types of information relating to the vehicles are needed : data on its physical characteristics and data on its operation. The physical characteristics are needed in order to simulate the vehicle movement in the model in an appropriate manner. These include vehicle capacity and the average running speed between stops. The data of bus service operation, however, are treated as endogenous inputs in order to get the financial performance at the end of simulation. The data on bus service operation includes vehicle price, operating cost per kilometre run and operating cost per time unit run. Operating cost per time unit run should include the option for both one person operated and two person operated.

9.3. Sensitivity test

Although the model has been developed to represent reality, it is unavoidable that the result produced by the model will be a function of the assumptions incorporated within it. The assumptions are commonly based on the understanding of the behaviour of the system being modelled.

In this model the assumptions are based on the behaviour of travellers toward public transport and the characteristics of the public transport itself. No consideration is taken regarding the other modes in the system (except walking trips). It is implied that, to some extent, the result will be marginal, with no adaptation of behaviour outside the range represented within the model. For example, the model cannot represent the effect of the level of bus service operation to the mode split between public transport and private car, or the effect of bus operation to the traffic flow.

However, despite such limitations, it is necessary to ensure that the behaviours of the system represented in the model logically agree with the real world, that is to say, that a change in one of the variables in the model will result in a change in the output of the model as happens in the real world. For example, a change in fare level on a particular route will result in a change in the number of travellers who use the route concerned. The change is obvious. However, the problem is how sensitive the change is that can be predicted by the model, and whether such change logically agrees with the situation in the real world. The process used to achieve this is called the sensitivity test.

Because the behaviour of travellers was used as the basic approach in the development of the model, the sensitivity test of the model was therefore carried out to check whether the perception of travellers toward the change in fare level, or the change in level of frequency, in the model logically agree with the real world or not.

In order to do this an artificial network (see, *Figure 9.1*) and hypothetical travel demand data were used to investigate the sensitivity of the model output towards some input variables. It was assumed that in the base condition, each particular route in the network was operated by a fleet of double-decker buses with a headway of 4.5 minutes (frequency of 13.3 bus/hour) and with a flat fare of 50 pence per trip.

disutility of the journey is measured in terms of the generalised cost.

Because in making a journey from one place to another the travellers may travel along more than one path, it is reasonable to incorporate a method of probabilistic multi-path trip assignment in this model. In this method N alternative bus paths are allowed to be used by travellers stochastically.

A path here means a sequence of links. Most often it consists of : *loading link, bus links, transfer links* and *unloading link.* Because each particular route is represented as a set of unique links, it is possible to know which combination of routes the travellers will take if a path has been found.

In finding the path, the method applied in the model produces two items of information for each pair of zones; a sequence of direct journey that represents the least cost path from start zone to end zone; and the generalised cost.

For each pair of zones, the generalised costs of travelling via each possible pair of start and end nodes are calculated using the least cost path between them. The first N are selected as paths between which the trip will be assigned. These paths are generated by considering the total generalised cost (zone to zone) of using different links, and selecting those for which generalised costs are the least.

In finding the N path between each pairs of zone, the following step are carried out :

1. Using generalised cost value calculated from the input (i.e, frequency, fare, speed) find the shortest path between each pairs of zones.
2. Spread the error on generalised cost stochastically over the links in the network, so that each link has a new value of generalised

cost, which may or may not the same with the previous one.

3. Using the new value of generalised cost found in the previous step, find the new shortest path between each pair of zones.
4. Repeat steps 2 and 3 to find another set of shortest path.

8.7.3. Path choice

The travellers from one zone to another are assigned to a number of different paths. The theoretical basis for this method relies on a dissagregate approach to model formulation. It starts with the fundamental hypothesis that an individual, if faced with a travel decision, will choose that alternative which does not have a greater generalised cost than any of the others. The less the generalised cost of the path the more the number of trips along that path will be. For the purpose of representing this situation the logit model is used, that is, to estimate the proportion of travellers who use a certain path. If for a particular pair of zones there are N possible paths to be considered, then the proportion of the trips using path q^{th}, P^q_{ij} , is given by :

$$P^q_{ij} = \frac{e^{-\lambda . C^q_{ij}}}{\sum_{q=1}^{N} e^{-\lambda . C^q_{ij}}} \qquad (8.8)$$

where C^q_{ij} is the generalised cost of using path q^{th} and λ is a calibrated parameter.

8.7.4. Allocating travellers to routes

As multiplicity of choice is considered in the model, trips between any given pair of zones are assigned to more than one path between centroid.

From *Tables 9.1* and *9.2* it can be observed that the model is sensitive to a change in fare level. It can be observed that changes in the level of fares on one particular route have resulted in changes in the level of demand on the route concerned. It can also be observed that the magnitude of the change varied from one route to another. It was found that the magnitude of the change was dependent upon the location of the route in the network. Route 7, for example, which is closely located to the other routes in the network had more change in the level of demand than the other two routes when the level of fares was changed in the same proportion. From the Table, it can be observed that the fare elasticity value in route 7 is greater than the others. This condition also applies to the change in the level of service frequency.

Overall, it was found that the model represents the behaviour of the system sufficiently well, as it can be observed that the value of fare elasticity and frequency elasticity of the demand resulting from the model is close to what empirical evidence suggests, namely -0.3 for fare elasticity and -0.5 for frequency (or, headway) elasticity of the demand (see, for example, Webster, 1980).

9.4. Validation

One of the key stages in developing a computer model is to ensure that it accurately represents the situation to which it is going to be applied, so that the prediction it makes will be a reliable estimate of what will actually happen in any given set of circumstances. The process of comparison between the prediction produced by the model and the real life situation is called validation.

Basically, the process of validation can be achieved by comparing the variables predicted in the model to the ones in the real life situation that have been represented in the model. However, before one tries to design a validation process, there are some issues to mention.

The first and the most important is the availability and the validity of basic input data that are needed for the model. It is apparent that the availability of basic data will depend on the nature and the complexity of the system being modelled and also on the level of detail of the model. When the nature of the system being considered in the model is simple and the level of complexity is not too high, it is most likely that the readability of the data will not be a great problem. A simple survey can be used to collect the data. However, this is not likely to be the case when the scale and the nature of the system are complicated. It seems that a comprehensive survey needs to be carried out and a lot of resources need to be provided.

Moreover, it is important to know the nature of the data needed. Questions like the following may be asked : Is it primary data or secondary data ? If the data needed by the model are primary data, or the data that were taken from a survey, then care should be taken with the techniques and methods that were applied to get and compile such data. It is most likely that, as the technique to be applied for collecting the data gets better the validity of the data will also improve.

However, if the nature of the data needed by the model is secondary data (i.e., data that is predicted by a model), then the question of the validity of such data becomes obvious. In this circumstance one has to consider very carefully ; from where are the data taken, and what is the sort of model that produced such data ? In most cases, this type of data comes from a prediction model. For example, the data needed for a trip distribution model are the output of a trip generation model. So, in this situation, care should be taken not only with the techniques of collecting the data, but also with the quality of the prediction model used.

Further consideration in the validation process involves the the problem of deciding the aspects of the system that will be needed for the purpose of validation. Ideally, one should consider as many aspects as possible, particularly those that are thought to be important, and those that are closely related to the sort of factors which are to be predicted by the model. However, before deciding on these aspects one should consider the availability of such data. Overall, the validation process of a model is only possible if the basic input data and the data of the aspects that will be checked are available and their accuracy is reliable.

Considering the above it can be concluded that to validate the *COMBO.2* model, basically two types of data are required : the first, data related to basic input data for the model and, second, data related to the aspects of the system that are to be compared.

The data related to basic input for the model were mentioned in *Section 9.2*. Of all the data mentioned in *Section 9.2*, it is clear that one of the basic data needed has to be derived from other sources, i.e, it has to be derived from the trip generation model, mode split model and trip distribution model. This means that one has to go through three steps of execution to get the data needed, and in order to do this, one need to have the data required for the trip generation model.

There are many aspects of the system that are thought to be important and relevant for the purpose of validation. Most of them are related to the performance of the bus operation. The following are some aspects of the system which are relevant to the validation process :

1. Bus loading profile for each particular route in the system.
2. Patronage for each particular route in the system during peak-hour period.
3. Operating costs for each particular route in the system

4. Revenue for each particular route in the system.

Of the above aspects, only the first two can be collected, i.e, through major surveys in the study area being considered. The other two aspects are, however, rather difficult to get since this information are usually strictly confidential to the operators, especially in a deregulatory environment.

Due to the fact that one of the objectives of validation process is to check whether the representation of the entities of the system in the model is sufficient to replicate a real life situation, it is important to consider the approach taken in developing the model. If the approach taken in the development of the model is one that can be classified as a new approach, then a validation process is required to check whether or not it sufficiently agrees with that of a real life situation. However, if the approach taken in the modelling process is one that is well known, i.e, an approach that has been widely used and tested, the validation process is not required to check it, except for the algorithm used.

As mentioned in *Section 8.2.*, two levels of approach were taken in the development of the *COMBO.2* model : first was on the allocation of the travellers to the route and, second, on the allocation of the travellers on the routes to vehicles. This means that, ideally, a complete validation process is required to ensure that the model allocates the travellers in the system to the routes in a proper manner (validation of approach level I), and is sufficiently accurate in allocating the travellers on the routes to the vehicles (validation of approach level II).

It was stated in *Section 8.6* that the technique used in approach level I is basically a probabilistic multi-path assignment technique, with some improvement in the definition of the generalised cost concept and modification to the description of the network system. This technique is well known in transport planning modelling, for public transport as well as for road traffic, and has been widely used in many transport models. Thus, if approach level I is to be validated, the techniques used need no checking, except for the algorithm.

The validation of approach level II, on the other hand, is needed in order to check whether or not the technique used appropriately replicates real life. This is so because the approach level I is a new approach, which has never been applied. However, since this approach is basically the same as the one that has been used in the *COMBO.1*, which has been shown in *Chapter 6* to perform reasonably well. It is, therefore, arguable that it is not a great necessity to validate this approach any more.

However, if one attempted a complete validation for both approaches, one would need data for patronage of each particular route in the system to validate approach level I, and data of the bus loadings profile, the revenue and operating costs for each particular route in the system to validate approach level II. If this was the case, one would have to undertake a comprehensive survey to collect the basic input data, so a lot of resources have to be provided.

Because at the time the study was carried out no travel demand data (primary data for trip generation purposes of a secondary data from the other model) were available, no complete validation therefore was attempted.

9.5. Conclusions

This chapter dealt with the problem of data preparation, sensitivity test and model validation. It was found from the sensitivity test that the model represents the behaviour of the travellers in the system sufficiently well, and from the model exercises it was found that the value of fare elasticity and frequency elasticity of demand were close to the ones suggested by empirical evidence.

CHAPTER 10
THE USE OF THE *COMBO.2* FOR POLICY ANALYSIS OF A BUS OPERATION ON AN URBAN NETWORK SYSTEM

10.1. Introduction

In order to illustrate the applicability of the *COMBO.2* model to a real situation and to provide some insights into the features of bus operation in a network system, a series of examples of the operation of bus services in an urban area have been studied. These examples consist of investigation of various possible strategies of bus operation in an urban network, in terms of : the allocation of vehicles, the fare systems and the vehicle type.

The first part of this chapter describes the input data needed for the model and the simplifications made. It is then followed by a description and analysis of the results from the model exercises.

10.2. Study area

The study area under consideration was Roehampton, in South-West London (see *Fig.10.1*). This is one of the suburb of London where much of the land is covered in green and residential areas. Public transport that easily available in this area consists of routes of London Buses Ltd, which includes : routes number 85, 72, 264, 265 and 170.

10.3. Description of input data

The input data were taken from the actual situation which includes : the actual network, the demand, and the total number of buses operated.

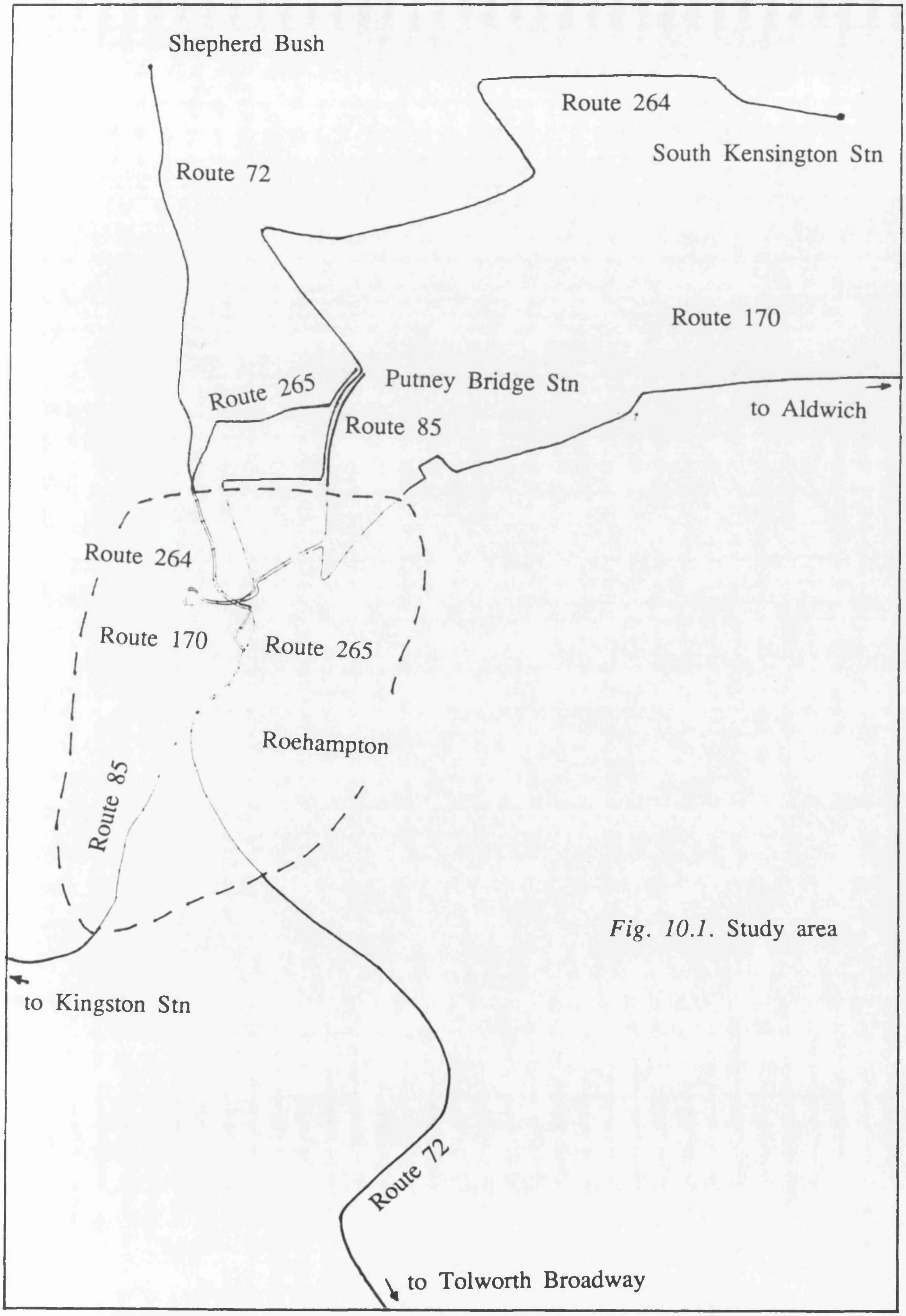


Fig. 10.1. Study area

10.3.1. Data preparation problem

Before we go further, it is worth mentioning some problems that arise in the preparation of data. Since the capability of the model is limited to cope with area which has 25 routes and 120 zonal systems, only a small or a medium size town can be analysed using this model. For a big city like London, however, this model cannot be applied to analyse the whole network system, since the catchment area is too big and the number of routes is too many to consider.

When the study was carried out, no data on a network system of a small town or medium town were available. The data available at the time were the data on routes in the Roehampton area, in the South-West part of London.

Due to the geographical condition of the study area, it was found that some problems arose during the preparation of the data. These included : problems of the definition of the study area, and problem of the compilation of travel demand data.

Ideally, the study area to be considered should be an area which contains all the routes under consideration. This means that the size of the area under consideration would be dependent upon the area covered by of all the routes under consideration. The longer the length of the routes the bigger the size of the study area will be. This implies that if one intends to consider a small study area, one has to find an area in which the routes are not too long.

In the case of the Roehampton area, however, it was found that the coverage area of the routes under consideration is very large. If these are considered to be the main criterion in the definition of the study area, one finds that the size of the study area is very large, and other bus routes which are located nearby will need to be included. Hence,

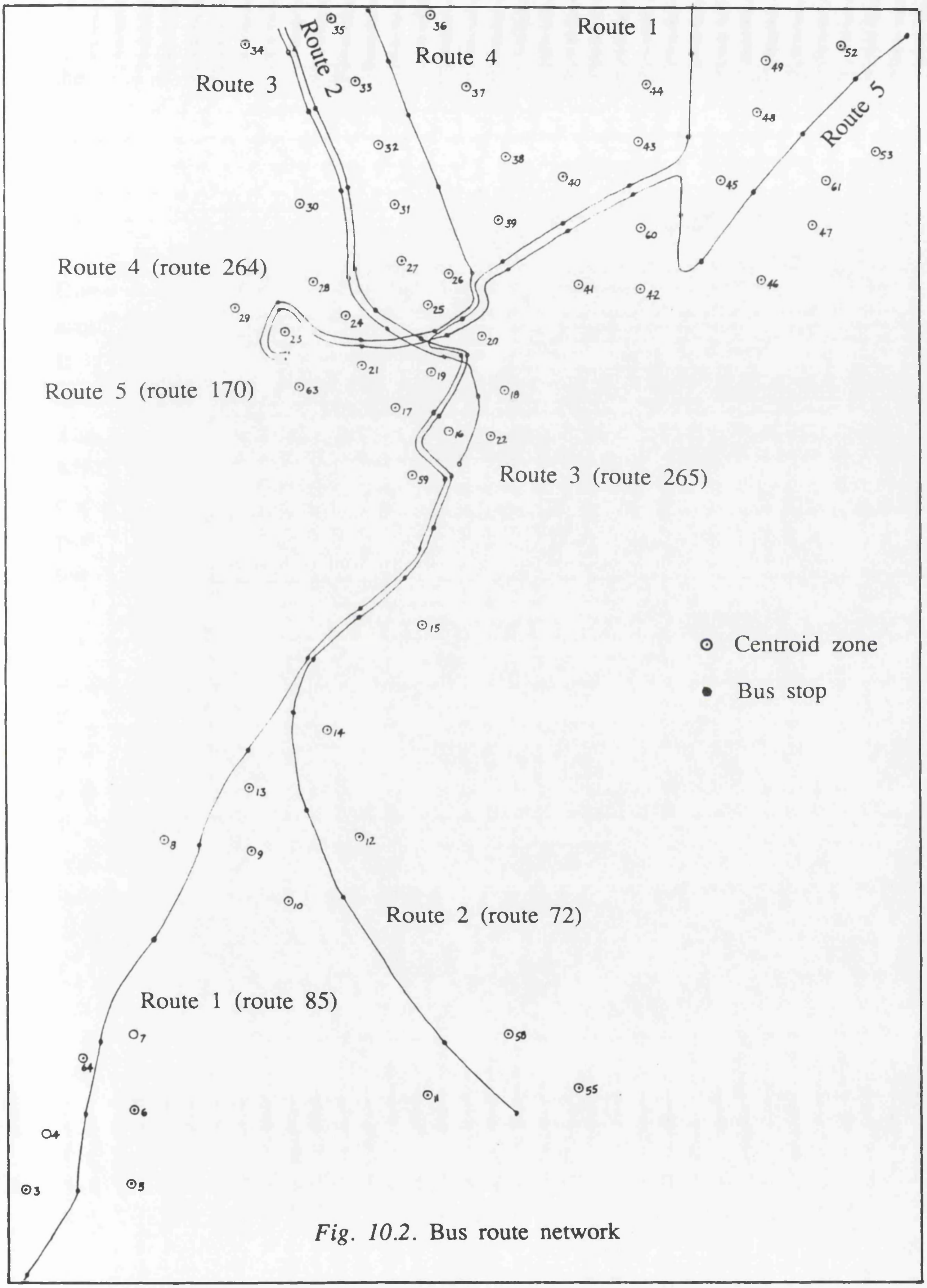


Fig. 10.2. Bus route network

the study area under consideration becomes even bigger. This problem arises because of a complicated structure of bus routes in London. Most of the bus routes in the London area cover a long corridor, for example : from suburbs to centre, or from a suburb to another suburb through the centre of London. No area in London covers several routes inclusively.

Due to the situation described above, it is difficult to define a study area which represents inclusively only the route under consideration. It is therefore necessary to make simplifications.

The simplification made in this study was to define an inclusive area in which no other routes were located inside it except the ones under consideration. This means that the study area defined only covered some part of the routes under consideration (*Fig 10.2*). The other parts of the route corridors are therefore located outside the study area.

To some extent, this simplification has produced another problem, that is the problem of data compilation. Ideally, in this type of study, the travel demand data needed are in the form of trip matrix data for every pair of zones (i.e, the place where the people start and end their journey). However, because the study area under consideration only covers some part of the corridor of the routes, another simplification needs to be made. In this study, the simplification was made on the basis of where the travel demand exists. This included : *1)* the travel demand in the study area, *2)* the travel demand between the study area and the rest of the corridors outside the study area, and *3)* the travel demand within the remaining route corridors outside the study area.

The travel demand for journeys for the first category were represented in the form of a trip matrix, each cell of which represents the total number of trips between a pair of zones, whereas the trip demand for categories 2 and 3 were represented in the form of a stop-to-stop trip matrix.

10.3.1. The network data

The study area was divided into two parts : the inner area which represents the study area itself, and the outer area which represents the remaining corridor of the routes (see *Fig. 10.2*). The inner area was divided into 64 zones, each representing the place where travellers start and end their journey. The outer area, however, was represented by bus stops along the route. Hence, the interaction between routes is expected to occur only in the inner area. The travel demand on the routes in the outer area, however, was considered to be a function of the level of service offered in the route concerned. In this case, a change in the level of travel demand in the outer area is estimated on the basis of travel demand elasticity theory.

In the inner area, each bus stop is represented by a node. It represents the place at which the travellers can access to or egress from the bus services. The links between nodes are defined as follows : *loading links*, between zone centroid and bus nodes; *bus links*, between two adjacent bus nodes on a bus route ; *transfer links*, between bus nodes of a different bus route ; *unloading links*, between bus nodes and centroid zones ; and *walk links*, between two adjacent centroid zones.

10.3.2. The demand

The demand data for the study area were taken from the results of a survey made by the London Buses Ltd. The basic data given were on a route to route basis in the form of stop-to-stop trip matrices.

Using these data, two sets of travel demand data were set up : *1)*, trip matrix between zones in the inner area, and *2)*, the trip demand between stops on each particular bus route in the outer area, and between stop in the outer area and stops in the inner area.

10.3.3. The buses

The bus network in the Roehampton area in the spring of 1986 is illustrated by *Fig. 10.1* . Since no information exists about the type of vehicles used in the study area, it was assumed that the vehicle type used on each particular route was the same as the vehicle type that is usually used in other parts of London, that is, the original double-decker bus (capacity of 72 pass.). In the following table (*Table 10.1*) the characteristics of the services in the network under consideration are given.

TABLE 10.1. THE SERVICE CONDITION OF THE STUDY AREA

No	*Bus route name*	*No of stops (each direction)*	*Headway (mnts)*	*Number of buses*	*Bus type*
1	85	35	8	10	D/Decker
2	72	45	14	8	D/Decker
3	170	21	15	3	D/Decker
4	265	40	9	12	D/Decker
5	264	45	12	11	D/Decker

10.4. Representation of the results

In analysing the results produced from each particular execution of the model, one should ideally consider all indicators of bus operational performance. However, because of the difficulties in representing them clearly and briefly in full, only the main features of bus operation are given. These include : patronage, revenue and profit. Complete results can be seen in **Appendix 4**.

Table 10.2. BUS OPERATION PERFORMANCES IN THE BASE CONDITION

ROUTE	1	2	3	4	5
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	10	8	3	12	11
Bus Oprtd :	10	8	3	12	11
Fare Sys :	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]
Patronage :	3573	1557	1730	1315	2408
Highest Ld:	68	52	40	51	47
Occ rate :	58.8	36.7	33.3	16.6	31.7
M Share :	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0
AWT (mnts):	6.79	11.40	13.54	5.24	7.77
Av Fare :	50.0	50.0	50.0	50.0	50.0
Gen Cost :	93.3	115.9	104.7	79.7	88.6
Tot Op C :	356.32	288.47	107.21	434.64	394.45
Revenue :	788.16	343.46	381.62	290.07	531.18
Profit :	431.84	54.99	274.41	-144.57	136.73

TOTAL PATRONAGE = 10583

TOTAL REVENUE (£) = 2334485.29
TOTAL OP COST (£) = 1581091.18
TOTAL PROFIT (£) = 753394.11

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	44

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 286489.01

10.5. Base condition

The model was run using the service condition shown in *Table 10.1.*, and its results are shown in *Table 10.2.* In the base condition, it has been assumed that all the routes in the study area adopted a flat fare system with a fare of 50 pence per trip.

Since no data were available for comparison, except the total peak-hour patronage, no validation has been made to compare the results of the base condition with what actually happened. The results of modelling exercises therefore just represent an estimate operational performance of the service on each particular route for a given assumption taken.

From the Table, it can be observed that route 1 produced the best performance. This is not surprising as the level of demand on this route was quite high, and also because the service on offer matched the demand. This can be seen from the Table, that at this level of service the average rate of occupancy was 48.8 percent with the highest loading of 67 passengers.

The service on route 4, however, produced the worst performance. The main reason for this is that the service on offer on this route exceeded the demand. It can be seen from the Table that the average occupancy rate on this route was a mere 16.3 per cent with the highest loading of 50 passengers.

10.6. Strategies on the operation of bus services

Operational strategies of a bus service in an urban area play a key role in determining the success of an operation. These are obvious as running a bus service has a similarity with running other business matters, that is, to offer a particular service to the people who need it in order to make a profit. In general, it can be argued that the main idea in determining the strategies of a bus operation is on how to match the service offered to the demand so that an optimal operational performance can be achieved. This implies that it is essential for the operator to know the conditions of demand. For example, who will use the service, and how many people are expected to use it ?

Unlike on a self-contained single route, bus operations on a network system are more difficult to manage. The problem arises not only because one has to consider more than one route simultaneously, but also because the nature of a bus operation on an urban network system is more complicated than that on a single route. In a single route, for example, one may consider the route corridor as a market in which no other factor will affect travel demand, except for the level of service on offer. However, in an urban bus network system, this may not be the case. There will be some interaction between each particular route in the network. A change in one particular route, for example, will not only affect the level of travel demand on the route concerned, but will also affect the level of demand on the other routes in the system. Hence, the characteristics of travel demand on the routes in the network are likely to be unstable. As a result, one cannot consider each particular route in the network individually, but it is necessary that the system is considered as comprehensively as possible.

As the conditions of travel demand on routes in the network tend to be unstable, it can be expected that the operator will have difficulty in identifying the characteristics of travel demand on each particular route in the network. It is difficult, for example, to identify what sort of trips are being made on a particular route. Is it predominantly by short journey travellers, or by long journey travellers ?

Given the fact that the characteristics of travel demand on the routes in the network system are difficult to identify, it is obvious that the operator will face many problems in setting the operational strategy of the bus service. It is difficult, for example, to determine the type of vehicle that should be operated on one particular route, the level of frequency it should provide, and the fare system. Looking at this situation, it seems likely that the optimal performance of a bus service in the route to route basis is hard to achieve. It can also be expected that a good performance on a particular route will be at the expense of the other routes. Hence, the definition of an optimal performance on a route to route basis becomes irrelevant. The definition of an optimal bus operation on a network basis seems to be more appropriate.

In the following paragraph, the problem of bus operational strategies in the study area is examined. The basis of the analysis will be the existing situation mentioned in *Table 10.2*. However, before we go further, it is worth mentioning some of the possible consequences that can be expected to occur as the result of the simplifications made in the representation of the network and in the data compilation. From *Fig. 10.1* it can be observed that the network under consideration is only about 20 % part of the whole routes. Hence, the effect on passengers diverting from one route to another, or switching from a walking trip to bus journey, or the effect of changing trip path will be relatively marginal compared to the overall change that might happen. Much of the change in the level of demand therefore will be as a result of the change in the travel demand in the outer parts of the route which are located in the outer area. This implies that an ideal feature of a bus operation will be difficult to find in the network under consideration.

10.6.1. Setting the fare system and the fare level

Of the various possible strategies in the operation of bus services, a fare strategy is the one that seems most likely to be adopted by most operators. This is predictable as a strategy of fare systems, or a strategy on fare levels, does not need much resources. The only additional expenditure is the cost of advertisement and equipment. Hence, in reality, in terms of total operating costs, the change in fare strategy will only have a marginal effect.

Before one determines which fare strategy to adopt, it is necessary to consider the likely expected outcome. Among other things, it seems that the implication of the fare strategy to the change in revenue is the most important one to consider. To examine this matter one needs to observe the relationship between fares, the level of patronage and the amount of revenue. It is clear that the level of revenue generated will be a function of the level of patronage carried. The greater the number of passengers carried the greater will be the level of revenue. This is due to the fact that a large fraction of the revenues of a bus operation are generated from fares paid by the passengers. The remaining question now is how significant an effect does a change in the fare system have on the level of patronage carried ?

Unlike the operation of a bus service in a single route, the implications of a change in the fare system in a route in a network for the level of demand is more difficult to tackle. In a self-contained single route, for example,it can be expected that a change in the level of travel demand can be the result of additional passengers generated (if the change is positive), or the result of the disappearance of passengers (if the change is negative). In a network system, however, this may not be the case. A change in the level of demand on one particular route, for example, is not only the result of additional passengers generated, but also a result of diversion of passengers from other routes, or a result of a change in trip path.

All these features arise from the fact that the fare structure plays the main role in determining passengers' perception of the service. For a particular level of service offered in the network, the travellers will decide the path they will take for their journey, and, to some extent, the specific route. These decisions are usually taken on the basis of the disutility of the journey, in which the fare plays a key role. Hence, any change in the fare level or fare system on one particular route in the network will affect the decision taken by travellers, which, in turn, will change the allocation of travel demand on the route concerned. In general, it can be expected that if a bus service on one particular route in the network changes its fare level or its fare system, the number of travellers using that particular route will also change, and it is expected that this will be at the expense of the level of demand for other routes in the network.

As mentioned in *Chapter 7*, it is clear that the main idea behind the formulation of a fare strategy is to set the fare system in such a way that it will match the pattern of travel demand and, if possible, attract more passengers so that a maximum level of revenue can be generated. In a single route situation, the problem of setting the fare system and fare level is not difficult, as the characteristics of travel demand are easy to identify. In a network system, however, this is not the case as the pattern of travel demand on each particular route tends to change from one service to another. Hence, the operator will find it very difficult to identify the pattern of travel demand on one particular route. This is particularly true if the route under consideration is located in a network with a highly dense structure.

For a network which has a sparse structure, the problem of fare strategy can be approached in a similar manner to the self-contained single route. This is so because the interaction between the routes in the network will not be too strong. Hence, one can consider each particular route individually.

In the following, the problem of fare strategies in the study area under consideration is examined using the model. In these exercises, it was assumed that the operator is considering whether to change the fare system to be applied in the network. He needs to know the best system of fares to be adopted for the network. Apart from the existing fare system which is the base condition, two other fare systems are considered, each of which has an approximate average fare of 50 pence per trip. These include : *1)* stage fare system with the fare of 35, 50 and 70 pence per trip, for a of short, medium and long journey respectively, and *2)* distance-based fare with initial fare of 25 pence and 5 pence per kilometre per trip. *Table 10.3.* illustrates the result of these exercises. It shows the operational performance of a bus service on each particular route and for each fare strategy, in terms of peak-hour patronage and revenues. Full results of these exercises, however, can be seen in **Appendix 4**.

From the *Table 10.3.*, it can be observed that for different fare systems, the operation of the bus service produces a different operational performance. This is predictable as a change in the fare system in the network will have various implications. First, it either encourages more people from use the service, or discourages the existing travellers to using the service. Second, it allows the existing travellers to be aware of their journey cost, which, in turn, will redefine their decision regarding the path, and therefore the route, they will take. Hence, there will be a situation where some travellers switch from their original path to one they consider better, which also means that they switch from one route to another.

If one looks at the results on a route to route basis, one finds that the magnitude of change in the level of patronage as well as the change in revenues varies from one route to another. Peak-hour patronage for route 1, for example, declined from 3573 to 3375 when the fare system change from a flat fare to distance-based fare, whereas in the same situation the level of peak-hour patronage on route 4 increased from 1316 to 1370. These results indicate that there is an interaction

TABLE 10.3.

BUS OPERATION PERFORMANCES WITH DIFFERENT FARE STRATEGIES

Route	Flat fare		Stage fare		Distance-based fare	
	Ptrg[1)]	Rev[2)]	Ptrg	Rev	Ptrg	Rev
1	3573	788.2	3584	890.1	3375	714.8
2	1557	343.5	1503	354.8	1429	354.9
3	1730	381.6	1731	373.8	1823	328.6
4	1316	290.1	1309	274.9	1370	245.2
5	2408	531.2	2347	487.2	2378	435.9
TOTAL	10583	2334.6	10474	2380.8	10375	2079.4

1) *Peak-hour patronage*
2) *Revenues for three months operation (in thousands of pounds)*

between the condition of one route and the condition of the other though the differences are very marginal.

In terms of revenues generated, the results of the exercises seem to be more difficult to follow as an increase in peak-hour patronage on one particular route does not necessarily mean an increase in revenue generated. This is predictable as the pattern of travel demand on each particular route in the network is different. Routes 3 and 4, for example, consist predominantly of short trip travellers. This can be observed from the table that, although the highest patronage was produced when a distance-based fare was adopted, the highest revenue is produced when a flat fare was introduced.

Given the fact that the magnitude of the fare system in each particular route in the network is different, it can be argued that the optimal revenue can be achieved if the fare system on each particular route is different, depending on the pattern of travel demand. For example, a stage fare system for route 1, a distance-based fare for route 2, and a flat fare for routes 3,4 and 5.

However, if the operator is considering applying the same fare system for each particular route in the whole network, then it can be argued that in terms of the peak-hour patronage carried, a flat fare system was the best policy to adopt for the network as a whole, and in terms of revenues, which denotes profit, it is found that a stage fare system is the best alternative.

10.6.2. Allocating the vehicles to the routes

Another problem which is often faced by bus operators is the problem of allocating the available vehicles to the routes in the network. To illustrate this problem, consider the operation of a bus service in an urban network. For a given operational performance over a particular period, the operator ought to realise that the performance of his service in the network varies from one route to another.

These conditions usually emerge as the result of a mismatch between supply and demand. On one particular route the demand may exceed the capacity, and on another route the level of demand is far below the capacity of the service. Here, it is important to allocate the available vehicles to the right place, and in the right number. It is true that one can cross-subsidise the service : the profit from one route, for example, can be allocated to cover the deficit on another route. However, it has to be recognised that it is more convenient for the operator to allocate his vehicles in an optimal manner so that all the services he offer produces a good performance.

The vehicle allocation problem is particularly important in a deregulated environment as the main constraints in the industry are financial. The task of the operator would be to allocate his vehicles to the routes in the network so that all the services he offers produce a good performance. This implies that the operator should allocate his vehicles in such a way that each route in the network is sufficiently served. Ideally, a good allocation of vehicles will result in a situation in which every single route in the network is served to match demand.

Due to the fact that the problem of vehicle allocation is similar to the problem of matching demand with supply, all the information relating to the level of travel demand and the characteristics of each particular route becomes crucial for the operator. The level of travel demand and its pattern gives the idea to the operator of the number of vehicles he should operate on one particular route.

As the characteristics of travel demand play an important role in determining the allocation of vehicles, ideally, it is essential for the operator to have accurate information about the characteristics of each particular route in the network. It is essential to know, for example, how significant the level of demand is on each particular route in the network, and what the pattern of travel demand is on the route concerned ?

However, it has to be recognised that reliable information relating to the travel demand for the routes in the network is very difficult to obtain. This is due the fact that the characteristics of travel demand on each route in the network tend to be unstable. They tend to change from one situation to another, and are strongly influenced by services offered on the route concerned and the other routes in the system. This situation is particularly crucial for an area in which the structure of the network is very dense. The obvious implications of this situation are that the operator needs to be very careful in allocating his vehicles. It can be expected therefore that it will be very difficult for the operator to allocate his vehicles in an optimal manner.

One possible approach to this problem is through simplification. One simplification is to consider the existing situation of the routes in the network on a detailed, route-to-route basis, and use them as the main basis in allocating vehicles to the network. This approach is not too difficult to implement as the existing situation on each particular route in reality is easily available, particularly if the operator keeps a record of all performance parameters of his bus service operation (revenue, operating cost, patronage). However, it should be recognised that this particular approach is only appropriate if the structure of the network is not very dense, or if the interaction between routes is not too strong.

In this approach, the situation of each particular route is considered individually and its operational performance is examined in detail. For example, how significant is the existing level of travel demand ?, can the service offered match the demand ?, and so on. If one found out that the service capacity on one particular route in the network matched its demand, it would be reasonable to maintain that service, and change only those routes which were not performing well.

Another similar approach is to consider the existing level of patronage on each particular route, and use their proportion to the total patronage in the network as a basis for allocating vehicles to the routes in the network. This is a very simple approach and very easy to implement as the only information needed is the level of patronage on each particular route in the network.

Another possible approach is to spread all the available vehicles evenly over the network, so that every single route will be served by approximately the fleet size. This means that the operator need not know the exact situation of each particular route.

The obvious advantage of this approach is that no information on travel demand is needed. However, there are some disadvantages. First, the length of each particular route in the network varies, so the headway of the service on each route will be different. Some short routes will be served by a high frequency service, and the others by a low frequency service. Hence, some passengers who use a long route will suffer a longer waiting time than the others. However, it has to be recognised that this disadvantage also holds if one allocates vehicles to the routes in the network on the basis of the proportion of existing patronage.

The second disadvantage of this approach is variability in the performance of the operation. This is due to the fact that the level of demand on each particular route in the network is different. For one particular service condition offered to the network, it can be expected that the performance will vary from one route to another. At one extreme it might be the case that the operational performance on one particular route produces a deficit while another makes a profit. Overall, it can be argued that the applicability of this approach will depend upon the homogeneity of the routes in the network ; the more homogeneous the characteristics of the routes in the network is,the higher the chances of producing a good result, provided that the capacity of the services offered covers the demand sufficiently.

In order to examine the vehicle allocation problem of the study area, consider again the operational performance of the service in the base condition mentioned in *Table 10.2*. Suppose that now, the operator wants to know whether the present allocation of vehicles is the best possible one, in terms of patronage carried as well as in terms of profit generated.

To investigate this problem three possible cases (or, strategies) were considered :

1), to reduce the number of vehicles on the routes with deficit, or on the route in which the level of occupancies is not too high, and put them onto routes in which the occupancy rate is high (reduce the number of vehicles in routes 4 and 5 and put them on routes 1 and 3, and maintain the status quo on route 2).

2), to allocate the vehicle to the routes on the basis of the proportion of existing levels of patronage on the routes concerned, and

3), to reallocate all the vehicle available evenly over the network so that every single route is served with approximately the same number of vehicles.

For the three strategies considered, it was assumed that the fare system adopted was the same as the one in the base condition, which is the flat fare system at a cost of 50 pence per trip. It was also assumed that the total operating cost would only depend on the number of vehicles operating in the network. It can be expected therefore that the reallocation of vehicles from one route to another will not affect the total operating costs. *Table 10.4.* shows the results of the three strategies, together with the existing situation, in terms of peak-hour patronage carried on each particular route. The full results of these exercises, however, can be seen in **Appendix 4**.

From the table it can be observed that the present allocation of vehicles did not produce the best operational performance. The results show that to reallocate vehicle in the study area would produce promising results. All strategies considered in these exercises produced some improvement in the operational performance compared to the existing conditions. The total peak-hour patronage carried, patronage carried, for example, increased from 10583 to 11465 when strategy 1 was introduced, to 11493 for strategy 2, and to 11282 for strategy 3. Since the actual number of vehicles operated in the three strategies was the same as in the base condition, it is therefore not surprising that the increase in the level of patronage also meant an improvement in the level of profit. From these exercises, it is found that the strategy that produces the highest profit is strategy 2.

TABLE 10.4.

BUS OPERATION PERFORMANCES FOR DIFFERENT VEHICLE ALLOCATIONS

ROUTE		1	2	3	4	5	TOTAL
	Fleet	10	8	3	12	11	44
Base	Ptrg 1)	3573	1557	1730	1315	2408	10583
	Prof 2)	431.8	55.0	274.4	-144.6	136.7	753.4
	Fleet	17	8	7	5	7	44
Case 1	Ptrg	4320	1448	2836	896	1965	11465
	Prof	343.9	30.9	378.7	15.8	181.7	950.9
	Fleet	15	7	7	5	10	44
Case 2	Ptrg	4159	1363	2837	896	2238	11493
	Prof	380.8	47.9	378.8	15.8	134.7	958.0
	Fleet	9	9	8	9	9	44
Case 3	Ptrg	3436	1590	2909	1182	2165	11282
	Prof	437.0	26.6	359.2	-65.6	154.4	911.5

1) *Peak-hour patronage carried.*
2) *Profit of three months operation (in thousands of pounds).*

If one looks at the results of strategy 1 on a route-to-route basis, one finds that the trend of the change in operational performance is predictable. The improvement in the service on one particular route can be achieved by matching demand with supply. For those routes with a low level of demand compared to the capacity of the service, or routes in which the existing service has a low occupancy rate, a reduction of the number of vehicles, or a reduction in the capacity of the service would be the appropriate step to produce an improvement.

It can be observed from the figure that the performance of the services on routes 4 and 5 improved when the number of buses was reduced. In this case, the profit level on both routes increased. This was because the reduction in the number of vehicles on the two routes did not change the level of demand (and, therefore the level of revenue) very much, but it reduced the operating costs significantly.

However, if one looks at the operational performance of the other routes, one finds that although strategy 1 produced improvements in routes 4 and 5, at the same time it reduced the level of profit of the service on the other routes, that is route 1, where the additional vehicles were introduced, and route 2, where no change was made. The decrease in the level of profit on route 1 occurred simply because the percentage increase in the level of peak-hour patronage carried on route 1, which was the result of a better level of service or higher frequency, was less than the percentage increase of total operating cost. The decrease in the level of profit on route 2, however, is rather surprising since no change was made in this route. The possible reason for this situation is that the decline in the level of profit was caused by a decrease in patronage, which resulted from the diversion of some existing passengers to another route.

When the operator introduced strategy 3, i.e, spreading the available vehicles all over the network, it was found that the overall performance of the service was better than the base condition. The services on routes 3, 4 and 5 improved, whereas the service condition on route 1 and 2 changed slightly. The improvement on routes 4 and 5 occurred as a result of the reduction in the number of buses operated, so that the

10.5. Base condition

The model was run using the service condition shown in *Table 10.1.*, and its results are shown in *Table 10.2.* In the base condition, it has been assumed that all the routes in the study area adopted a flat fare system with a fare of 50 pence per trip.

Since no data were available for comparison, except the total peak-hour patronage, no validation has been made to compare the results of the base condition with what actually happened. The results of modelling exercises therefore just represent an estimate operational performance of the service on each particular route for a given assumption taken.

From the Table, it can be observed that route 1 produced the best performance. This is not surprising as the level of demand on this route was quite high, and also because the service on offer matched the demand. This can be seen from the Table, that at this level of service the average rate of occupancy was 48.8 percent with the highest loading of 67 passengers.

The service on route 4, however, produced the worst performance. The main reason for this is that the service on offer on this route exceeded the demand. It can be seen from the Table that the average occupancy rate on this route was a mere 16.3 per cent with the highest loading of 50 passengers.

Moreover, it is worth mentioning that the value of average waiting times for each route in the network are slightly more than half the headways. This is because the model treats the arrival of passengers as random regardless of the value of the average headways. When large numbers of passengers board, they tend to increase the time spent at the stop, so the average waiting time weighted by the number of passengers tends to be greater than the simple unweighted mean. Hence the average waiting time is more than half the headway.

These findings agree with those suggested by most authors in this field, both theoretically and empirically (see, for example, Chapman, 1976). It should be noted that these findings are only valid when average headway is less than 10 minutes. For headways of more than 10 minutes, however, the results do not represent reality, since, in reality, the arrival of passengers at a bus stop is not random, but tends to happen a few minutes before the arrival of a bus (Jollife and Hutchinson, 1975).

10.6. Strategies on the operation of bus services

Operational strategies of a bus service in an urban area play a key role in determining the success of an operation. These are obvious as running a bus service has a similarity with running other business matters, that is, to offer a particular service to the people who need it in order to make a profit. In general, it can be argued that the main idea in determining the strategies of a bus operation is on how to match the service offered to the demand so that an optimal operational performance can be achieved. This implies that it is essential for the operator to know the conditions of demand. For example, who will use the service, and how many people are expected to use it ?

Unlike on a self-contained single route, bus operations on a network system are more difficult to manage. The problem arises not only because one has to consider more than one route simultaneously, but also because the nature of a bus operation on an urban network system is more complicated than that on a single route. In a single route, for example, one may consider the route corridor as a market in which no other factor will affect travel demand, except for the level of service on offer. However, in an urban bus network system, this may not be the case. There will be some interaction between each particular route in the network. A change in one particular route, for example, will not only affect the level of travel demand on the route concerned, but will also affect the level of demand on the other routes in the system. Hence, the characteristics of travel demand on the routes in the network are likely to be unstable. As a result, one cannot consider each particular route in the network individually, but it is necessary that the system is considered as comprehensively as possible.

As the conditions of travel demand on routes in the network tend to be unstable, it can be expected that the operator will have difficulty in identifying the characteristics of travel demand on each particular route in the network. It is difficult, for example, to identify what sort of trips are being made on a particular route. Is it predominantly by short journey travellers, or by long journey travellers ?

Given the fact that the characteristics of travel demand on the routes in the network system are difficult to identify, it is obvious that the operator will face many problems in setting the operational strategy of the bus service. It is difficult, for example, to determine the type of vehicle that should be operated on one particular route, the level of frequency it should provide, and the fare system. Looking at this situation, it seems likely that the optimal performance of a bus service in the route to route basis is hard to achieve by an operator who runs the services on the whole network. It can also be expected that a good performance on a particular route will be at the expense of the other routes. Hence, by assuming that only one operator runs the service in the network, the definition of an optimal performance on a route to route basis becomes irrelevant. The definition of an optimal bus operation on a network basis seems to be more appropriate.

In the following paragraph, the problem of bus operational strategies in the study area is examined. The basis of the analysis will be the existing situation mentioned in *Table 10.2*. However, before we go further, it is worth mentioning some of the possible consequences that can be expected to occur as the result of the simplifications made in the representation of the network and in the data compilation. From *Fig. 10.1* it can be observed that the network under consideration is only about 20 % part of the whole routes. Hence, the effect on passengers diverting from one route to another, or switching from a walking trip to bus journey, or the effect of changing trip path will be relatively marginal compared to the overall change that might happen. Much of the change in the level of demand therefore will be as a result of the change in the travel demand in the outer parts of the route which are located in the outer area. This implies that an ideal feature of a bus operation will be difficult to find in the network under consideration.

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Of the various possible strategies in the operation of bus services, a fare strategy is the one that seems most likely to be adopted by most operators. This is predictable as a strategy of fare systems, or a strategy on fare levels, does not need much resources. The only additional expenditure is the cost of advertisement and equipment. Hence, in reality, in terms of total operating costs, the change in fare strategy will only have a marginal effect.

Before one determines which fare strategy to adopt, it is necessary to consider the likely expected outcome. Among other things, it seems that the implication of the fare strategy to the change in revenue is the most important one to consider. To examine this matter one needs to observe the relationship between fares, the level of patronage and the amount of revenue. It is clear that the level of revenue generated will be a function of the level of patronage carried. The greater the number of passengers carried the greater will be the level of revenue. This is due to the fact that a large fraction of the revenues of a bus operation are generated from fares paid by the passengers. The remaining question now is how significant an effect does a change in the fare system have on the level of patronage carried ?

Unlike the operation of a bus service in a single route, the implications of a change in the fare system in a route in a network for the level of demand is more difficult to tackle. In a self-contained single route, for example,it can be expected that a change in the level of travel demand can be the result of additional passengers generated (if the change is positive), or the result of the disappearance of passengers (if the change is negative). In a network system, however, this may not be the case. A change in the level of demand on one particular route, for example, is not only the result of additional passengers generated, but also a result of diversion of passengers from other routes, or a result of a change in trip path.

All these features arise from the fact that the fare structure plays quite significant role in determining passengers' perception of the service. For a particular level of service offered in the network, the travellers will decide the path they will take for their journey, and, to some extent, the specific route. These decisions are usually taken on the basis of the disutility of the journey, in which the fare plays a quite significant role. Hence, any change in the fare level or fare system on one particular route in the network will affect the decision taken by travellers, which, in turn, will change the allocation of travel demand on the route concerned. In general, it can be expected that if a bus service on one particular route in the network changes its fare level or its fare system, the number of travellers using that particular route will also change, and it is expected that this will be at the expense of the level of demand for other routes in the network.

As mentioned in *Chapter 7*, it is clear that the main idea behind the formulation of a fare strategy is to set the fare system in such a way that it will match the pattern of travel demand and, if possible, attract more passengers so that a maximum level of revenue can be generated. In a single route situation, the problem of setting the fare system and fare level is not difficult, as the characteristics of travel demand are easy to identify. In a network system, however, this is not the case as the pattern of travel demand on each particular route tends to change from one service to another. Hence, the operator will find it very difficult to identify the pattern of travel demand on one particular route. This is particularly true if the route under consideration is located in a network with a highly dense structure.

For a network which has a sparse structure, the problem of fare strategy can be approached in a similar manner to the self-contained single route. This is so because the interaction between the routes in the network will not be too strong. Hence, one can consider each particular route individually.

In the following, the problem of fare strategies in the study area under consideration is examined using the model. In these exercises, it was assumed that the operator is considering whether to change the fare system to be applied in the network. He needs to know the best system of fares to be adopted for the network. Apart from the existing fare system which is the base condition, two other fare systems are considered, each of which has an approximate average fare of 50 pence per trip. These include : *1)* stage fare system with the fare of 35, 50 and 70 pence per trip, for a of short, medium and long journey respectively, and *2)* distance-based fare with initial fare of 25 pence and 5 pence per kilometre per trip. *Table 10.3.* illustrates the result of these exercises. It shows the operational performance of a bus service on each particular route and for each fare strategy, in terms of peak-hour patronage and revenues. Full results of these exercises, however, can be seen in **Appendix 4**.

From the *Table 10.3.*, it can be observed that for different fare systems, the operation of the bus service produces a different operational performance. This is predictable as a change in the fare system in the network will have various implications. First, it either encourages more people from use the service, or discourages the existing travellers to using the service. Second, it allows the existing travellers to be aware of their journey cost, which, in turn, will redefine their decision regarding the path, and therefore the route, they will take. Hence, there will be a situation where some travellers switch from their original path to one they consider better, which also means that they switch from one route to another.

If one looks at the results on a route to route basis, one finds that the magnitude of change in the level of patronage as well as the change in revenues varies from one route to another, and, generaly, the changes are small. Peak-hour patronage for route 1, for example, declined from 3573 to 3375 when the fare system change from a flat fare to distance-based fare, whereas in the same situation the level of peak-hour patronage on route 4 increased from 1316 to 1370. These results indicate that there is an interaction between the condition of one route and the condition of the other, though the differences are very marginal. This also indicates that the role of fare is not too significant in the passengers' perception toward the service.

TABLE 10.3.

BUS OPERATION PERFORMANCES WITH DIFFERENT FARE STRATEGIES

ROUTE	FLAT FARE		STAGE FARE		DISTANCE-BASED FARE	
	PTRG*)	REV**)	PTRG	REV	PTRG	REV
1	3573	788.2	3584	890.1	3375	714.8
2	1557	343.5	1503	354.8	1429	354.9
3	1730	381.6	1731	373.8	1823	328.6
4	1316	290.1	1309	274.9	1370	245.2
5	2408	531.2	2347	487.2	2378	435.9
TOTAL	10583	2334.6	10474	2380.8	10375	2079.4

*) *Peak-hour patronage*
**) *Revenues for three months operation (in thousands pounds)*

In terms of revenues generated, the results of the exercises seem to be more difficult to follow as an increase in peak-hour patronage on one particular route does not necessarily mean an increase in revenue generated. This is predictable as the pattern of travel demand on each particular route in the network is different. Routes 3 and 4, for example, consist predominantly of short trip travellers. This can be observed from the table that, although the highest patronage was produced when a distance-based fare was adopted, the highest revenue is produced when a flat fare was introduced.

Given the fact that the magnitude of the fare system in each particular route in the network is different, it can be argued that the optimal revenue can be achieved if the fare system on each particular route is different, depending on the pattern of travel demand. For example, a stage fare system for route 1, a distance-based fare for route 2, and a flat fare for routes 3,4 and 5.

However, if the operator is considering applying the same fare system for each particular route in the whole network, then it can be argued that in terms of the peak-hour patronage carried, a flat fare system was the best policy to adopt for the network as a whole, and in terms of revenues, which denotes profit, it is found that a stage fare system is the best alternative.

10.6.2. Allocating the vehicles to the routes

Another problem which is often faced by bus operators is the problem of allocating the available vehicles to the routes in the network. To illustrate this problem, consider the operation of a bus service in an urban network. For a given operational performance over a particular period, the operator ought to realise that the performance of his service in the network varies from one route to another.

These conditions usually emerge as the result of a mismatch between supply and demand. On one particular route the demand may exceed the capacity, and on another route the level of demand is far below the capacity of the service. Here, it is important to allocate the available vehicles to the right place, and in the right number. It is true that one can cross-subsidise the service : the profit from one route, for example, can be allocated to cover the deficit on another route. However, it has to be recognised that it is more convenient for the operator to allocate his vehicles in an optimal manner so that all the services he offer produces a good performance.

The vehicle allocation problem is particularly important in a deregulated environment as the main constraints in the industry are financial. The task of the operator would be to allocate his vehicles to the routes in the network so that all the services he offers produce a good performance. This implies that the operator should allocate his vehicles in such a way that each route in the network is sufficiently served. Ideally, a good allocation of vehicles will result in a situation in which every single route in the network is served to match demand.

Due to the fact that the problem of vehicle allocation is similar to the problem of matching demand with supply, all the information relating to the level of travel demand and the characteristics of each particular route becomes crucial for the operator. The level of travel demand and its pattern gives the idea to the operator of the number of vehicles he should operate on one particular route.

As the characteristics of travel demand play an important role in determining the allocation of vehicles, ideally, it is essential for the operator to have accurate information about the characteristics of each particular route in the network. It is essential to know, for example, how significant the level of demand is on each particular route in the network, and what the pattern of travel demand is on the route concerned ?

However, it has to be recognised that reliable information relating to the travel demand for the routes in the network is very difficult to obtain. This is due the fact that the characteristics of travel demand on each route in the network tend to be unstable. They tend to change from one situation to another, and are strongly influenced by services offered on the route concerned and the other routes in the system. This situation is particularly crucial for an area in which the structure of the network is very dense. The obvious implications of this situation are that the operator needs to be very careful in allocating his vehicles. It can be expected therefore that it will be very difficult for the operator to allocate his vehicles in an optimal manner.

One possible approach to this problem is through simplification. One simplification is to consider the existing situation of the routes in the network on a detailed, route-to-route basis, and use them as the main basis in allocating vehicles to the network. This approach is not too difficult to implement as the existing situation on each particular route in reality is easily available, particularly if the operator keeps a record of all performance parameters of his bus service operation (revenue, operating cost, patronage). However, it should be recognised that this particular approach is only appropriate if the structure of the network is not very dense, or if the interaction between routes is not too strong.

In this approach, the situation of each particular route is considered individually and its operational performance is examined in detail. For example, how significant is the existing level of travel demand ?, can the service offered match the demand ?, and so on. If one found out that the service capacity on one particular route in the network matched its demand, it would be reasonable to maintain that service, and change only those routes which were not performing well.

Another similar approach is to consider the existing level of patronage on each particular route, and use their proportion to the total patronage in the network as a basis for allocating vehicles to the routes in the network. This is a very simple approach and very easy to implement as the only information needed is the level of patronage on each particular route in the network.

Another possible approach is to spread all the available vehicles evenly over the network, so that every single route will be served by approximately the fleet size. This means that the operator need not know the exact situation of each particular route.

The obvious advantage of this approach is that no information on travel demand is needed. However, there are some disadvantages. First, the length of each particular route in the network varies, so the headway of the service on each route will be different. Some short routes will be served by a high frequency service, and the others by a low frequency service. Hence, some passengers who use a long route will suffer a longer waiting time than the others. However, it has to be recognised that this disadvantage also holds if one allocates vehicles to the routes in the network on the basis of the proportion of existing patronage.

The second disadvantage of this approach is variability in the performance of the operation. This is due to the fact that the level of demand on each particular route in the network is different. For one particular service condition offered to the network, it can be expected that the performance will vary from one route to another. At one extreme it might be the case that the operational performance on one particular route produces a deficit while another makes a profit. Overall, it can be argued that the applicability of this approach will depend upon the homogeneity of the routes in the network ; the more homogeneous the characteristics of the routes in the network is,the higher the chances of producing a good result, provided that the capacity of the services offered covers the demand sufficiently.

In order to examine the vehicle allocation problem of the study area, consider again the operational performance of the service in the base condition mentioned in *Table 10.2*. Suppose that now, the operator wants to know whether the present allocation of vehicles is the best possible one, in terms of patronage carried as well as in terms of profit generated.

To investigate this problem three possible cases (or, strategies) were considered :

1), to reduce the number of vehicles on the routes with deficit, or on the route in which the level of occupancies is not too high, and put them onto routes in which the occupancy rate is high (reduce the number of vehicles in routes 4 and 5 and put them on routes 1 and 3, and maintain the status quo on route 2).

2), to allocate the vehicle to the routes on the basis of the proportion of existing levels of patronage on the routes concerned, and

3), to reallocate all the vehicle available evenly over the network so that every single route is served with approximately the same number of vehicles.

For the three strategies considered, it was assumed that the fare system adopted was the same as the one in the base condition, which is the flat fare system at a cost of 50 pence per trip. It was also assumed that the total operating cost would only depend on the number of vehicles operating in the network. It can be expected therefore that the reallocation of vehicles from one route to another will not affect the total operating costs. *Table 10.4.* shows the results of the three strategies, together with the existing situation, in terms of peak-hour patronage carried on each particular route. The full results of these exercises, however, can be seen in **Appendix 4**.

From the table it can be observed that the present allocation of vehicles did not produce the best operational performance. The results show that to reallocate vehicle in the study area would produce promising results. All strategies considered in these exercises produced some improvement in the operational performance compared to the existing conditions. The total peak-hour patronage carried, patronage carried, for example, increased from 10583 to 11465 when strategy 1 was introduced, to 11493 for strategy 2, and to 11282 for strategy 3. Since the actual number of vehicles operated in the three strategies was the same as in the base condition, it is therefore not surprising that the increase in the level of patronage also meant an improvement in the level of profit. From these exercises, it is found that the strategy that produces the highest profit is strategy 2.

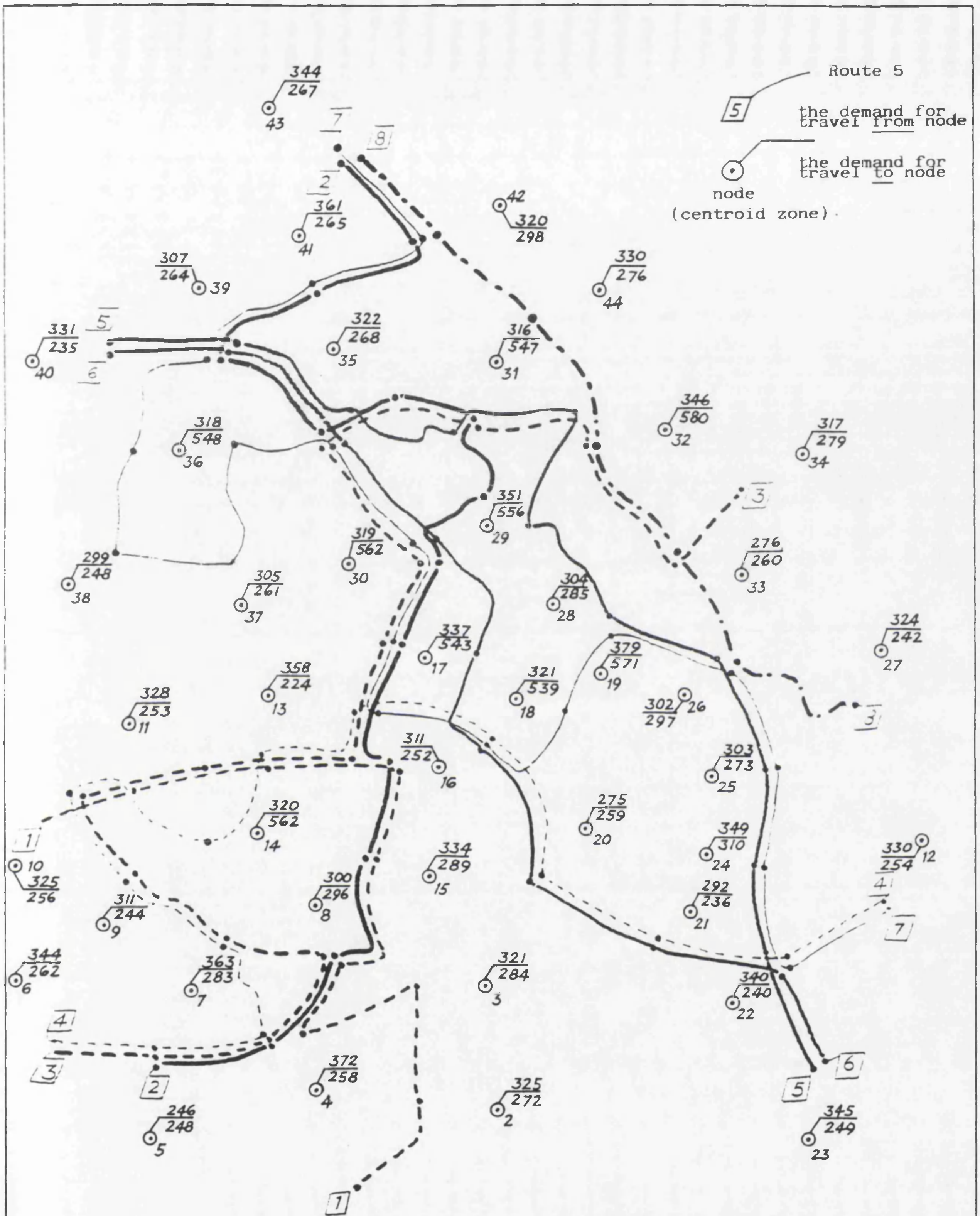


Fig. 11.1. Study area

11.3. Travel demand

The travel demand under consideration was hypothetical data in the form of trip matrices. The data on the total number of trips originating from each particular zone and the total number of trips destined for each particular zone in the study area can be seen in *Fig. 11.1*.

11.4. The buses

The type of buses considered in these exercises was the same as those mentioned in *Chapter 7*. However, for practicality, these are shown again in *Table 11.2* below.

Table 11.2. TYPES OF VEHICLE AND THEIR CHARACTERISTICS

	MINI BUS	MIDI BUS	SDRD BUS	DOUBLE-DECKER
Price (pound)	18,500	31,300	36,000	66,500
Capacity	20	35	45	72
Speed (Km/hr)	24	22	20	18
System of operation	OPO	OPO	OPO	TPO
Operating Cost :				
Kilometre related cost (p/Km)	16	20	26	30
Time related cost (p/Hr)	1000	1096	1166	1355

source : Glaister (1986) .

11.5. The results

As mentioned in *Section 9.10*, a number of different parameters of bus operation can be produced for each particular execution of the model. They range from estimated conditions of bus operation (patronage, revenue and operating costs), to estimated conditions of each fleet (bus loadings), and to an estimation of what would be perceived by the travellers (in terms of perceived generalised costs and waiting time).

In analysing these results, ideally one should consider them all. However, because of the difficulties in representing them clearly and briefly in full, it is reasonable to represent only the main features of bus operation. These include :patronage, revenue and profit. Complete results can be seen in **Appendix 5**.

11.6. Entering a competitive market

The scenario under consideration was a situation in which a new entrant intends to enter the market with limited resources. It was assumed that he has only £ 750,000 to spend on the provision of vehicles. He could enter the market with any strategy he likes. He could, for example, decide to buy minibuses and operate them on some selective routes, with each route using a different fare system, or alternatively, he could decide to buy double-decker buses and operate them on one particular route only.

For a given sum of money available he has four alternatives to choose from, whether to spend all his money on providing 11 double decker buses, 21 standard buses, 24 midibuses, or 40 minibuses (see, *Table 11.3*). Each of these fleets has a capacity of approximately 800 seats.

Table 11.3. ALTERNATIVES AVAILABLE

Alternative	Type of vehicle	Fleet size	Service capacity
1	Double-Decker	11	792
2	Standard	21	945
3	Midi bus	24	840
4	Mini bus	40	800

11.6.1. Base condition

It was assumed that in the base condition there was already an existing operator running a services on all the routes in the network. He operates a fleet of double decker buses on each route with average headways of 4.5 minutes, and with a flat fare system of 50 pence per trip. The operational performance of the existing service in the base condition can be seen in *Table 11.4.*

Table 11.4. BUS OPERATION PERFORMANCES IN THE BASE CONDITION

ROUTE		1	2	3	4	5	6	7	8
Vhcl type	:	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity	:	72	72	72	72	72	72	72	72
Sys Op	:	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz	:	7	10	10	10	8	7	15	6
Bus Oprtd	:	7	10	10	10	8	7	15	6
Fare Sys	:	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage	:	2051	3048	2271	2293	1323	1000	3728	1225
Highest Ld	:	32	36	32	27	13	14	34	10
Occ rate	:	26.6	26.2	24.9	19.3	11.6	12.4	25.3	9.8
M Share	:	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Card Hldr	:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT	:	2.6	2.3	2.6	2.2	2.1	2.0	2.1	1.8
Av Fare	:	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost	:	65.3	64.3	67.9	64.4	62.7	63.2	65.7	59.3
Tot Op C	:	245.16	350.79	347.20	345.38	283.32	249.92	517.93	209.46
Revenue	:	452.43	672.35	500.96	505.81	291.84	220.59	822.35	270.22
Profit	:	207.27	321.56	153.76	160.43	8.52	-29.33	304.42	60.76

```
TOTAL PATRONAGE     =   16939      TOTAL REVENUE (£) =  3736544.12
                                   TOTAL OP COST (£) =  2549158.98
                                   TOTAL PROFIT  (£) =  1187385.14
VEHICLES            = Mini     Midi     Stdrd    D/Decker
                        0        0        0        73
TOTAL OVERALL GENERALISED COST (Pass.mnts) =  1102965.58
```

11.6.2. Problems and strategies of the new entrant

Given the fact that the behaviour of the competitor is unpredictable, it is obvious that the new entrant will find many problems regarding the bus service operation when he tries to enter the network. The first problem is the uncertainty of the market. This is due to the fact that the level of demand on one particular route not only depends on the level of service on the route concerned but also on the level of service on other routes in the system. So it is apparent that a high level of uncertainty exists in the market. This implies that there are difficulties in identifying the pattern and the structure of travel demand on each route in the system. These tend to change from one situation to another. As a result, the new entrant will have difficulties in fixing the strategies of his bus operation. It is difficult, for example, to decide on the route for which he should adopt a particular fare system.

The problems of uncertainty become more apparent as the behaviour of the competitor becomes very unpredictable. It is most likely that whenever the new entrant changes his operational strategy, the existing operator will follow suit by changing some of his operational strategies.

Let us consider again the scenario mentioned above. This scenario, in fact, is a typical problem usually faced by a new entrant upon entering the market. The new entrant usually has limited resources and has to decide on a strategy that is supposed to be appropriate to meet his operational objectives, which can be profit maximization or, simply to take the competitor off the road.

In setting his strategy, the first step to be taken is choosing the appropriate type of vehicle for his fleet. This is the most important part of his strategy because it determines how big the size of the fleet will be, how many people will be needed to operate them, and most important of all, how much money will be needed to cover its operating costs. However, it should be recognised that if one has chosen one particular type of vehicle, one will only use that type of vehicle, since it would be uneconomic and troublesome to sell the vehicle and change it for another type during the operation. So, in deciding on the type of vehicle to operate with, one has to bear in mind that it is unlikely to be changed. If he still intends to expand his fleet, however, he can consider buying some other vehicles later on, either of the same type or different ones.

For a given amount of resources available, the new entrant has to decide on the vehicle type. He can choose any type of vehicle, minibuses, or midibuses, or standard buses or double-decker buses, each of which will have different implications. If minibuses are chosen, for example, he will find that he has a big fleet. This is because the price of small vehicles is usually lower than that of bigger ones. Hence, it can be expected that the new entrant will be able to offer a frequent service to travellers, which means that his fleet will be in a better position to capture the market. However, it should be recognised that this choice implies considerable outlay on operating costs, since more drivers are needed. On the contrary, if big buses are chosen then he would have a quite small fleet, and therefore not too many drivers are needed. This means that the total operating costs will be small, but at the same time, the service offered to travellers will not be so frequent.

Having chosen the type of vehicle he wishes to operate, the new entrant's other decision is how he should allocate his fleet to the network ?, or, in other words, on which route should he operate each particular bus ? Should he allocates all his vehicle to one particular route, or should he spread all the vehicles over the network, or should he allocate them to some selected routes ? All of these alternatives will obviously affect the way the service should be run on different routes, and will also affect the level of revenue and the total operating costs.

However, before one considers the alternatives in detail, it is worth mentioning some of the considerations. The first, and the most important one, is the level of overall travel demand. How significant is the level of overall existing demand ?. If the level of overall demand is significantly high, then it can be expected that most of the routes in the network will be able to sustain competition. Hence, the new entrant will be able to allocate all his vehicles safely to any route, particularly to those routes in which the travel demand is expected to be high. However, if the existing overall travel demand is quite low, then the new entrant has to be very careful in examining which route to choose. Of course, it is reasonable to consider just those routes which are expected to sustain competition. However, it might be the case that all the routes in the system will be unable to sustain any competition at all. In this situation, it is not feasible for the new entrant to enter the market.

The second consideration is the existing condition of each route in the system. How does the existing operator run his fleet in the system, and how does he allocate his resources to the network ? If, for example, the existing operator runs his fleet only on some particular routes, and keeps other routes without any bus service, then the new entrant will have the opportunity of taking the empty routes, and serving them as a monopoly operation in the hope that travellers will be generated on those routes. The likely case would be that the new entrant would prefer to choose an empty route, since the risk of suffering a deficit is less than on competitive ones.

Furthermore, if the existing operator operates his fleet on all routes in such a way that demand on some particular routes becomes too high, then it is reasonable for the new entrant to consider those routes as possible candidates for allocating his fleet. Again, it has to be recognised that because of the interaction between routes in the system, the new entrant must be aware of the possible changes in the level of demand on that particular route. This is because the level of demand on some routes tends to change from one particular situation to another, as the competitor is likely to change his service from time to time.

The third factor that should be considered is the structure and the configuration of the network, or, more specifically, the location of each particular route. If the structure of the network is dense, or the location of one route is close to another, then it can be expected that the interaction between routes will be strong. Hence, the operator should consider the routes as a system rather than as individual routes. A comprehensive and integrated view is therefore needed. One has to consider the whole network more carefully and in more detail. However, if the structure and the configuration of the route network in the system is quite sparse, then it can be expected that the interaction between routes will not too strong. Consequently, one can consider each particular route individually as a self-contained route, in which the level of demand can be assumed to only depend on the service provided on the route concerned. Here, the operator may set the strategy for each particular route independently, and may ignore the possible effects caused by other routes. What he needs to consider is the operational condition of the existing operator on the route concerned.

Given that the new entrant has a number of buses in his fleet, he can consider various possible strategies regarding the allocation of buses. The following are some of the strategies :

- Operate all of the vehicles available on one particular route.
- Spread all the vehicles over the network so that bus competition will occur on every single route.

In what follows the two strategies mentioned above will be examined.

11.6.3. Choosing the right route

Let us suppose that the new entrant intends to allocate all the vehicles available only to one particular route. This means that competition will occur on one particular corridor only, the other routes operating in a monopoly, or, maybe without any service at all.

The obvious advantage of this strategy is that the new entrant will be able to concentrate all his attention on one particular route, in the sense that he only needs to consider what his competitor's strategy is on that particular route. Of course it would be better if he also knew the service conditions on other routes in the system, since they will affect the level of demand for the route to which he intends to allocate his fleet.

The other advantage to be expected from this strategy is the simplicity of its technical and administrative. It can be expected that the fleet will not need too many workers for maintenance or administration. Hence, the allocation of resources tends to be effective and efficient. The operation also becomes more efficient since garages can be located in a place with good access : it can be located either at the end or in the middle of the route. With this strategy controlling the bus operation becomes relatively easy and cheap since only a few people are needed to effect it.

Since all the vehicles are allocated to one particular route, it is likely that this service will become more frequent. Thus, the new entrant will be able to offer a good service to the travellers. It can be expected therefore that the service will be able to capture the market on the route operated. This advantage becomes more apparent if the level of demand on that particular route is high, so that the revenue generated from the operation is expected to be able to cover its operating costs.

However, it should be recognised that this strategy is appropriate only if the size of the fleet is not too big, since through allocating too many buses to one particular route will make the operation unprofitable. When the new entrant allocates too many buses to one particular route, operating costs tend to be relatively higher than revenues, particularly if the level of demand on the route to which the fleet is allocated is not significant.

Although this strategy has some advantages, however, it has a weakness. If, for example, the new entrant allocates his fleet to a route where the level of demand is low, then it can be expected that the revenue generated from the operation will be less than its operating cost, so the operation is expected to go into deficit. Hence, the risk of bankruptcy is very likely. Because of this weakness, it is very important to allocate the fleet to the right route, which will generate a high level of revenue.

In choosing the route, one would intuitively consider those routes that are expected to produce a profitable operation. At this point one would consider those routes in which the demand is expected to be heavy enough to sustain at least two operators. However, the problem for the new entrant is to know which route in the system has heavy demand. Theoretically, one would consider a route covering a large corridor area with a quite dense population as one which could have a high travel demand. This implies that one could consider a long route passing through a city centre as one with a high level of demand. However, it should be recognised that to compete for a service on a long route and maintaining a good service one needs to operate a big fleet. Hence, there is a risk that the money generated from fares will not be sufficient to cover operating costs.

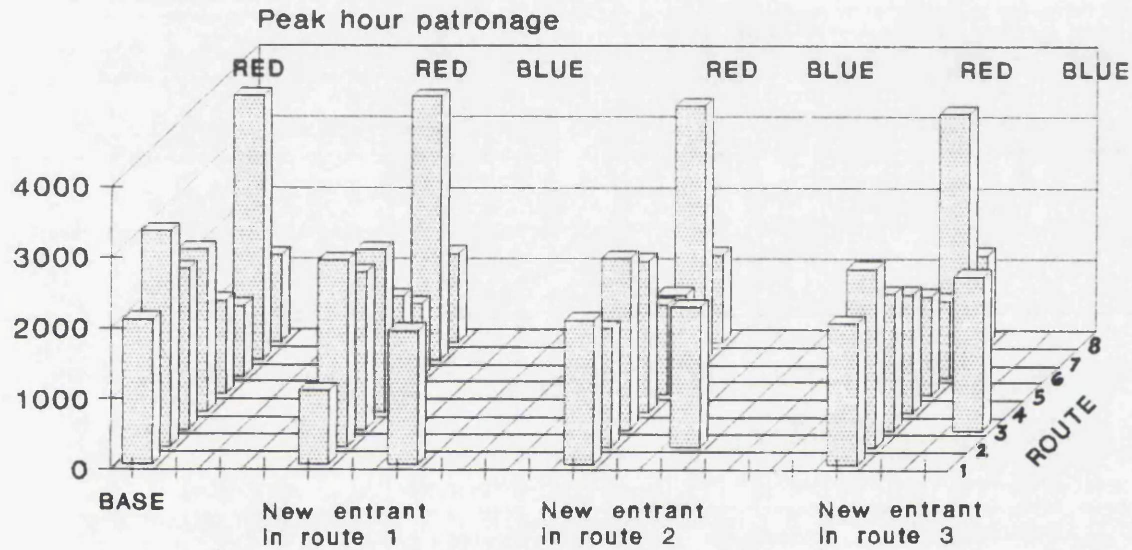
Another consideration in choosing the route is the operational condition of the existing operator on the route concerned. How does the existing operator run the service, and what is the resulting operational performance ? If the new entrant chooses a route in which the existing operator runs a fleet with a low frequency service, then it can be expected that the new entrant will be able to capture the market on that particular route when he operates with a high frequency service.

In the following, the problem of allocating all vehicles to one particular route is investigated using the model. The model was run using a situation in which the new entrant operates all his vehicles on one particular route. It was assumed that the existing operator maintains his service as mentioned in *Table 12.4.*, whereas the new entrant considers four different options : *1)*, to operate 11 double-decker buses, *2)*, to operate 21 standard buses, *3)*, to operate 24 midi buses, and *3)*, to operate 40 mini buses. In each case the new entrant adopted a flat fare system with a fare of 50 pence per trip.

Figs. 11.2 to *11.4* illustrate the operating conditions of the two operators for *Case 1*, that is, when the new entrant decided to operate 11 double-decker buses and concentrate all of them on one particular route. They show the implications of this strategy for the performance of each operator, in terms of peak-hour patronage, when the new entrant operates his fleet on various routes.

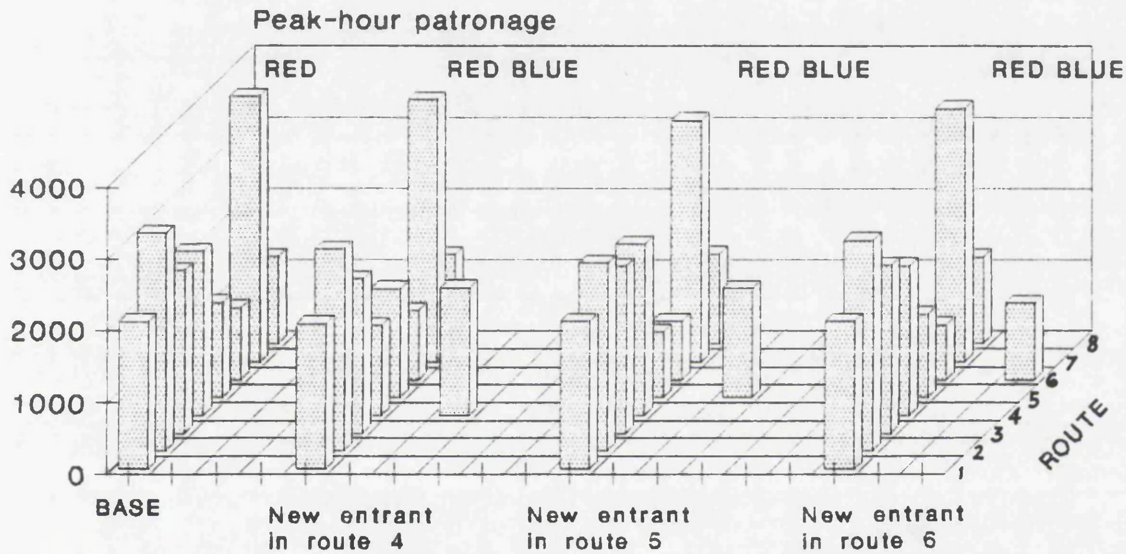
It can be observed from the charts that the level of peak-hour patronage for the new entrant varied from one route to another. It was found that its level depended on where his fleet was operating and on the service provided by the existing operator. The service provided by the existing operator is also important, as it determines how significant the competitiveness of the new entrant was on that particular route compared with the existing service.

Fig. 11.2. Competition in a network : Allocates all vehicles in one route



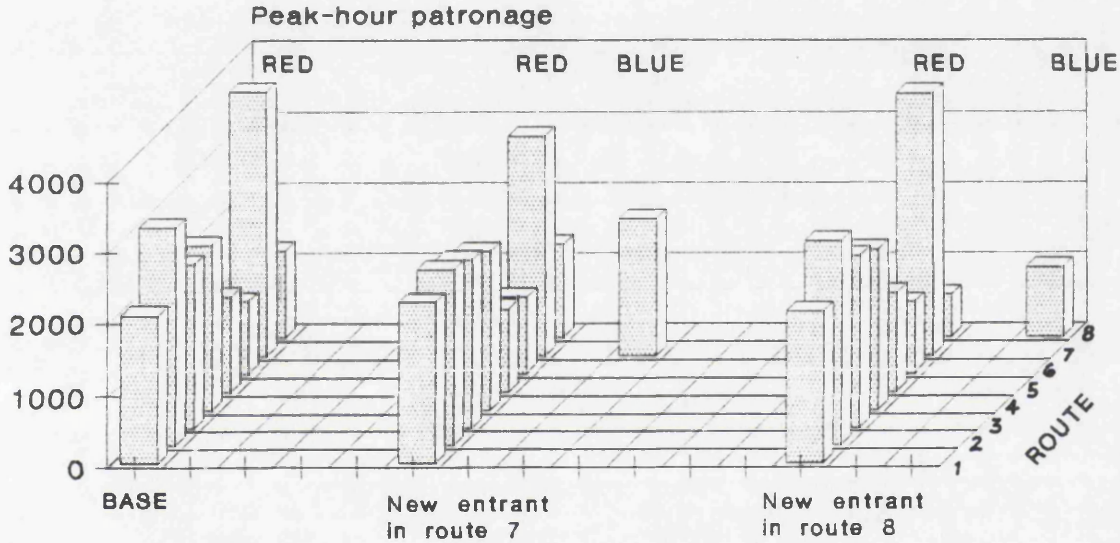
ROUTE	RED	RED	BLUE	RED	BLUE	RED	BLUE
8	1225	1244		1228		1229	
7	3728	3704		3575		3467	
6	1000	1034		1161		1089	
5	1323	1393		1270		1396	
4	2293	2299		2140		1676	
3	2271	2235		2428		1929	2179
2	3048	2644		1686	1991	2533	
1	2051	1047	1900	2052		2011	
TOTAL	16939	15600	1900	15540	1991	17509	2179

Fig.11.3. Competition in a network : Allocates all vehicles in one route



ROUTE	RED	RED	BLUE	RED	BLUE	RED	BLUE
8	1225	1250		1261		1213	
7	3728	3675		3386		3554	
6	1000	965		813		759	1063
5	1323	1515		910	1520	1159	
4	2293	1248	1780	2396		2095	
3	2271	2152		2334		2347	
2	3048	2819		2627		2952	
1	2051	2023		2059		2064	
TOTAL	16939	15647	1780	15786	1520	16143	1063

Fig. 11.4. Competition in a network : Allocates all vehicles in one route



ROUTE	RED	RED	BLUE	RED	BLUE
8	1225	1315		598	977
7	3728	3102	1925	3702	
6	1000	1067		995	
5	1323	1142		1372	
4	2293	2208		2231	
3	2271	2330		2398	
2	3048	2448		2859	
1	2051	2241		2108	
TOTAL	16939	15853	1925	16263	977

In general, it can be argued that the level of patronage carried by the new entrant will depend on his competitiveness, and also on how much demand a competitive market can generate. If the competitiveness of the new entrant is greater than that of his competitor, so that his service is more attractive, and if the total number of travellers generated is high, then it can be expected that the level of patronage carried by the new entrant will be significant. It is worth mentioning that the competitiveness of the new entrant will depend on the service provided by the existing operator, whereas the level of demand at which competition occurs depends on the location of the routes in the system. Take, for example, routes 5 and 6 which have a location close to other routes. When the new entrant operates his fleet on either route 5 or 6, it is found that the competitiveness of his fleet is greater than that of the existing operator (which has eight buses on route 5 and seven buses on route 6), and the level of patronage generated through competition is very high, so that the level of patronage carried by the new entrant is even higher than that of the existing operator in the base condition.

Since in this case (*Case 1*) the two operators offer services with the same type of vehicles and the same fare system and fare level, it is clear that their market share on the routes where they compete will depend on their proportion of the fleet. This means that the new entrant will have a significant level of peak-hour patronage if the service provided by the existing operator is less frequent than his, and if he operates his fleet on a route where the number of travellers that can be generated is quite high. On the contrary, the new entrant will have a smaller patronage if he allocates his fleet to a route where not many travellers can be generated through competition. The level of patronage carried will be even lower when the competitiveness of the new entrant is less than that of the existing operator.

In *Case 1*, it has been found from the model that the new entrant received the highest level of peak-hour patronage when he operated his fleet to route 3, and got the lowest when he allocated his fleet to route 8. The new entrant got the highest level of patronage partly because the level of travellers generated through competition on this route is quite significant, and partly because his service (which operates eleven buses) is more attractive than that of his competitor (who operates ten buses). The new entrant got a very low level of patronage on route 8 simply because the total number of travellers generated through competition on this route was not too significant. Therefore, although his fleet was more attractive than that of the existing operator, its patronage was very low.

Because the level of operating costs incurred by the new entrant was the same regardless of his fleet allocation, it is apparent that his profit will depend on the level of patronage carried. The greater the patronage the greater his profit will be. In *Case 1* it is found that the new entrant got most profit when he operated his fleet on a route in which he got most patronage, namely route 3, and got the lowest profit when he operated on route 8.

If one tries to compare the operational performance of the existing operator in the base condition with the performance when the new entrant operated his fleet in the network, the total level of demand on the route in which competition occurs will always be higher than in a non-competitive market (base condition). This indicates that bus competition on a particular route tends to attract more passengers to use the services. This condition is predictable, as competition makes the total frequency of the service on the route increase significantly. This result actually agrees with what has been suggested in the single route case described in *Chapter 7*.

However, it should be recognised that the level of increase in patronage in a route in which competition occurs varies from one route to another.

It is found that the percentage increase in total patronage is not only a function of the percentage increase in the total level of frequency, but also, a function of how important the location of the route in the network is.

The other important feature that can be observed from these exercises is the interaction between routes in the system. The performance of the bus operations of the existing operator on each particular route in the system tends to change whenever the new entrant allocates his fleet to one particular route. This change is particularly significant when the new entrant allocates his fleet to a route whose location is close to another route.

Furthermore, if one considers the change in operational performance from one situation to another, one finds that the increase in the number of travellers on one particular route is always at the expense of another route (it can be positive or negative). From these results, therefore, it can be suggested that the network has to be considered as a system.

When the new entrant decides to operate smaller vehicles (standard buses, or midibuses, or minibuses), the results from the exercises of the model show that the general features of bus operation performance of the two competing operators are similar to what has been described above : the total number of travellers on the route in which competition occurs always increases significantly, whereas the level of demand on the other routes in the network tends to change (either increase or decrease). The difference is in the detailed operational performance of each operator.

Table 11.5 shows the summaries of the results of *Cases 1* to *4* (a complete results of these exercises can be seen in *Appendix 2*). It shows the best and the worst operational performances of the new entrant when applying different types of vehicles.

From *Table 11.5*, it can be observed that the introduction of smaller vehicles (*Cases 2* to *4*) tends to make the operational performance of the new entrant better than that of *Case 1*. In general, the level of patronage carried by the new entrant increases considerably when small vehicles are used. This trend happens not only when the new entrant allocates all his fleet to one particular route, but also when he allocates all his fleet to the other routes in the network. These results are not surprising, as the use of small vehicles makes his fleet more attractive than when he uses 11 double-decker buses. For example, when the new entrant decided to operate midibuses (*Case 2*), its fleet size becomes 24 buses, and because the average running speed of midibuses is faster than big ones, it is likely that the new entrant could offer a high frequency service.

TABLE 11.5.

THE PERFORMANCE OF THE NEW ENTRANT WHEN ALLOCATES ALL AVAILABLE VEHICLES IN ONE PARTICULAR ROUTE

Case	Vehicle	The best performance			The worst performance		
		Ptrg[1)]	Profit[2)]	Route	Ptrg	Profit	Route
1	D/Decker	2179	108.0	3	977	-155.1	8
2	Standard	3436	297.7	7	1296	-125.4	8
3	Midibus	3834	424.4	7	1346	-136.3	8
4	Minibus	3907	177.9	7	1305	-364.4	8

1) *Peak-hour patronage*
2) *Profit for three months operation (in thousands of pounds)*

The other feature that is worthwhile mentioning is the routes along which the new entrant gets the most patronage. From *Table 12.5*, it can be observed that the route where the new entrant gets the most patronage varies. For example, when the new entrant operates 11 double-decker buses (*Case 1*), he gets the highest patronage when he operates all his fleet on route 3, whereas when he operates 21 standard buses (*Case 2*), or 24 midibuses (*Case 3*), or 40 minibuses (*Case 4*), he gets the highest patronage when he operates all his fleet on route 7. There are two explanations for this feature. First, when the new entrant operates 11 double-decker buses, his service is more competitive on all the routes in the network, except route 7. So, although route 7 has the highest travel demand, the new entrant cannot get a significant level of patronage. He only managed to get a significant level of patronage when he operated his fleet on route where the competition from the existing operator was less and when the total traveller generated through competition was quite high. Second, as the new entrant operates 21 standard buses, or 24 midibuses, or 40 minibuses, his service becomes more attractive than that of the existing operator on all routes in the network, including route 7. Hence, his service will be able to capture the market wherever it operates in the network. Since route 7 has the highest level of demand, it is not surprising that the new entrant will get the highest patronage on this route.

It has to be recognised, however, that despite the advantage of capturing the market by using small vehicles, the risk of facing a deficit still remains. This is particularly so if the new entrant chooses the wrong route for his fleet. Here, the wrong route means the route in which the total travellers generated through competition is low, and the competition from the new entrant is less than that of its competitor. If this is the case, he finds that the revenue generated from the patronage will not be able to cover the operating cost. As a result, it can be expected that he will suffer a deficit. As shown in *Table 12.5*, the new entrant get the lowest patronage when he operates his fleet on route 8, with all types of vehicles.

Given all the results mentioned above, it can be concluded that the best way for the new entrant to get the highest profit is to buy 24 minibuses *(Case 3)* and allocate them to route 7.

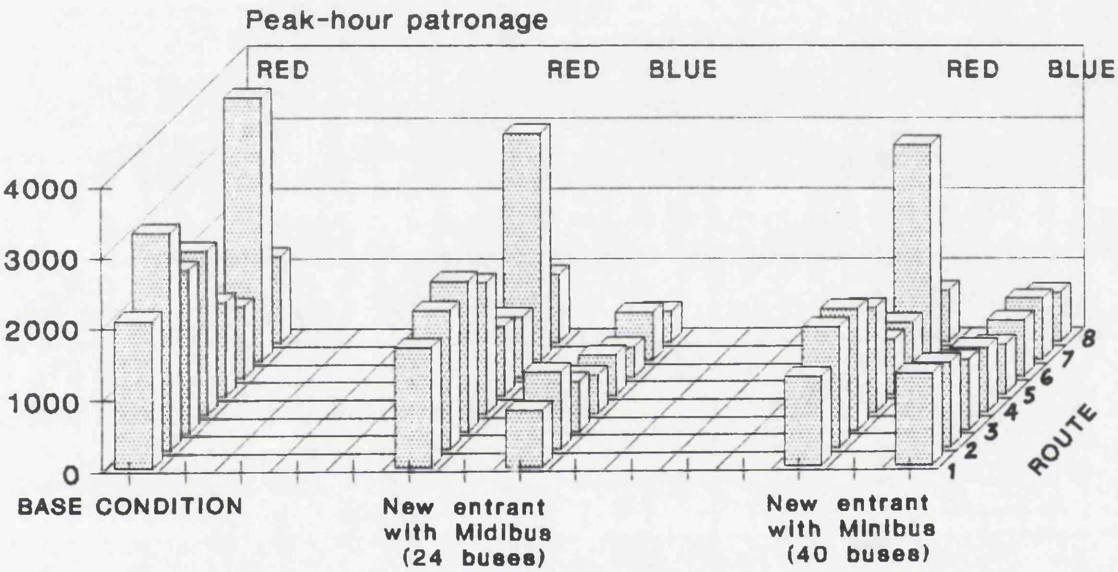
11.6.4. Spreading the fleet over the network

Another possible strategy for the new entrant is to allocate all the vehicles available throughout the network, so that on every single route there will be competition between two different services. The obvious implication of this strategy is that the new entrant has to be ready to fight against the existing operator on all fronts of the network. The potential advantage of this strategy is that the new entrant will be able to cross-subsidise his service from one route to another. The profit on one route, for example, can be used to cover a deficit operation that may occur on another. Hence, the overall service will be able to survive competition better than with the previous strategy since the risk of a deficit is less. The possible disadvantage of this strategy is the need to allocate more people to control the operation of bus services on each particular route. This means that management becomes less effective. Hence, the cost of the operation will be higher. Overall, this strategy seems to be appropriate if the additional operating costs can be compensated by revenue.

Since this strategy means competition in each route in the system, it seems apparent that the level of patronage carried will vary from one route to another. This is expected to be dependent upon the capability of the service on each particular route to compete with the existing operator. The greater the capability of the service to compete with the existing operator, the higher the level of patronage will be.

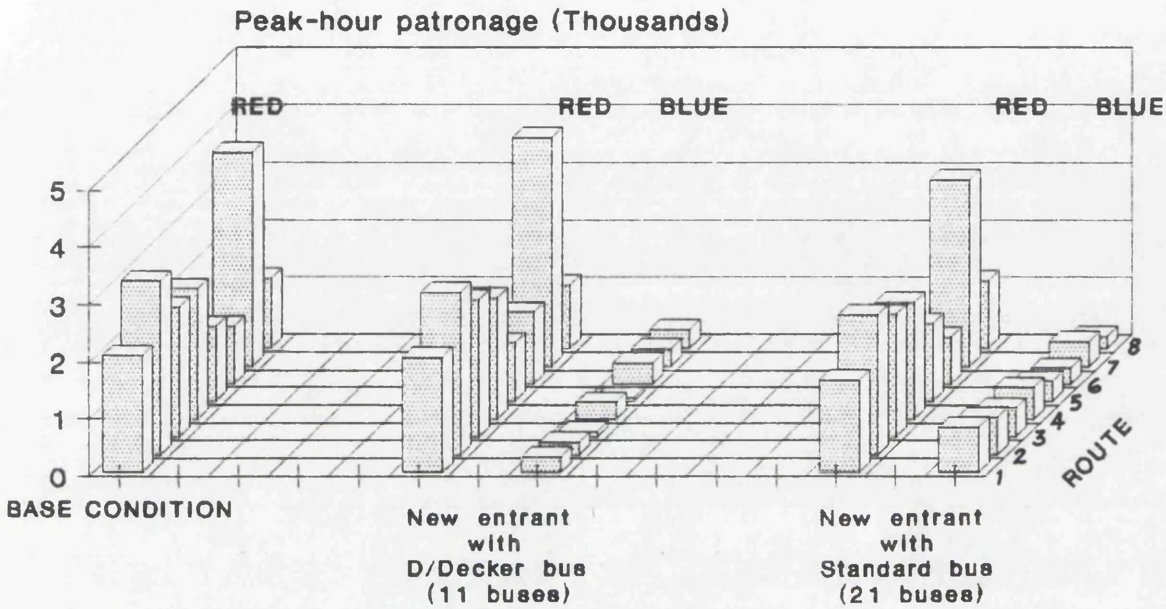
Figs 11.5. and *11.6.* show the results of model exercises when the new entrant allocates all the vehicles available to each route in the system. Four possible cases were examined in these exercises : *1)* the new entrant decides to choose 11 double-decker buses as his fleet (alternative 1) and operates 1 or 2 buses on each route, *2)* the new entrant decides to operate 21 standard buses (alternative 2) and operates 2 or 3 buses on each route, *3)* the new entrant decides to

Fig. 11.5. Competition in a network : Spreads all vehicles over the network



ROUTE	RED	RED	BLUE	RED	BLUE
8	1225	973	432	732	698
7	3728	3217	668	3050	863
6	1000	858	430	769	799
5	1323	975	564	772	701
4	2293	1850	539	1474	912
3	2271	2119	696	1711	996
2	3048	1948	1079	1705	1193
1	2051	1675	797	1256	1293
TOTAL	16939	13615	5205	11469	7455

Fig. 11.6. Competition in a network : Spreads all vehicles over the network



ROUTE	RED	RED	BLUE	RED	BLUE
8	1225	1107	323	1186	798
7	3728	3996	306	3263	652
6	1000	1257	378	820	508
5	1323	1027	65	1371	563
4	2293	2135	297	2054	366
3	2271	2401	94	2158	290
2	3048	2844	225	2453	436
1	2051	2030	275	1633	216
TOTAL	16939	16797	1963	14938	3829

operate 24 midibuses (alternative 3) and operates 3 buses on each routes, and *4)* the new entrant decides to operate 40 minibuses (alternative 4) and operates 5 buses on each route. In these exercises it was assumed that the fare system and fare level adopted by the new entrant was the same as that of the existing operator. It was also assumed that the extra costs as a result of spreading the vehicles throughout the network were ignored. The total operating costs were therefore calculated only on the basis of the number of vehicles operated.

From the graphs depicted in *Figs 11.5* and *11.6*, it can be observed that the success of the new entrant in applying this strategy depends solely on the attractiveness of his fleet, or, more precisely, on its capability to compete with the existing operator on each particular route in the network. When the new entrant chooses double-decker buses, for example, it was found from this exercise that he gets the lowest level of patronage compared with the other alternatives. These results are not surprising as the choice of double-deckers makes his fleet less attractive than that of the existing operator on each particular route. With this alternative the new operator can only operate 11 buses, which means that he operates only one or two buses on each route to compete with the existing operator who has a considerable number of buses on each route. Since both operators run the same type of vehicle with the same fare system, the level of patronage carried by each operator will therefore depend on the proportion of each fleet in the route. In this case the new entrant only got a mere 10 - 20 % of market share on each route, as it only ran 1 or 2 buses compared with the existing operator who runs at least 6 buses on each route.

When the new entrant operates small vehicles, the results of competition on each route were better. The level of patronage carried by the new entrant increased considerably compared with when he operated double decker buses. These results are not surprising, since the introduction of small vehicles improves the competitiveness of his fleet on each route. This is true because, for the same amount of money the new operator can provide more vehicles on each particular route, and as the small buses have a faster speed the service on each route becomes more frequent. From these exercises it was found that the new operator got the most patronage when he introduced 40 minibuses, that is when the new entrant operated 5 minibuses on each route.

Although the level of total operating costs needed to run minibuses is higher than for the other alternatives, it is found that in terms of profit the choice on minibuses is the best in this scenario. This is predictable as the level of revenue generated was relatively higher than the operating costs.

11.7.4. The best strategy

Given the results of the two possible strategies mentioned in the previous section, one may come to the question of the best possible strategy to for the new entrant to adopt to compete with the existing operator if he only has a certain amount of money to spend on providing the vehicles.

To answer this question, consider the summaries of the results of the two strategies mentioned in the previous section shown in *Table 11.6*. It can be observed that in terms of patronage carried or profit, for any type of vehicle, strategy 2 seems superior to the best of strategy 1.

The first strategy, which was to allocate all the vehicles available to one particular route, seems to be appropriate if the size of the fleet is not too big and if the new entrant knows exactly to which route should he allocate his fleet so as he get the highest possible patronage. This means that this strategy is appropriate if the new entrant is familiar with the network, and knows the condition of the route well.

TABLE 11.6.

THE BEST OPERATION PERFORMANCE OF THE NEW ENTRANT

Vehicle		Strategy 1 (concentrate on one route)		Strategy 2 (spreads over the network)	
		Patronage[1)]	Profit[2)]	Patronage	Profit
D/decker	(11)	2179	108.0	2505	166.6
Standard	(21)	3436	297.7	3829	394.9
Midibus	(24)	3843	424.4	5598	794.6
Minibus	(40)	3907	177.9	7445	930.4

1) *Peak-hour patronage*
2) *Profit for three months operation (in thousands of pounds)*

If the new entrant is not too familiar with the condition of the network, however, strategy 1 will not be feasible. This is due to the fact that it is very difficult for the new entrant to identify which route in the network will have the highest level of travel demand. There is a risk of a new operator to running into deficit if he chooses the wrong route.

The second strategy seems to be more promising. This can be observed from the fact that the new entrant does not need to know the situation on each particular route in the network. What he needs to do is to spread all his vehicles evenly over the network. Of course, it would be useful for the new entrant to know the situation on each particular route, as he could avoid those routes with a very low demand.

Overall, if the additional operating cost which incurred as a result of spreading vehicles over the network is considered to be very marginal, then it can be argued that the second strategy is likely to be better than the first one in any case.

Given these arguments, one may come to the conclusion that if the new entrant has a certain amount of money and tries to compete with the existing operator, then the best strategy for him to adopt is to buy small vehicles (minibuses) and spread them throughout the network.

11.7.5. Fare strategy

The strategies described above are all concerned with the choice of type of vehicle and the method of allocating them to the network. The other strategy that is likely to be considered by the new entrant is through the fare system and adjusting the level of fares. This strategy is likely to be adopted when the new entrant has decided on the type of vehicle to operate with and has also decided on the route they will be allocated to.

The formulation of a fare strategy in a competitive environment on a network system seems to be more complicated than in a competitive environment on a single route. This is because the implications of one particular fare strategy in a network are wide ranging. A change in fare level on one particular route, for example, will not only affect the allocation of demand on the route concerned, but, more widely, will also change the allocation of demand for the other routes in the network. This expectation is derived from the fact that the perception of travellers towards fares is significantly important compared with other elements of the journey. A change in fare level or fare system on one particular route, for example, will change the decision of some passengers regarding their journey path. It can be argued therefore that there will be some changes to the allocation of travel demand in the network : some travellers will switch their journey from one route to another.

Considering the features mentioned above, it is clear that two factors have to be considered if a new entrant tries to enter the market at a different fare level and with a different fare system. The first relates to the ability of the service to generate more travellers on the route concerned, and the second relates to the ability of the service to compete with the existing operator.

If the new entrant sets the level of fare on his service on one particular route in such a way that it is cheaper than that of the competitor, then the obvious thing that can be expected is that the ability of the new entrant's service to capture the market becomes greater. Moreover, as the new entrant introduces a service with a cheap fare on one particular route, some additional travellers will be generated. This derives from the fact that travellers' awareness of the route increases. Overall, it can be expected that the introduction of a cheaper fare to compete with the existing operator will raise the level of patronage.

It is worth mentioning that the ability of the service to attract more travellers depends on the location of the route concerned, as well as on the structure of the network. If the location of the route in which competition occurs is close to other routes, and if the structure of the network is dense, then it can be expected that the number of travellers attracted will be significant. In this case, it is most likely that the travellers attracted are those travellers who switch their path from other routes, those who switch from walking trips, and also new passengers generated. However, if the location of the route is isolated, and the structure of the network is sparse, the number of new travellers that are attracted is expected to be very small, and most of them will be from those who have switched from walking to a bus journey.

In the following exercises the importance of a fare strategy is examined. The situation under consideration is the same as the previous section, that is the situation when a new entrant intends to enter the market. The problem to be examined was the type of fare system the new entrant should adopt for a particular strategy.

Let us consider again *Case 1* of strategy 1 mentioned in the previous section. In this strategy the new entrant enters the market with 11 double-decker buses, and allocates them to one particular route. When the new entrant adopts the same fare system as the existing operator (flat fare system of 50 pence per trip), it has been found that the new entrant gets the most profit when he allocates all his vehicles to route 3 and get the worst performance when he allocates them on route 8 (see *Figs. 11.2. and 11.4.* and *Table 12.5*). To examine other possible fare systems, this strategy was tested again for a situation where the new entrant introduced : *1)* stage fare with a fare of 35 pence, 50 pence and 70 pence per trip for a short, medium and long journey respectively, and *2)* distance-based fare with an initial fare of 25 pence and an additional fare of 7 pence per kilometre. *Table 11.7.* shows the summaries of the results. It shows the two extreme performances of the new entrant : when he allocates his fleet to the right route (with the highest level of patronage and profit), and when he allocate his fleet to the wrong one (with the lowest level of patronage and profit). The complete results of these exercises, however, can be seen in **Appendix 5**.

It can be observed from the table that a fare strategy has a strong influence on the results of competition. In general, it can be observed that the route where the new entrant gets the most patronage was the same regardless of the fare system. The difference is in the level of patronage. In these exercises it was found that the route on which the new entrant gets the most patronage is route 3.

It can also be observed from the table that the introduction of a stage fare or distance-based fare resulted in two advantages for the new entrant. First, it attracted more passengers to use the route in which competition occurs, and, second, it increased the attractiveness of the new entrant compared with the existing operator.

TABLE 11.7.

THE PERFORMANCE OF THE NEW ENTRANT WHEN INTRODUCING VARIOUS FARE SYSTEMS

FARE SYSTEM	The best performance			The worst performance		
	Patroge	Profit	Route	Patronage	Profit	Route
Flat fare	2179[1] *(53%)*[3]	108.0[2]	3	977 *(62%)*	-155.1	8
Stage fr	2945 *(67%)*	126.1	3	1444 *(84%)*	-146.1	8
Distance-based fr	3627 *(72%)*	182.6	3	1397 *(78%)*	-187.8	8

1) *Peak-hour patronage*
2) *Profit for three months operation (in thousands of pounds)*
3) *Market share in the route concerned*

It can be seen from the Table that the level of patronage carried increased when the new entrant allocated his fleet to route 3 and introduced a stage fare and distance-based fare. This indicates that with these fare systems the number of new travellers attracted was quite significant and the new entrant was able to capture the market. These results are predictable as the introduction of a distance-based fare makes the service offered by the new entrant more attractive than that of the existing operator, particularly for those passengers who use the service for short journey trips.

From the system of fares introduced by the new entrant the results show that a distance-based fare gives the new entrant the best performance, in terms of patronage as well as in terms of profit. These results are not surprising as a distance-based fare offers a very low fare level (minimum fare price 25 pence) compared with a stage fare (minimum fare price 35 pence).

When the new entrant allocates all his fleet to the wrong routes (i.e the routes which have a very low demand), the introduction of a stage fare and a flat fare also have an advantage, in the sense that it generates more travellers to use the route, and therefore increases the level of travel demand, and puts the service in a better position to capture the market. It can be seen from the Table that the level of patronage carried by the new entrant increases when he operates all his fleet on route 8 with either a stage fare or distance-based fare. However, because route 8 is a very short route, and most of the travellers who use the route are short journey travellers, it is not surprising that the operation of the new entrant suffers runs at a loss.

From these results, it can be argued that a fare strategy can be used by the new entrant to his advantage in competing with the existing operator in a network. This is particularly so if he could offer services in which the fare level is lower than that of the competitor, and if it is adopted on a route on which the level of demand is high.

12.8. Conclusions

In this chapter the features of bus competition on an urban network system were investigated using the *COMBO.2* model. This chapter has concentrated on an investigation of strategies for a new entrant when entering a competitive market in a network system. The operating strategies considered in this chapter were in terms of : vehicle allocation, vehicle type and the fare system.

From the model exercises it was found that it is very important for the new entrant to decide on a good operating strategy before entering the market, since competing with an existing operator with the wrong strategy will incur heavy losses.

Ideally, in deciding on which strategy to adopt, the new entrant should consider the existing situation of each particular route in detail such as : the level of travel demand, the size of the competitor's fleet, the fare system of the competitor and so on. These are important, as the main idea behind the formulation of operational strategy is to make the service offered more competitive and capable of attracting more passengers through competition.

However, due to the fact that information about the situation of each particular route in the network is difficult to obtain, it is apparent that the new entrant will have difficulties in deciding on his operational strategy for his vehicle. Nevertheless, given such a situation, it was found that the new entrant still had a chance of producing a good performance with a simple approach. Take, for example, the strategy on the allocation of vehicles in the network. Among some possible approaches considered in the model exercises, it was found that the new entrant could produce a good operational performance if he spread his available vehicles evenly over all the network. This approach is valid for all types of vehicles.

In terms of the type of vehicle to use for the entrant to use, it was found that for a particular amount of money available, the use of a small vehicle will produce a good performance, since the fleet on offer becomes more attractive and more competitive than that of the existing operator.

Given the two findings mentioned in the previous paragraph, it can be suggested that the new entrant will perform well in competition with the existing operator if he uses small buses (minibuses) and allocates them in such a way that there is competition-on-the-road in every single route in the network.

In deciding on the fare system to adopt in a competitive situation, it was found that the fare system that differentiates fares on the basis of distance (distance-based fare and stage fare) produces a good performance. This is because the service offered becomes very attractive for those travellers who have a short journey trip, but at the same time is still capable of attracting some long journey travellers, particularly those who are in a high income group.

CHAPTER 12
CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

12.1. Introduction

This last chapter of the thesis summarises the conclusions of the study and outlines the proposals for further research. The purpose of the former part is to present the main lines of argument and bring together the research findings and their implications. In the latter part some directions for further research arising from the investigations described in this thesis are presented. This chapter has been organised in such a way that it follows approximately the order of the main body of the work.

12.2. The deregulation of bus industry

The first two chapters of the thesis reviewed the condition of the public transport industry. It is clear that deregulation in the public transport industry in a sense was one of the answers given by some experts (and some governments) to the problem of the industry's decline in recent years. It was, in fact, the manifestation of the belief that only through deregulation can the productivity and efficiency of public transport be increased, and that the force of the public transport market is capable of stimulating adequate responses for public transport services.

In most cases, the form of deregulation is created by introducing a free market regime within the industry, that is by allowing the operators to run the service commercially. Within the framework adopted in Britain anyone can participate in the provision of the public transport service, provided that the service has been registered.

The people who are directly affected by this new environment are the operators, and in general, deregulation has forced them to change the way they operate the service. It changes to a situation where financial constraint becomes the main issue. The operation of bus services has become more commercial than before and the need for greater accountability has increased. They now need to have greater awareness of the cost and revenue implications of their decisions. The operators therefore need to have new skills so that they can match accurately the service offered with the pattern of demand and, more importantly, they can estimate revenue more precisely. This implies that extra care is needed when decisions have to be made on the route to operate, on the type of vehicle to use, on the system and level of fare to adopt, on the level of service frequencies to offer, and so on.

One possible way of coping with this new challenge is by means of a modelling exercise where it is possible to examine the implications of the various possible operational strategies for the bus service. With this as the starting point, the research was aimed at the development of a model of bus operation that can be used for the purpose mentioned above.

12.3. Bus operation modelling

It is clear that modelling can play an important role in the study of bus operation. In general, there are two ways of modelling bus operation, either analytically or through a simulation model. In an analytical model the relations between the variables are expressed using a deterministic analytical expression which is usually in the form of an optimisation problem, while in a simulation model the relationships between variables are, to some extent, represented to replicate the step-by-step interaction processes between elements of the system.

Of the two types of model, simulation models are more applicable to the analysis of bus route operation for a number of reasons : they are able to represent the movement of buses and passengers more realistically than in the analytical models, they normally represent the operation of the system by dealing with changes in the system in an evolutionary way and, most importantly, they allow gaming experiments to be conducted on the system in which a human operator interacts with the simulated system as time passes.

This argument led to the conclusion that the better way to represent a bus operation system is by means of a simulation model, since it would be expected to represent the dynamics of the operation far more realistically, including many details of processes such as arrivals at stops, boarding buses, and movements of buses in a route or in a network.

The model that has been developed in this research is a simulation model of bus operation under two different conditions : one is of a single-route bus operation and the other is of a bus operation in a network. Both forms of model have been developed to represent the responses of passengers (demand) toward the service offered by the operator (supply) under monopoly conditions as well as in a competitive market.

The main features incorporated in the model are as follows:

The single route model

1) The vehicle movements in the system were treated stochastically.

2) The arrivals of potential passengers were generated randomly on the basis of a stop-to-stop trip demand matrix.

3) The passenger movements between stops were represented in the model in great detail such that the model can trace the condition of each particular passenger, e.g, from which stop they came and at which stop they left.

4) A passenger will board the first suitable bus that arrives (subject to a capacity constraint) if there is no competition. If there is more than one suitable bus, i.e. competition, the passenger will make a decision whether or not to board this bus on the basis of the perceived generalised cost of this bus relative to that of the next bus of the competing company. The generalised cost includes the cost of the journey, the anticipated travel time and the anticipated waiting time for the alternative bus.

5) Travelcards were represented in the model.

6) Three different fare systems were considered : flat fare, stage fare and distance-based fare.

7) The actions of the operator were input exogenously.

8) The revenues were calculated on the basis of the number of passengers who boarded the bus, and also on the basis of the fare system and fare level adopted.

The network model

1-8 The same as those in the single route.

9) Passengers' decisions on the path they would take in their journey (and therefore on the specific route) were formulated on the basis of the disutility of the journey which included : walking time to the stop, waiting time, money fare for the trip, in-vehicle time, transfer time (if necessary), and walking time from the bus stop to the destination.

10) Probabilistic multi-path assignment was incorporated in the model to represent the allocation of travel demand to the routes in the network.

The model performance has been assessed by validation tests using data on bus operation in London. Good accuracy was obtained between average bus loadings predicted by the model and what has been observed in the real world.

12.4. Applicability of the model

The two models developed in this research were essentially models that represent the response of passengers toward the service offered by the operator. Direct interaction between passengers and operator was not represented endogenously, since the behaviour of the operator is too complicated to represent in the model. Consequently, the two models cannot be used to predict or to estimate the likely outcome of competition, but, rather, they can be used to estimate the implications of various operating strategies of bus operation, both in a monopoly and in a competitive environment.

This feature has some potential advantages in terms of its application. The first is the applicability of the model as a decision-making tool in the operation of bus services. As has been shown in *Chapters 7, 10* and *11*, the models have been used to analyse the operation of services on some London bus routes. The model was used to investigate possible operating strategies for an operator to adopt if he intends to operate bus services on a route or on a network. The operating strategies were represented in terms of service frequency, fare system, vehicle type and the route to operate (in a network system). Moreover, it was shown that the model can also be used to investigate the best possible strategy to be adopted for a new entrant who intends to enter the competitive market (both on a single route and in a network system).

The second advantage of the model is the capability of the model to be used as a gaming simulation model. This is possible, since the model provides the user with an artificial environment of bus operations where some of the characteristics of a real situation are replicated. It enables the 'players' (or, operators) to follow up the consequences of their decisions with rapid responses. Using the model, two individuals can be involved in 'engineered' situations of a bus operation where a number of outcomes are possible. Decisions by the users when they set the values of the input parameters generally have a bearing on the state of the simulated environment. Each set of results is influenced not only by the players' own decisions but also by those of other players.

However, although the models have the capability to predict or to estimate some possible implications of various operational strategies of the operator, it has to be recognised that their results depend on the assumptions taken and the availability of data. For a single route model, it was shown in *Chapter 6* that there were no particular problems in relating the data to the validity of the model. The remaining question is whether the assumptions taken in the formulation of the model represent the real world. Take for example, the representation of the passengers' decision in a competition market situation. It was assumed that the behaviour of passengers in such a situation was best formulated using a logit model. The idea behind the logit model is that the passenger uses his or her perception of disutility of the journey in deciding whether he or she will take the first bus available, or wait for the next bus to come. He or she will take the first bus if he or she feels that the disutility of taking the first bus available is less than that of the competing bus which is expected to come. However, one may argue that this assumption is still questionable, since no empirical evidence has been advanced since the phenomenon of bus competition has only just appeared in recent years. This problem also applies to the network model since competition was also included in this model.

Another matter that is worthwhile considering is the representation of passengers' movement in the network. In the model, it was assumed that passengers' movement in the network is in two stages : first, the decision on the path they will take in their journey and, second, the decision on the vehicle is that they will catch. The advantage of this assumption that the model can represent the movement of travellers in a very disaggregate manner. It allows the model to represent in detail the situation of the bus operation. It is able, for example, to estimate the revenue generated for various fare systems. It is also able to estimate the occupancies of buses along the route, and the expected waiting time at each particular bus stop.

Again, one may argue that this assumption is not always true, since in making the journey some passengers will take the path on the basis of immediate conditions, and not always on the basis of pre-planned journey.

In the process of passengers' allocation to the routes in the network, the model incorporates a probabilistic multi-path assignment. This approach is appropriate to represent passengers' movement in the network. However, it has to be recognised that this does not allow the model to represent passenger movement when overcrowding occurs. One may argue that overcrowding is an important feature in public transport that needs to be represented in these modelling exercises. Ideally, one ought to include equilibrium assignment in the modelling of public transport to represent overcrowding.

The reason for not adapting the equilibrium assignment mechanism in this model is simply the difficulties in finding the appropriate variables to be used as a feedback parameter. It was argued in *Chapter 4* that the main difficulties in representing the feedback parameter in the model is due to the fact that the nature of public transport is different to that of road traffic. In road traffic assignment one can use a flow-speed relationship as the parameter feedback. However, in a public transport model, this is not the case, since overcrowding in public transport has little, if any, effect on the speed of the vehicle.

One possible answer to this problem is to use the waiting time as the feedback parameter, since in the real world the relationship between overcrowding and waiting time does exist. It can be argued that overcrowding deters travellers from using the route in which it happen, since an overcrowded service means a longer waiting time.

The use of waiting time as the feedback parameter in the equilibrium assignment has been tried to be adopted in this model. It is possible to do this because part of the output of the model is the waiting time encountered at each particular bus stop. However, due to the fact that the simulation of vehicle movements on the routes involves stochastic processes, it was found that the value of waiting time produced is not always consistent. It is therefore predictable that an equilibrium condition would be difficult to achieve.

12.5. Bus operational strategies

Having viewed the problems of bus operation, one has to consider some possible scenarios in which bus services are operated. The first related to the characteristics of the route where bus services are run, and the second related to the condition of the market in which the bus services are operated. The characteristics of the routes can be considered under two different conditions : a self-contained single route and routes in a network. Their market condition, however, can be differentiated between a monopoly condition and a competitive regime.

A route is classified as a self-contained route if no other factors, apart from the level of service offered, will affect travel demand on of the route. For a route in a network, however, travel demand will not only depend on the service on the route concerned, but will also depend on the services on the other routes in the system.

In general, it can be argued that the problem of setting an operational bus service strategy in a monopoly is much simpler than under a competitive regime. This is due to the fact that the nature of the market under competition is more dynamic that in a monopoly.

In a monopoly, the problem of setting the operational bus operation strategy is essentially the same as the problem of matching travel demand with the service. Hence, it will be quite easy to set a good operational strategy in a self-contained route, since its level and its pattern of travel demand are easy to identify. However, this is not the case for bus services in a network system. It is rather difficult to set a good operational strategy for the service, since the conditions of the routes under consideration tend to be unstable as the interaction between routes in the network is strong. Hence, the idea of an optimal bus operation performance on a route-to-route basis becomes irrelevant, and optimal performance of bus operations on a network as a whole is more appropriate.

The operational strategy under a competitive regime is more difficult to identify since the factors to consider include not only the characteristics of travel demand, but also the service provided by the competitor. Hence, the nature of the market becomes unpredictable. There will be a strong interdependence between the actions of the operators. The action of any one operator will affect the others, provoking a response leading to competitive strategies being developed in terms of fare, frequency and other operational factors. The problem becomes increasingly difficult to identify when competition occurs in a network system, since the number of variable strategies available becomes significantly high.

The operational problems that have been investigated in this research are twofold : one is the problem of setting the operational strategy under a monopoly, and the other is the problem of a new entrant in setting his strategy when he intends to enter the market.

In a monopoly, factors that need to be considered in setting the operational strategy for a bus service are : *1)* the resources available, *2)* the level of travel demand in the route concerned (for a self-contained route) or, the total level of travel demand in the network (for routes in a network), and *3)* the pattern of travel demand (for a self-contained route), or the structure of the network (for routes in the network).

Moreover, if a new entrant is considering competing with the existing operator, all the factors mentioned above will also need to be considered, with the addition that the new entrant has to consider the existing service provided on the route or routes. Furthermore, in setting the strategy to adopt, the new entrant has to consider : *1)* The possible capability of the service to generate more passengers, and *2)* The possible capability of the service to compete with the existing one.

The following are the summary and some of the findings that can be drawn from the model exercises :

Optimal frequency The problem of setting the right fleet size for a bus operation on a self-contained route is essentially the same as the problem of setting the appropriate service frequency to match the level of demand. For each particular self-contained route, it was found that there is always an optimal frequency at which the operator will get the highest profit. This condition applies for bus operation in a monopoly as well as in competition. Moreover, it was found that the optimal frequency of bus operations depends on the level of existing travel demand and the type of vehicle to be used (in a monopoly), and also on the operational situation of the competitor (under competition).

Vehicle allocation For a bus operation in a network, the problem of setting the right fleet size is the same as the problem of allocating the appropriate number of vehicles to the right route. This is a complicated problem since the level of travel demand on each particular route in the network tends to be unstable and difficult to identify.

It was found that in a monopoly condition, the allocation of vehicles on the basis of the proportion of existing level of patronage was the best possible strategy to adopt in producing the optimal operational performance. For a new entrant who intends to enter the market, however, it was found that the best possible allocation strategy to adopt was to spread available vehicles evenly all over the network. The possibility that the new entrant allocates his vehicles on the basis of the proportion of competitor's existing patronage was not investigated since it was assumed that the new entrant does not know the existing situation of the route in detail.

Vehicle size The decision on the type of vehicle to be used in the operation of a bus service involves two main issues : the ability of the service to generate passengers (and therefore revenue), and the total operating cost. It is clear that for a particular amount of money, the choice of a small vehicle will make the service more frequent, which therefore becomes more attractive and better capable of generating new passengers. However, at the same time, the use of small vehicles also means that the total operating costs will be higher since more drivers are needed to operate them. Hence, there is a trade-off between the revenue and operating costs. The optimal size of vehicle therefore is the one at which there is the greatest difference between revenue and operating cost.

It was found that in most cases the type of vehicle that gives the best operational performance is minibuses (20 seats). This condition applies for a service in both a monopoly and under competition, and both in a self-contained and in a network system. There is one case, however, where midibuses (35 seats) produced the best operational performance, that is when it was used by the operator on a self-contained route where the value of overall demand elasticity to frequency is between -0.2 and -0.5. The minibus is superior if the value of overall demand elasticities to frequency is less than -0.5.

Fare system The problem of setting the fare system on a self-contained route is different to that on a network system. This is because the pattern of travel demand on a self-contained route tends to be unique and stable, whereas the pattern of travel demand on the routes in a network tends to be unstable, since their condition will depend on the service provided on the route concerned and the other routes in the network. Hence, the problem of setting the fare system in a network system is more complicated than that of the self-contained route.

As the pattern of travel demand on one particular route is unique, it is apparent that the fare system that gives the maximum revenue will be the one that sufficiently matches the pattern of travel demand. It was found that for each particular route there is one fare system that gives a maximum level of revenue.

Under a competition regime, however, the decision on the fare system to be adopted is rather difficult to make, since there will be a trade-off between the market share to be captured and revenue to be generated. To win the market share, one can set one's fare system or fare level in such a way that one's service is more attractive than that of the competitor. However, it has to be recognised that winning the market share does not necessarily means running a profitable service. It was found that for each particular self-contained route, there is always one particular fare system and one particular fare level that gives the new entrant the maximum level of profit. This depends on the pattern of travel demand, the fare system applied by the competitor and the level of overall travel demand.

12.6. The effects of deregulation

The following are the general conclusions that can be drawn from the study on the effects of deregulation :

Services Given the fact that deregulation in the bus industry has forced operators to face a more restricted financial situation, it can be expected that most operators will change their attitude and their operational objective to become more profit-orientated. This means that it is most likely that more innovation will arise in the provision of public transport. It is expected therefore that more operators will use small vehicles, and, if possible, more operators will set their fare system in such a way as to match the pattern of travel demand on the route concerned.

Passengers The implications of bus deregulation for passengers will depend on the response of the operators to the new environment, and will also depend on the consequences. If it is true that the operator will use small vehicles, then the travellers will benefit most, since the service on offer to them will be more frequent. It has to be recognised that this will only be the case on routes where the level of travel demand is high. For a corridor area whose level of demand is not too significant, passengers can expect to suffer most. This is due to the fact that the operator will only provide the service which produces a profit, which means that the service on offer for such a corridor area will be low in frequency, which also means the passengers have to wait longer for buses.

The benefit that the travellers can expect to gain when competition-on-the-road occurs is two-fold : one is a possibly better service frequency (as the overall frequency of bus services in the corridor becomes higher compared with that in a monopoly situation), and the other is having more than one option to choose from. However, it has to be recognised that in terms of fare to be paid, this may not be the case.

Competition As the overall level of travel demand tends to increase when competition-on-the road occurs, it is apparent that a new entrant will always have a chance of capturing the market and, if possible, producing a profitable service. However, it should be recognised that because the gain for one operator is at times at the expense of another (its competitor), it is likely that in most cases competition-on-the-road will not last for long. Competition-on-the-road therefore is likely to happen only on routes where the level of travel demand is high enough to sustain two operators.

12.7. Recommendations for further research

The following areas have been identified for further research :

1) Detailed examination of passengers' behaviour in the process of making a journey in an urban public transport system.
2) Detailed examination of the behaviour of passengers in a competitive bus service environment using real data.
3) Incorporation of traffic conditions in the model and also representation of the effect of bus services on traffic conditions.
4) Incorporation of capacity restraint assignment (or equilibrium assignment) in the model by using other feedback parameters.
5) Modifications in the representation of vehicle movements and in the estimation of vehicle operating costs so that it is possible for the model to be used for the analysis of operations of other mode of public transport, such as : tram, underground train and urban railway.

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ABBREVIATIONS

For the simplification purposes, the following abbreviations are used :

Vhcl type = The type of vehicle.

Sys Op = System of operation of the service (it can be OPO, One Person Operated or TPO, Two Person Operated).

Capacity = Capacity of the vehicle (passengers per vehicle).

Fleet Sz = The size of the fleet.

Bus oprtd = The number of buses to be operated on one particular route.

Fare Sys = System of fare adopted :

F : Flat fare system.

S : Stage fare system.

D : Distance-based fare system.

Patronage = The number of passengers carried during peak-hour period.

Highest L = The highest bus loadings in the route.

Occ rate = The average occupancy of the service.

M Share = The percentage of the market captured in the route.

Card Hldr = The number of passengers carried who hold travelcard.

AWT = Ther average waiting time of the passenger in the route (in minutes).

Av Fare = The average fare paid by the passengers.

Gen Cost = The average generalised cost perceived by the passengers (pence).

Tot Op C = The total operating costs of the service in the route for three months operations (in thousands of pounds)..

Revenue = The total revenues generated in the route for three months operations (in thousands of pounds).

Profit = The profit of bus operation on the route for three months operations (in thousands of pounds).

APPENDIX 1

EXERCISE RESULTS OF THE *COMBO.1* MODEL

BUS OPERATIONS ON A SELF-CONTAINED SINGLE ROUTE

BUS OPERATIONS ON ROUTE 85 : STRATEGY ON HEADWAY

Headway	Fleet Size	Patronage	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen Cost
3.47	28	3673	32	987.1	858.4	-128.7	1.98	81.53
4.05	24	3400	33	858.7	797.7	- 61.0	2.02	81.27
4.42	22	3256	35	791.3	764.4	- 26.9	2.45	82.94
4.86	20	3104	37	705.5	730.5	25.0	2.88	85.17
5.40	18	2945	38	645.3	689.5	44.2	3.09	84.93
6.08	16	2776	38	579.5	651.9	72.4	3.42	86.25
6.48	15	2688	38	536.7	630.0	93.3	4.17	88.28
6.94	14	2597	41	506.4	610.9	104.5	4.16	89.20
7.48	13	2502	41	464.1	589.3	125.2	4.20	88.38
8.10	12	2404	42	433.9	565.8	131.9	4.64	89.89
8.84	11	2302	43	391.4	541.5	150.1	4.81	90.21
9.72	10	2194	44	361.6	515.0	153.5	5.35	91.73
10.8	9	2082	42	325.5	488.4	163.0	6.32	93.62
12.15	8	1963	41	289.5	459.7	170.2	7.37	98.27
13.89	7	1836	37	253.6	432.0	178.5	8.77	101.50
16.20	6	1699	35	217.6	341.5	123.9	11.0	108.85

Vehicle type : Double/decker
Fare : a stage fare system with a fare of 35, 50 and 70 pence per trip for short, medium and long trips respectively.

BUS OPERATIONS ON ROUTE 24 : STRATEGY ON HEADWAY

Headway	Fleet Size	Patronage	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen Cost
3.54	29	4438	30	1046.9	959.2	- 87.7	2.03	71.06
3.95	26	4177	30	934.0	901.4	- 32.6	2.28	71.55
4.47	23	3928	32	815.7	849.0	33.3	2.85	73.20
5.41	19	3571	32	686.7	770.3	83.7	3.14	73.96
6.00	17	3389	34	607.4	732.7	125.3	3.51	75.42
6.42	16	3276	35	576.8	707.5	130.7	3.76	75.92
6.85	15	3172	35	541.3	684.9	143.6	3.78	76.58
7.34	14	3064	35	499.6	663.1	163.5	4.37	78.16
7.91	13	2953	37	469.2	637.7	168.5	4.21	77.72
8.56	12	2847	38	433.1	614.9	181.8	4.57	78.21
9.34	11	2716	37	395.3	587.5	192.2	5.23	80.96
10.28	10	2625	37	360.9	566.2	205.4	5.67	81.61
11.42	9	2503	36	324.7	540.9	216.2	6.63	84.42
12.85	8	2316	35	289.1	499.4	210.3	7.87	87.82
14.68	7	2167	32	253.4	439.6	186.2	9.67	93.84

Vehicle type : Double/decker
Fare : a stage fare system with a fare of 35, 50 and 70 pence per trip for short, medium and long trips respectively.

BUS OPERATIONS ON ROUTE 85 : FARE STRATEGY

Fare System	Fare Price	Patronage	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen Cost
Flat	50	2844	37	562.2	627.3	65.2	3.50	83.26
Stage	35/50/70	2793	36	566.5	654.3	87.8	3.41	85.69
Distance-based	25 + 7	2697	36	570.4	691.3	120.9	3.13	90.39

Vehicle type : Double/decker
Fleet size : 16 buses
Average headway : 6.08 minutes.

BUS OPERATIONS ON ROUTE 24 : FARE STRATEGY

Fare System	Fare Price	Patronage	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen Cost
Flat	50	3741	29	752.8	825.2	72.4	3.11	75.26
Stage	35/50/70	3830	30	752.3	827.4	75.1	3.12	74.50
Distance-based	25 + 7	3767	30	747.0	800.7	53.6	3.05	73.32

Vehicle type : Double/decker
Fleet size : 21 buses
Average headway : 4.89 minutes.

BUS OPERATIONS ON ROUTE 85 : FLAT FARE

Fare Price	Patronage	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen Cost
5	5640	62	559.0	124.4	-434.4	4.44	43.89
10	4581	55	556.1	202.1	-354.0	4.11	46.20
15	4056	50	546.7	268.4	-278.3	4.02	50.41
20	3721	47	543.9	328.3	-215.6	3.91	55.37
25	3480	45	571.3	388.8	-182.5	3.62	59.12
30	3294	42	558.8	435.9	-123.9	3.60	63.96
35	3146	41	571.5	485.5	- 86.0	3.49	68.59
40	3022	39	573.5	533.3	- 40.2	3.46	72.87
45	2917	38	570.4	579.1	8.7	3.51	78.28
50	2844	37	562.2	627.3	65.1	3.11	83.26
55	2747	36	564.2	666.6	102.4	3.19	87.22
60	2676	34	563.6	708.3	144.7	3.49	92.80
65	2612	34	564.2	749.0	184.8	3.35	97.68
70	2555	33	575.3	789.1	213.8	3.20	102.30
75	2503	33	574.3	828.2	253.9	3.26	107.98
80	2455	32	579.4	866.5	287.1	3.15	112.41
85	2410	31	571.4	903.8	332.4	3.14	117.08
90	2369	31	565.7	940.6	374.9	3.28	122.23
95	2331	30	571.6	976.9	405.3	3.13	127.40
100	2296	30	571.4	1012.8	441.4	3.23	132.42

Vehicle type : Double/decker
Fleet size : 16 buses
Average headway : 6.08 minutes.

BUS OPERATIONS ON ROUTE 24 : FLAT FARE

Fare Price	Patronage	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen Cost
5	6697	53	562.7	147.8	-414.9	4.80	34.45
10	5439	47	566.7	239.9	-326.8	4.45	38.79
15	4816	44	571.0	318.7	-252.3	4.43	44.31
20	4418	41	566.2	389.8	-176.4	4.47	49.63
25	4132	39	565.7	455.7	-110.0	4.42	54.12
30	3912	36	570.3	517.8	- 52.5	4.32	58.43
35	3735	35	572.4	576.8	4.4	4.31	63.47
40	3588	34	569.9	633.2	63.3	4.37	68.94
45	3464	33	570.0	687.7	117.7	4.21	73.36
50	3356	32	573.5	740.3	166.8	4.20	78.61
55	3261	31	571.9	791.3	219.4	4.20	83.50
60	3177	30	576.7	841.0	264.3	4.04	87.61
65	3102	29	578.6	889.5	310.9	3.91	92.57
70	3034	29	576.2	937.0	360.8	3.97	97.91
75	2972	29	576.4	983.4	407.0	3.88	102,62
80	2915	28	576.5	1028.8	452.3	3.87	107.37
85	2862	28	574.3	1073.2	498.9	3.74	112.10
90	2813	27	574.0	1117.0	543.0	3.83	116.89
95	2768	26	574.2	1155.2	581.0	3.91	122.27
100	2726	26	573.3	1202.6	629.3	3.76	126.93

Vehicle type : Double/decker
Fleet size : 16 buses
Average headway : 6.08 minutes.

which in turn make the service more profitable than the use of big buses (standard or double-decker buses). However, if there is no passengers' response at all to the change on service frequency (which is unlikely will be the case), then the use of standard or double-decker are become preferable for the operator, since the use of small vehicle makes the operating costs higher than the big ones, whilst the level of revenues is the same.

8. Under com p etition, however, the choice of vehicle in a self-contained route will depend on the traffic conditions in terms of congestion. When the traffic flows are low or quite low (not congested), the use of minibuses gives the best performance. This is because the use of minibuses makes the service so attractive to the passengers (since their running speed is high), and can easily capture a large market share. However, as the level of traffic increases, the superiority of minibuses becomes less significant. This is because in heavy traffic the average running speeds of all type of vehicle tends to be the same, which means the attractiveness of the competing service in terms of stop-to-stop journey time will be the same. Hence the use of minibuses makes the total operating costs increase (because of the number of staff requred), but the level of revenue will not increase to the same extent. In heavy traffic (or high traffic flow), the use of midibuses will be preferable to minibuses as their total operating costs are not so significant but they will offer a higher frequency service than larger buses (for a given capital expenditure). Since most urban routes are loaded with heavy traffic flows, it might be argued that the use of midibuses for competition would be the most appropriate one. However, for a small town in which traffic is not the main problem, the use of minibuses to compete with the existing operator would be strongly advised, particularly if the level of travel demand is high enough to sustain two operators.

9.The use of travelcards under monopoly conditions causes a decline in the level of revenue, and, therefore, a reduction in the level of profit. This is because the use of travelcards only make the level

BUS OPERATIONS ON ROUTE 85 : STRATEGY ON VEHICLE TYPE

Elasticity value	Vehicle type	Fleet Size	Patronage	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen Cost
-0.0	D/Decker	15	2793	40	536.3	654.8	118.5	3.04	87.52
	Standard	27	2793	34	610.5	656.5	46.0	1.39	79.63
	Midi bus	31	2793	37	579.9	655.6	75.7	1.12	75.69
	Mini bus	53	2793	32	990.5	655.2	-335.3	0.49	72.44
-0.2	D/Decker	15	2751	40	542.5	645.3	102.8	2.76	86.89
	Standard	27	3160	39	593.5	741.8	148.3	1.49	79.43
	Midi bus	31	3311	43	599.3	777.9	178.6	1.16	76.86
	Mini bus	53	3751	43	979.7	882.5	-97.2	0.58	72.76
-0.5	D/Decker	15	2688	38	537.5	630.8	93.3	2.88	86.71
	Standard	27	3802	45	602.6	897.3	294.7	1.50	80.08
	Midi bus	31	4273	52	577.4	1008.4	431.0	1.27	77.68
	Mini bus	53	5836	62	986.2	1393.0	406.9	0.78	75.35

Fare : a stage fare system with a fare of 35, 50 and 70 pence per trip for short, medium and long trips respectively.

BUS OPERATIONS ON ROUTE 24 : STRATEGY ON VEHICLE TYPE

Elasticity value	Vehicle type	Fleet Size	Patronage	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen Cost
-0.0	D/Decker	15	3830	42	538.7	828.0	289.3	4.05	78.35
	Standard	27	3830	34	553.8	826.9	273.1	1.70	68.73
	Midi bus	31	3830	38	611.2	828.2	217.0	1.66	67.80
	Mini bus	53	3830	33	983.9	824.4	-159.5	0.69	63.18
-0.2	D/Decker	15	3551	39	540.0	768.8	228.8	3.75	77.60
	Standard	27	4080	38	507.7	876.0	368.3	1.92	69.50
	Midi bus	31	4275	41	580.6	913.6	332.0	1.60	66.70
	Mini bus	53	4842	42	967.8	1042.1	74.3	0.81	63.26
-0.5	D/Decker	15	3172	35	540.9	685.3	144.4	3.74	77.36
	Standard	27	4486	40	530.7	962.9	432.2	1.73	68.63
	Midi bus	31	5041	47	554.7	1071.9	517.2	1.67	66.58
	Mini bus	53	6885	53	959.8	1469.4	509.6	0.87	63.14

Fare : a stage fare system with a fare of 35, 50 and 70 pence per trip for short, medium and long trips respectively.

BUS OPERATIONS ON ROUTE 24 : TRAVELCARD

Weekly T/Card	Patronage	Card Holder	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen Cost	Av. Fare
300	4147	3237	32	751.1	481.8	-269.4	3.07	51.50	43.79
350	4087	3071	32	752.1	535.4	-216.7	3.10	54.78	43.88
400	4029	2899	32	754.4	584.3	-170.1	3.15	58.30	43.91
450	3976	2700	31	748.2	631.5	-116.7	3.16	61.24	44.17
500	3925	2539	31	750.7	672.1	- 78.7	3.19	64.36	44.48
550	3877	2350	31	751.4	707.5	- 43.9	2.99	66.38	44.57
600	3831	2191	30	740.9	738.7	- 21.0	3.09	68.97	44.85
650	3788	1997	30	752.9	766.1	13.2	3.02	70.79	45.18

Vehicle type : Double/decker
Fleet size : 21 buses
Average headway : 4.89 minutes.
Fare : a stage fare system with a fare of 35, 50 and 70 pence per trip for short, medium and long trips respectively.

BUS OPERATIONS ON ROUTE 85 : TRAVELCARD

Weekly T/Card	Patronage	Card Holder	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen Cost	Av. Fare
300	3088	2487	40	561.9	359.0	-203.0	3.39	59.11	46.73
350	3044	2386	39	562.5	398.9	-163.6	3.47	62.75	46.76
400	3004	2262	38	565.3	438.4	-126.8	3.52	66.49	46.83
450	2965	2143	38	566.3	474.7	- 91.6	3.32	69.04	47.10
500	2929	2030	38	553.6	508.0	- 45.6	3.59	72.90	47.44
550	2895	1894	38	561.2	539.2	- 21.9	3.45	75.24	47.77
600	2862	1742	37	575.3	567.9	- 7.4	3.37	77.89	48.27
650	2831	1621	37	556.7	591.3	34.5	3.51	80.49	48.57

Vehicle type : Double/decker
Fleet size : 16 buses
Average headway : 6.08 minutes.
Fare : a stage fare system with a fare of 35, 50 and 70 pence per trip for short, medium and long trips respectively.

COMPETITION ON ROUTE 85: New Entrant with Various Service Frequencies

Operator	Headway	Patronage	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen. Cost	Ave. Fare
RED	6.00	2402	33	558.2	563.7	5.4	2.74	84.22	53.18
BLUE	24.30	701	21	141.2	166.1	25.0	3.45	87.67	53.65
RED	6.00	2559	33	561.7	601.1	39.4	2.96	84.68	53.25
BLUE	19.44	622	13	173.7	142.8	-30.9	2.44	81.19	51.91
RED	6.00	2456	33	566.8	576.1	9.3	2.92	84.79	53.18
BLUE	16.20	800	30	210.4	187.0	-23.4	2.44	82.68	52.85
RED	6.00	2343	30	569.2	550.2	-19.0	2.43	83.32	53.23
BLUE	13.89	985	27	250.0	228.8	-21.2	2.51	82.61	52.57
RED	6.00	2375	31	554.6	557.6	3.0	2.44	83.70	53.21
BLUE	12.15	1024	27	281.5	239.2	-42.3	2.13	81.06	52.87
RED	6.00	2331	31	570.6	547.2	-23.4	2.26	82.99	53.22
BLUE	10.80	1140	26	317.2	267.6	-49.6	1.84	81.69	53.16
RED	6.00	2302	33	559.2	542.4	-16.7	2.26	82.72	53.39
BLUE	9.72	1236	25	351.4	288.6	-62.8	2.24	82.72	52.84
RED	6.00	2229	30	566.5	523.0	-43.5	1.95	81.55	53.17
BLUE	8.84	1337	26	390.6	321.7	-68.8	2.35	81.99	52.90
RED	6.00	2171	30	566.4	511.3	-55.1	2.07	82.71	53.38
BLUE	8.10	1501	27	426.7	350.0	-76.8	1.99	81.14	52.82
RED	6.00	2149	29	550.8	503.6	-47.2	2.03	81.83	53.12
BLUE	7.48	1589	27	463.6	373.4	-90.2	2.00	82.24	53.26
RED	6.00	2066	29	556.2	485.2	-71.0	2.02	82.58	53.23
BLUE	6.94	1735	27	492.2	405.3	-87.6	1.92	80.90	52.91
RED	6.00	2123	29	567.5	499.9	-67.6	1.98	82.38	53.39
BLUE	6.48	1742	26	531.4	406.9	-124.5	1.68	80.36	52.94
RED	6.00	1825	25	559.1	425.1	-134.0	1.72	80.47	52.80
BLUE	5.40	2223	28	630.7	521.1	-109.6	1.67	81.06	53.13
RED	6.00	1835	25	557.7	426.0	-131.6	1.62	79.18	52.60
BLUE	5.12	2272	26	660.4	532.1	-128.3	1.73	80.93	53.08
RED	6.00	1870	26	563.8	439.8	-124.0	1.76	81.61	53.30
BLUE	4.86	2294	27	693.2	536.7	-156.5	1.62	80.45	53.01
RED	6.00	1918	27	554.5	452.9	-101.6	1.68	81.61	53.52
BLUE	4.42	2361	25	755.2	549.0	-206.1	1.52	79.19	52.71
RED	6.00	1668	23	552.5	391.8	-160.7	1.42	80.09	53.25
BLUE	4.05	2722	28	839.1	637.8	-201.3	1.64	80.63	53.11
RED	6.00	1709	25	564.4	402.5	-161.9	1.65	81.25	53.39
BLUE	3.74	2790	26	901.3	652.5	-248.8	1.50	80.25	53.00
RED	6.00	1614	23	545.8	376.7	-169.1	1.35	79.27	52.89
BLUE	3.24	3093	24	1020.4	719.7	-300.7	1.34	78.78	52.72

RED : EXISTING OPERATOR
======================
Vehicle type : D/Decker
Fare : Stage fare system (35/50/70p)

BLUE : NEW ENTRANT
==================
Vehicle type : D/Decker
Fare : Stage fare system (35/50/70p)

COMPETITION ON ROUTE 85 : NEW ENTRANT WITH FLAT FARE

Operator	Fare	Patronage	Op. Cost	Revenue	Profit	A.W.T	Gen Cost	Av. Fare
RED	35/50/70	1119	548.7	247.1	-301.6	8.75	90.03	50.04
BLUE	5	3575	543.7	79.2	-464.5	3.83	40.64	5.0
RED	35/50/70	1173	561.4	260.2	-301.2	8.90	95.32	50.29
BLUE	10	3411	553.9	150.8	-403.1	3.75	44.97	10.0
RED	35/50/70	1113	557.2	244.3	-312.9	8.93	92.03	49.91
BLUE	15	3313	556.1	223.3	-332.8	3.63	49.44	15.0
RED	35/50/70	989	555.8	205.8	-350.0	8.40	93.24	49.58
BLUE	20	3319	547.0	304.7	-242.3	3.45	53.82	20.0
RED	35/50/70	953	560.5	205.2	-355.4	8.42	90.65	48.68
BLUE	25	3315	544.1	370.0	-174.3	3.64	59.83	25.0
RED	35/50/70	1093	563.0	229.9	-333.2	7.39	85.62	47.59
BLUE	30	3111	550.0	414.8	-269.9	3.49	64.47	30.0
RED	35/50/70	1577	558.7	293.7	-265.0	8.11	83.19	42.19
BLUE	35	2576	546.1	397.9	-148.1	3.24	69.26	35.0
RED	35/50/70	1654	562.0	305.6	-257.0	7.78	82.10	41.86
BLUE	40	2436	549.2	428.9	-120.2	5.79	83.29	40.0
RED	35/50/70	1784	555.5	330.2	-225.4	7.29	79.33	41.94
BLUE	45	2235	551.7	444.2	-107.4	5.94	88.0	45.0
RED	35/50/70	1904	559.7	375.0	-184.7	6.11	76.75	44.67
BLUE	50	2059	550.3	454.0	-96.3	5.97	97.67	50.0
RED	35/50/70	2264	556.6	452.8	-103.7	7.4	82.97	45.33
BLUE	55	1636	559.4	398.3	-161.1	7.53	115.4	55.0
RED	35/50/70	2304	560.7	466.0	- 94.7	6.84	82.19	45.85
BLUE	60	1548	560.8	409.9	-150.8	7.34	119.73	60.0
RED	35/50/70	2344	556.6	486.9	- 69.6	6.88	85.64	47.09
BLUE	65	1471	562.6	418.6	-144.0	8.41	127.4	65.0
RED	35/50/70	2346	545.5	530.0	- 15.4	3.07	81.07	51.21
BLUE	70	1406	553.2	435.8	-117.3	7.55	129.0	70.0
RED	35/50/70	2721	541.2	630.5	89.3	3.51	84.24	52.52
BLUE	75	965	544.0	327.8	-216.2	7.92	125.4	75.0
RED	35/50/70	2856	559.3	669.8	110.4	3.54	85.54	53.14
BLUE	80	813	558.6	286.9	-271.6	8.70	124.77	80.0
RED	35/50/70	2864	547.8	669.7	121.9	3.54	87.16	53.32
BLUE	85	718	551.2	293.5	-257.7	9.48	131.23	85.0
RED	35/50/70	2895	559.7	679.4	119.7	3.49	86.58	53.2
BLUE	90	648	554.6	276.5	-278.1	9.87	135.64	90.0
RED	35/50/70	2741	549.1	643.0	93.9	3.45	86.63	53.17
BLUE	95	778	569.9	340.6	-229.3	9.85	141.89	95.0
RED	35/50/70	2765	561.3	650.3	89.0	3.45	86.96	53.3
BLUE	100	753	554.8	332.5	-222.3	9.81	146.65	100.0

RED : Existing operator

Vehicle type : Double/Decker
Headway : 6.08 minutes

BLUE : New entrant

Vehicle type : Double/Decker
Headway : 6.08 minutes

COMPETITION ON ROUTE 85 : NEW ENTRANT WITH DISTANCE-BASED FARE

Operator	Fare	Patronage	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen. Cost	Ave. Fare
RED	35/50/70	882	10	568.6	192.9	-357.7	7.54	89.42	49.45
BLUE	25 + 0	3424	49	545.2	377.7	-167.6	3.63	59.59	25.00
RED	35/50/70	907	11	546.1	197.4	-348.7	7.16	89.80	49.28
BLUE	25 + 3	3186	46	545.4	559.0	13.6	3.42	73.04	39.76
RED	35/50/70	1431	27	547.7	363.4	-184.3	5.93	111.91	57.70
BLUE	25 + 5	2544	32	552.1	498.4	-53.6	4.40	77.21	44.41
RED	35/50/70	2301	33	557.6	555.9	-1.7	4.81	96.22	54.77
BLUE	25 + 8	1519	14	550.9	322.7	-228.2	6.17	84.61	48.05
RED	35/50/70	2426	35	554.1	582.3	28.1	4.35	94.27	54.39
BLUE	25 + 10	1306	11	558.9	291.9	-226.9	8.56	100.74	50.59
RED	35/50/70	2751	39	553.9	659.6	105.7	3.73	89.69	54.35
BLUE	25 + 13	862	9	565.9	225.6	-340.2	8.85	117.44	59.19
RED	35/50/70	2767	38	552.6	656.5	103.9	3.63	88.77	53.74
BLUE	25 + 15	775	8	574.3	221.8	-352.5	9.23	123.25	64.06
RED	35/50/70	2687	38	557.1	635.3	78.3	3.72	88.82	53.60
BLUE	25 + 18	759	8	565.4	234.5	-330.9	10.46	132.78	69.61

RED : EXISTING OPERATOR
======================
Vehicle type : D/Decker
Headway : 6.08 minutes

BLUE : NEW ENTRANT
===================
Vehicle type : D/Decker
Headway : 6.08 minutes

COMPETITION ON ROUTE 24 : NEW ENTRANT WITH DISTANCE-BASED FARE

Operator	Fare	Patronage	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen Cost	Av. Fare
RED	35/50/70	1215	12	707.8	264.0	-443.8	6.82	86.72	48.97
BLUE	25 + 0	4564	37	755.4	503.4	-232.0	2.99	49.25	25.0
RED	35/50/70	1310	12	727.6	279.2	-448.4	6.10	83.33	48.29
BLUE	25 + 3	4248	35	731.5	652.8	- 78.7	2.96	59.40	34.83
RED	35/50/70	1910	26	732.2	456.3	-275.9	5.74	99.44	54.15
BLUE	25 + 5	3520	30	740.0	640.8	- 99.0	2.86	65.12	41.25
RED	35/50/70	2679	27	722.7	604.4	-118.3	5.13	88.24	51.12
BLUE	25 + 8	2580	17	724.5	519.0	-205.5	5.39	78.47	45.59
RED	35/50/70	3075	29	724.3	673.2	- 51.1	4.59	81.75	49.65
BLUE	25 + 10	2087	13	729.2	438.4	-290.8	6.31	83.51	47.68
RED	35/50/70	3595	32	728.4	784.8	56.4	3.55	77.01	49.49
BLUE	25 + 12	1478	10	725.5	334.0	-391.5	6.26	88.33	51.42
RED	35/50/70	3737	34	729.6	811.2	81.6	3.12	74.74	49.21
BLUE	25 + 15	1200	9	729.1	325.6	-403.5	6.45	103.67	61.62
RED	35/50/70	3581	31	732.6	775.7	43.1	3.12	74.39	49.09
BLUE	25 + 18	1239	9	716.2	370.4	-345.8	7.94	115.72	67.74
RED	35/50/70	3625	31	733.4	787.2	53.8	3.11	74.72	49.21
BLUE	25 + 20	1124	8	722.7	340.5	-382.2	8.03	117.99	68.99

RED : Existing operator
======================
Vehicle type : Double/Decker
Headway : 4.89 minutes

BLUE : New entrant
==================
Vehicle type : Double/Decker
Headway : 4.89 minutes

COMPETITION ON ROUTE 24 : NEW ENTRANT WITH VARIOUS TYPES OF VEHICLE
ON VARIOUS TRAFFIC CONDITIONS

Traffic	Operator	Vhcl type	Fleet Sz	Patronage	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen Cost
LIGHT	RED	D/Decker	16	3339	26	749.0	720.8	-28.2	2.29	71.99
	BLUE	D/Decker	7	994	30	247.0	215.8	-31.2	2.30	71.72
	RED	D/Decker	16	3059	24	735.5	643.0	-92.5	3.04	72.10
	BLUE	Standard	14	1893	36	258.4	406.0	147.7	2.51	70.24
	RED	D/Decker	16	2961	23	723.7	618.2	-105.4	3.79	72.52
	BLUE	Midi bus	16	2255	48	284.9	489.8	204.9	2.68	70.41
	RED	D/Decker	16	2264	16	728.2	477.0	-251.2	4.60	76.07
	BLUE	Mini bus	27	3919	30	490.5	837.0	346.5	2.19	66.63
MEDIUM	RED	D/Decker	16	3339	26	749.0	720.8	-28.2	2.29	71.99
	BLUE	D/Decker	7	994	30	247.0	215.8	-31.2	2.30	71.72
	RED	D/Decker	16	3068	24	742.7	647.6	-95.0	3.18	72.23
	BLUE	Standard	14	1882	36	280.5	406.4	125.9	2.18	69.73
	RED	D/Decker	16	2942	23	739.9	626.9	-133.0	2.72	70.91
	BLUE	Midi bus	16	2158	46	285.8	464.2	178.4	2.65	70.89
	RED	D/Decker	16	2528	19	723.0	537.0	-186.1	4.39	77.18
	BLUE	Mini bus	27	3405	55	485.0	732.1	247.1	2.37	69.39
HEAVY	RED	D/Decker	16	3339	26	749.0	720.8	-28.2	2.29	71.99
	BLUE	D/Decker	7	994	30	247.0	215.8	-31.2	2.30	71.72
	RED	D/Decker	16	2914	26	743.4	630.4	-113.1	2.00	71.05
	BLUE	Standard	14	1930	37	314.0	414.4	100.4	1.98	70.31
	RED	D/Decker	16	2908	25	742.1	630.5	-111.5	2.03	71.62
	BLUE	Midi bus	16	2074	46	318.5	444.9	126.2	1.88	69.56
	RED	D/Decker	16	3171	25	724.2	688.9	-35.3	2.32	72.32
	BLUE	Mini bus	27	2503	44	464.6	528.1	63.5	1.77	68.14

RED : Existing operator
======================
Vehicle type : Double/Decker
Headway : 4.89 minutes

BLUE : New entrant
==================
Vehicle type : Double/Decker
Headway : 4.89 minutes

COMPETITION ON ROUTE 85 : NEW ENTRANT WITH VARIOUS TYPES OF VEHICLE
ON VARIOUS TRAFFIC CONDITIONS

Traffic	Operator	Vhcl type	Fleet Sz	Patronage	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen Cost
LIGHT	RED	D/Decker	16	2343	30	569.2	550.2	-19.0	2.43	83.32
	BLUE	D/Decker	7	985	27	250.0	228.8	-21.2	2.51	82.61
	RED	D/Decker	16	2150	27	568.0	482.8	-85.2	4.82	83.08
	BLUE	Standard	14	1748	45	292.1	422.3	130.1	3.03	86.24
	RED	D/Decker	16	1890	20	569.2	410.7	-158.5	5.57	82.94
	BLUE	Midi bus	16	2249	15	312.7	560.7	247.9	3.28	88.61
	RED	D/Decker	16	1837	21	532.6	413.8	-118.8	6.52	88.68
	BLUE	Mini bus	27	3169	14	477.0	770.1	293.1	2.28	80.92
MEDIUM	RED	D/Decker	16	2343	30	569.2	550.2	-19.0	2.43	83.32
	BLUE	D/Decker	7	985	27	250.0	228.8	-21.2	2.51	82.61
	RED	D/Decker	16	2242	27	559.3	509.0	-88.3	4.44	82.99
	BLUE	Standard	14	1608	45	285.9	384.6	83.6	3.03	85.45
	RED	D/Decker	16	2105	24	553.3	467.1	-86.3	4.53	82.39
	BLUE	Midi bus	16	1928	60	298.6	471.8	173.3	3.11	88.30
	RED	D/Decker	16	2005	21	544.1	448.6	-95.6	6.23	87.40
	BLUE	Mini bus	27	2778	65	467.3	673.0	205.7	2.51	83.53
HEAVY	RED	D/Decker	16	2343	30	569.2	550.2	-19.0	2.43	83.32
	BLUE	D/Decker	7	985	27	250.0	228.8	-21.2	2.51	82.61
	RED	D/Decker	16	2175	29	545.2	494.2	-51.0	2.32	80.93
	BLUE	Standard	14	1627	43	301.3	395.5	94.1	1.93	83.49
	RED	D/Decker	16	2165	27	545.7	497.4	-48.3	2.30	80.08
	BLUE	Midi bus	16	1761	51	309.6	422.5	112.8	2.0	84.23
	RED	D/Decker	16	2365	29	546.1	557.2	11.1	2.83	84.81
	BLUE	Mini bus	27	2187	55	469.6	524.3	54.7	2.26	85.75

RED : Existing operator
======================
Vehicle type : Double/Decker
Headway : 6.08 minutes

BLUE : New entrant
==================
Vehicle type : Double/Decker
Headway : 6.08 minutes

COMPETITION ON ROUTE 24 : NEW ENTRANT WITH TRAVELCARD

Operator	Headway	Patronage	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen. Cost	Card Holder	Weekly T/Card
RED	4.89	2191	20	720.2	476.1	-244.1	5.86	87.93	0	-
BLUE	4.89	3366	27	746.2	501.8	-244.4	2.51	56.97	1747	300
RED	4.89	2232	20	725.4	479.0	-246.4	5.54	84.90	0	-
BLUE	4.89	3256	27	745.9	557.1	-188.8	2.55	62.13	1475	400
RED	4.89	2197	19	733.1	471.2	-262.0	4.56	81.39	0	-
BLUE	4.89	3259	27	746.2	590.1	-156.1	2.37	63.97	1358	450
RED	4.89	2325	20	727.9	500.9	-227.1	4.94	83.17	0	-
BLUE	4.89	3099	26	743.8	613.9	-155.0	2.26	65.79	1150	500
RED	4.89	2333	19	723.0	492.0	-231.0	4.79	81.35	0	-
BLUE	4.89	3059	26	742.4	605.2	-137.1	2.30	67.54	1047	550
RED	4.89	2379	20	729.3	506.6	-222.7	4.70	80.72	0	-
BLUE	4.89	2983	26	736.8	608.3	-128.5	2.30	69.14	920	600
RED	4.89	2290	19	724.5	481.6	242.9	4.42	79.38	0	-
BLUE	4.89	3042	26	733.3	637.4	-95.9	2.51	71.08	825	650

RED : EXISTING OPERATOR
======================
Vehicle type : D/Decker
Headway : 4.89 minutes

BLUE : NEW ENTRANT
==================
Vehicle type : D/Decker
Headway : 4.89 minutes

COMPETITION ON ROUTE 85 : NEW ENTRANT WITH TRAVELCARD

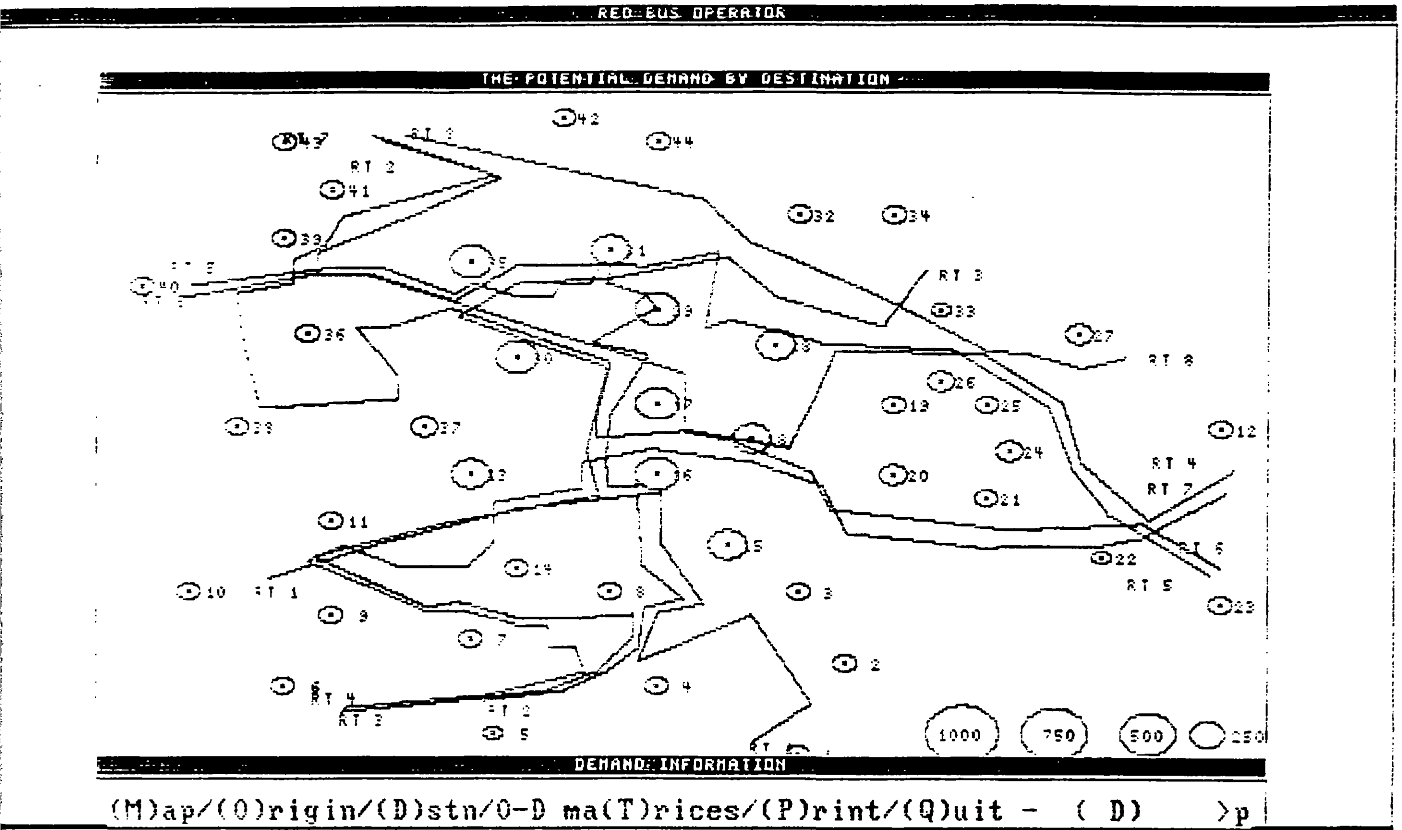
Operator	Headway	Patronage	Occ. Rate	Op. Cost	Revenue	Profit	A.W.T	Gen. Cost	Card Holder	Weekly T/Card
RED	6.08	1496	18	564.2	330.7	-233.5	7.78	101.80	0	-
BLUE	6.08	2626	36	543.7	4063.8	-137.3	3.00	67.60	1453	300
RED	6.08	1490	17	559.3	330.3	-229.1	7.43	96.59	0	-
BLUE	6.08	2607	35	549.7	432.5	-117.2	2.74	69.19	1381	350
RED	6.08	1484	19	565.0	332.2	-232.8	6.99	94.11	0	-
BLUE	6.08	2590	37	553.0	459.4	-93.4	2.91	72.14	1291	400
RED	6.08	1577	19	565.4	347.8	-217.6	6.81	94.50	0	-
BLUE	6.08	2475	36	553.9	470.1	-83.8	2.71	75.18	1119	450
RED	6.08	1571	19	556.5	349.5	-207.0	6.35	93.90	0	-
BLUE	6.08	2458	34	549.3	487.7	-61.6	2.69	76.80	1050	500
RED	6.08	1532	19	566.8	343.9	-222.9	5.74	88.28	0	-
BLUE	6.08	2474	35	558.9	513.7	-45.2	2.56	78.45	985	550
RED	6.08	1687	20	562.3	377.7	-184.5	6.26	91.72	0	-
BLUE	6.08	2299	33	560.4	494.7	-65.7	2.68	81.05	825	600
RED	6.08	1554	19	558.3	351.4	-206.9	5.74	91.08	0	-
BLUE	6.08	2410	34	549.5	536.6	-128.7	2.71	81.93	650	

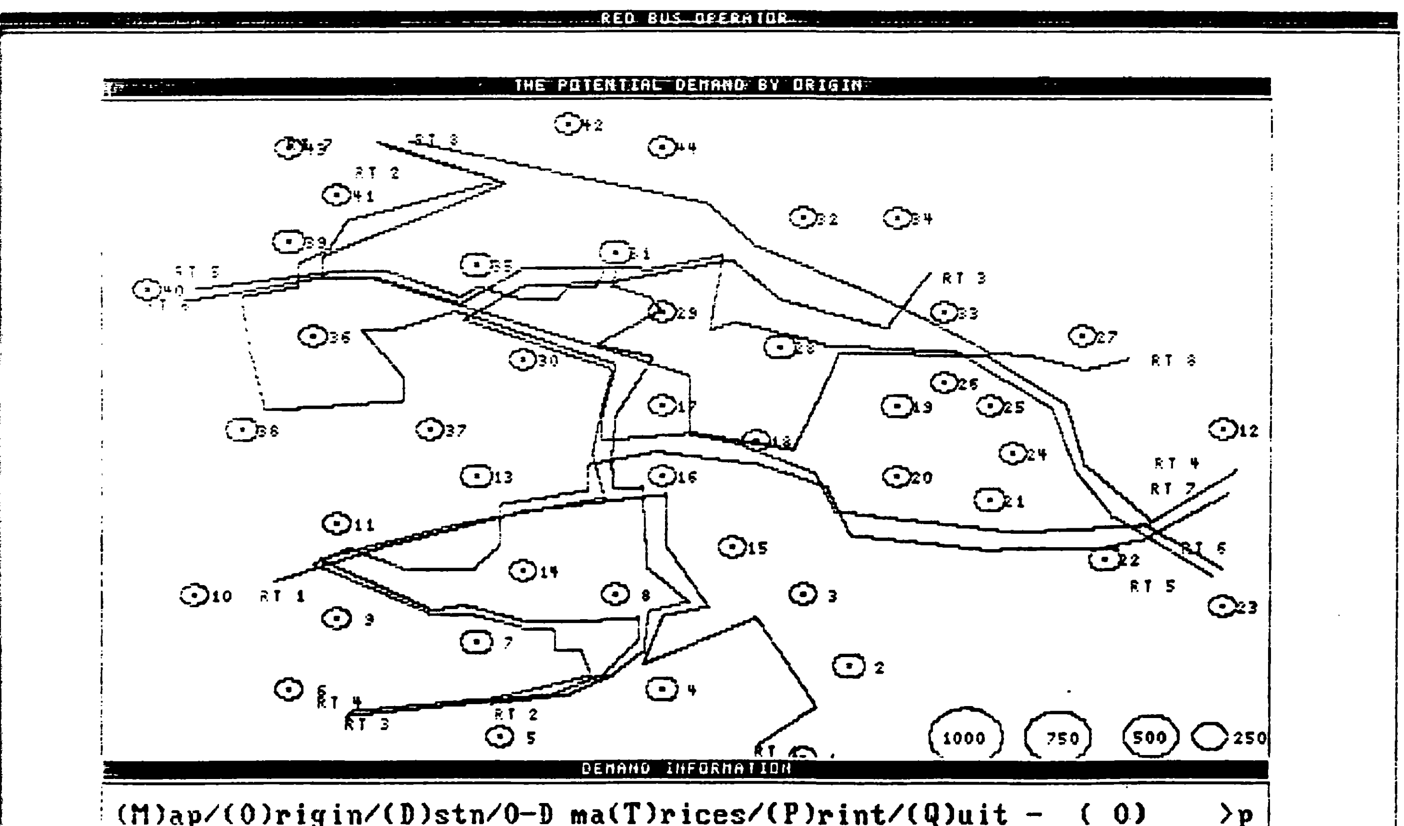
RED : EXISTING OPERATOR
======================
Vehicle type : D/Decker
Headway : 6.08 minutes

BLUE : NEW ENTRANT
==================
Vehicle type : D/Decker
Headway : 6.08 minutes

APPENDIX 2

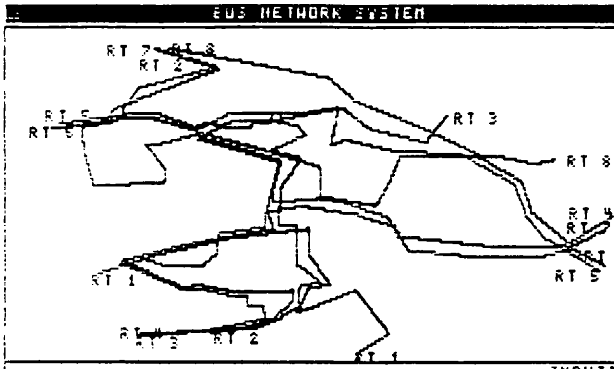
GRAPHIC REPRESENTATION OF INPUT/OUTPUT OF THE *COMBO.2* MODEL


RED BUS OPERATOR
THE POTENTIAL DEMAND BY DESTINATION
DEMAND INFORMATION
1000
750
500
250
(M)ap/(O)rigin/(D)stn/O-D ma(T)rices/(P)rint/(Q)uit - (D) >p


RED BUS OPERATOR
THE POTENTIAL DEMAND BY ORIGIN
DEMAND INFORMATION
1000
750
500
250
(M)ap/(O)rigin/(D)stn/O-D ma(T)rices/(P)rint/(Q)uit - (O) >p

RED BUS OPERATOR

BUS NETWORK SYSTEM



BUS AVAILABLE IN THE MARKET

	A	B	C	D
Vehicle :	Mini	Midi	Stnd	D/dck
Cap(pas):	20	35	45	72
Spd(Kph):	24	22	20	18
Prc(£t) :	18.5	31.3	36.0	66.5

INPUTING DATA

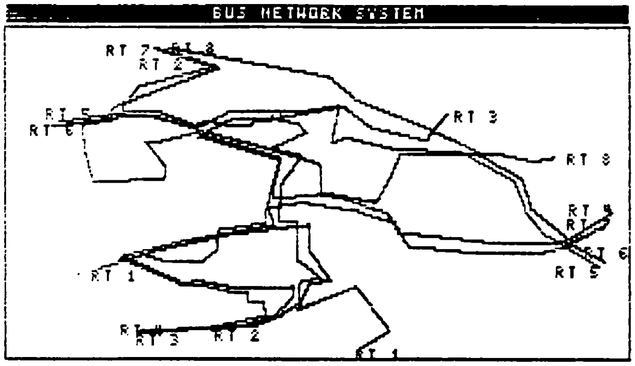
ROUTE 7

```
Enter the type of vehicle A/B/C/D                 (   )   >c
The average headway  (minutes)                   (0.0)   >5
The number of vehicle have to be operated                 =12
The number of vehicle to be alocated              ( 0)   >12
Enter system of operation (T)PO/(O)PO             (   )   >o
Enter system of fare (S)tage/(F)lat/(D)istn       (   )   >f
Fare per trip            (pence)                  ( 0)   >50

Enter the name of the route  (Press 0 to stop)    ( 7)   >0
```

RED BUS OPERATOR

BUS NETWORK SYSTEM



MAIN MENU

```
(D)emand information
(I)nputing data
(S)ystem-wide policies
(Q)uit
Enter option ( I)     >s
```

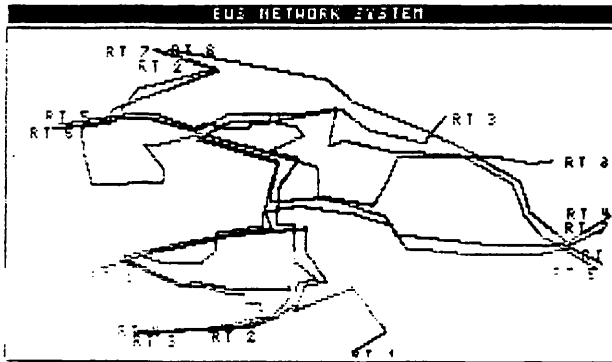
SYSTEM WIDE POLICIES

```
(F)are/(T)ravelcard/(O)p.system/(Q)uit
**** Enter the option **** (   )    >t

Introduce travelcard  ? (Y)es/(N)o  (   )    >y
Percentage of discount factor      ( 0)    >0
```

RED BUS OPERATOR

BUS NETWORK SYSTEM



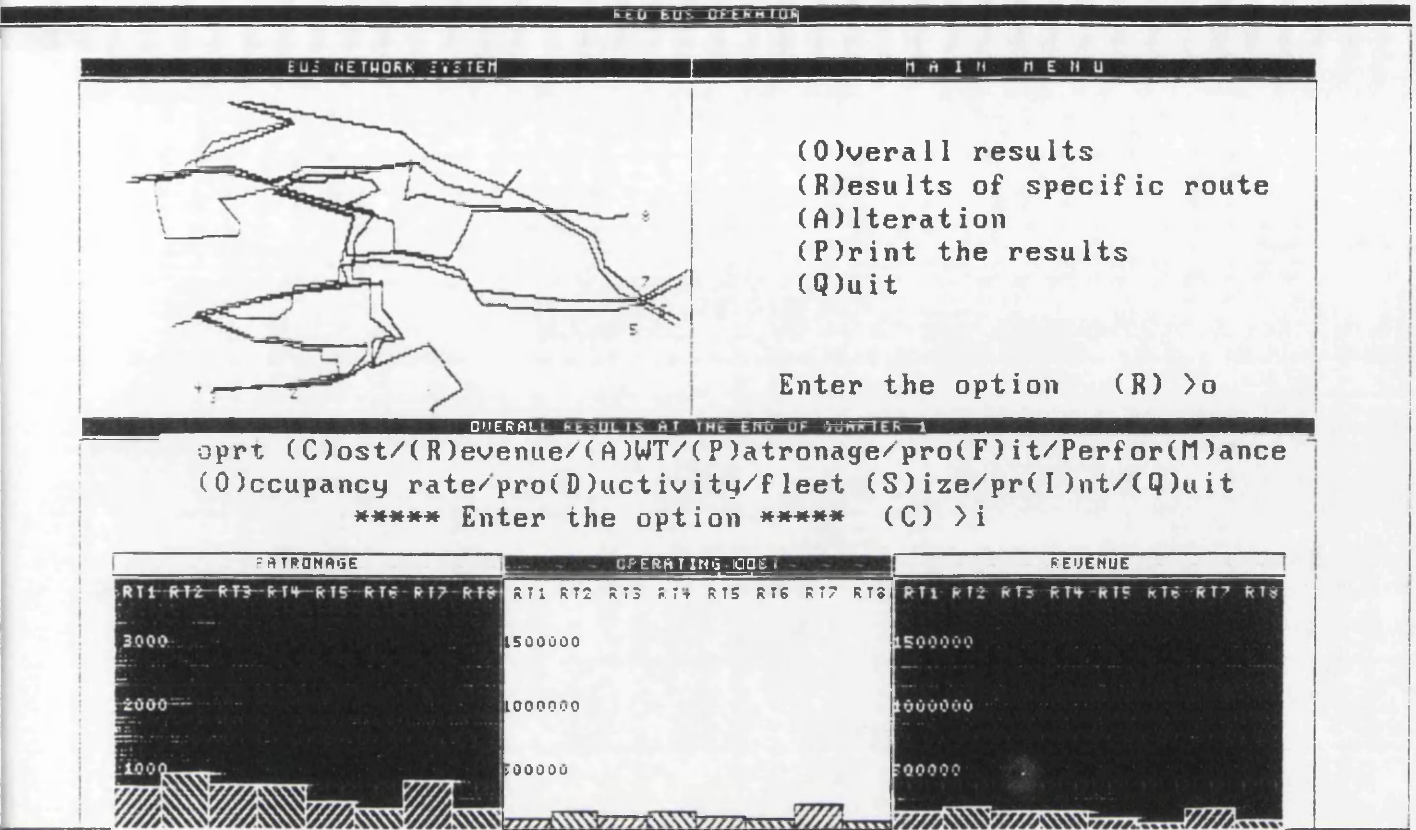
VEHICLE STOCK

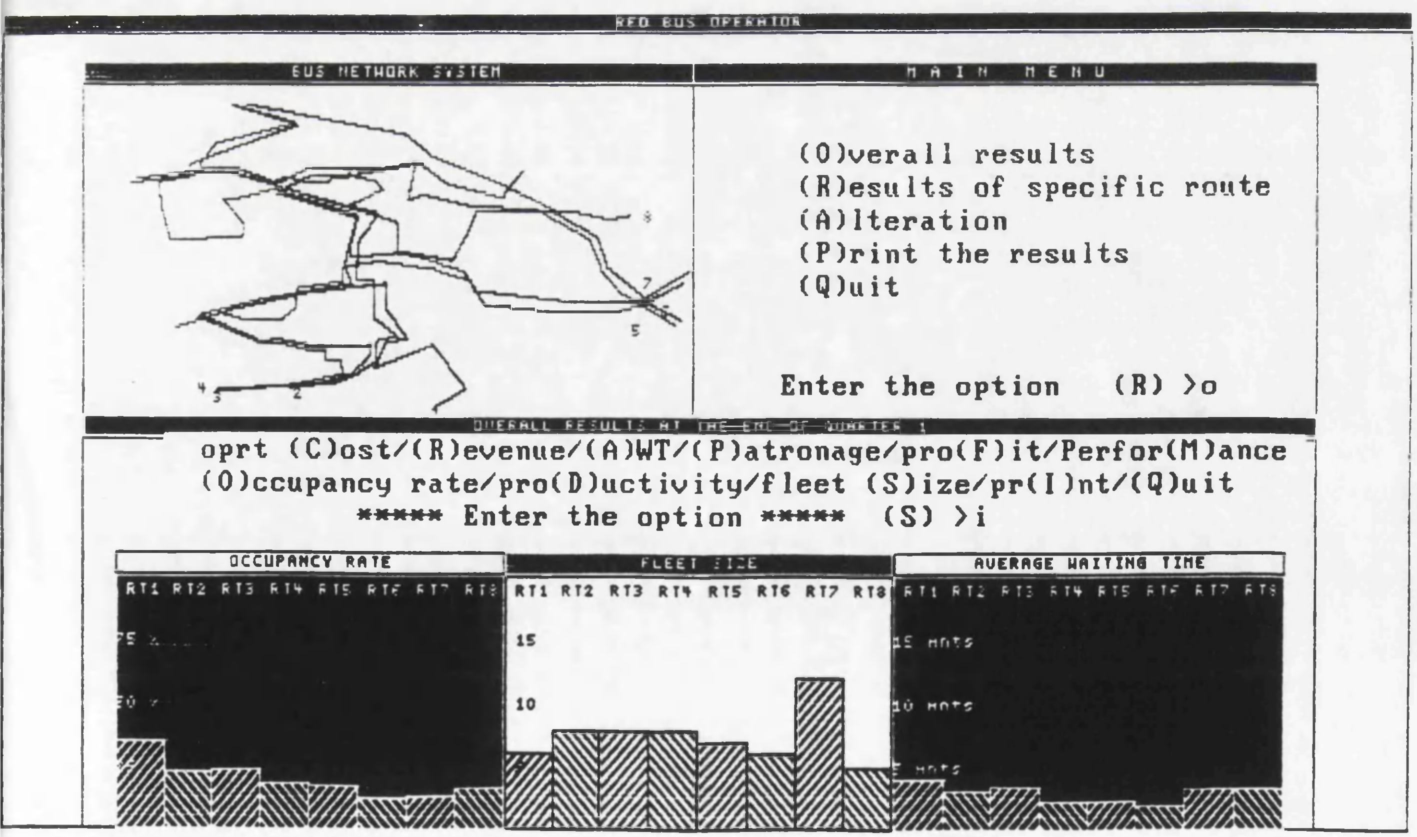
	A	B	C	D
Vehicle :	Mini	Midi	Stnd	D/dck
Alocated:	0	0	60	0

FINANCIAL MATTERS

To start this operation you need at least £ 2160000.00
You can borrow these from the Bank at
the rate of 10% p.a for 5 years

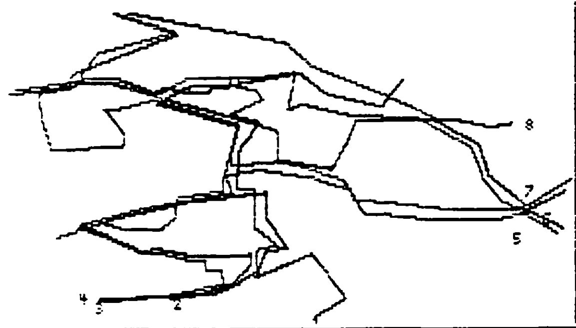
How much money do you want to invest ? (0.0) >2160000.00


RED BUS OPERATOR
BUS NETWORK SYSTEM
M A I N   M E N U
(O)verall results
(R)esults of specific route
(A)lteration
(P)rint the results
(Q)uit
Enter the option (R) >o
OVERALL RESULTS AT THE END OF QUARTER 1
oprt (C)ost/(R)evenue/(A)WT/(P)atronage/pro(F)it/Perfor(M)ance
(O)ccupancy rate/pro(D)uctivity/fleet (S)ize/pr(I)nt/(Q)uit
***** Enter the option ***** (C) >i
PATRONAGE
OPERATING COST
REVENUE
RT1 RT2 RT3 RT4 RT5 RT6 RT7 RT8
3000
2000
1000
1500000
1000000
500000


RED BUS OPERATOR
BUS NETWORK SYSTEM
M A I N   M E N U
(O)verall results
(R)esults of specific route
(A)lteration
(P)rint the results
(Q)uit
Enter the option (R) >o
OVERALL RESULTS AT THE END OF QUARTER 1
oprt (C)ost/(R)evenue/(A)WT/(P)atronage/pro(F)it/Perfor(M)ance
(O)ccupancy rate/pro(D)uctivity/fleet (S)ize/pr(I)nt/(Q)uit
***** Enter the option ***** (S) >i
OCCUPANCY RATE
FLEET SIZE
AVERAGE WAITING TIME
RT1 RT2 RT3 RT4 RT5 RT6 RT7 RT8
15
10
15 mnts
10 mnts
5 mnts

RED BUS OPERATOR

BUS NETWORK SYSTEM | MAIN MENU



(O)verall results
(R)esults of specific route
(A)lteration
(P)rint the results
(Q)uit

Enter the option (R) >o

OVERALL RESULTS AT THE END OF QUARTER 1

oprt (C)ost/(R)evenue/(A)WT/(P)atronage/pro(F)it/Perfor(M)ance
(O)ccupancy rate/pro(D)uctivity/fleet (S)ize/pr(I)nt/(Q)uit
***** Enter the option ***** (M) >i

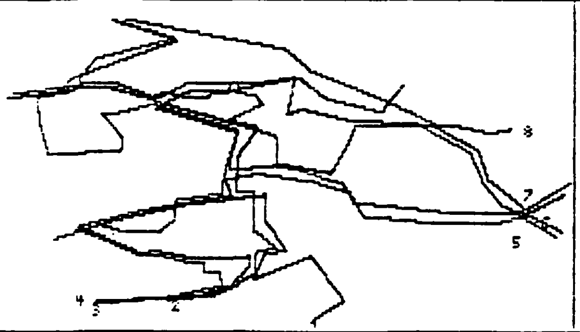
SYSTEM PERFORMANCE

TOTAL PATRONAGE =	5109	TOTAL REVENUE (£) =	1127170.11	
CASH IN HAND (£) =	16489.21	TOTAL OP COST (£) =	1110680.90	
DEBT TO THE BANK (£)=	1986064.92	TOTAL PROFIT (£) =	16489.21	
VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	60	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 492780.84

RED BUS OPERATOR

BUS NETWORK SYSTEM | MAIN MENU



(O)verall results
(R)esults of specific route
(A)lteration
(P)rint the results
(Q)uit

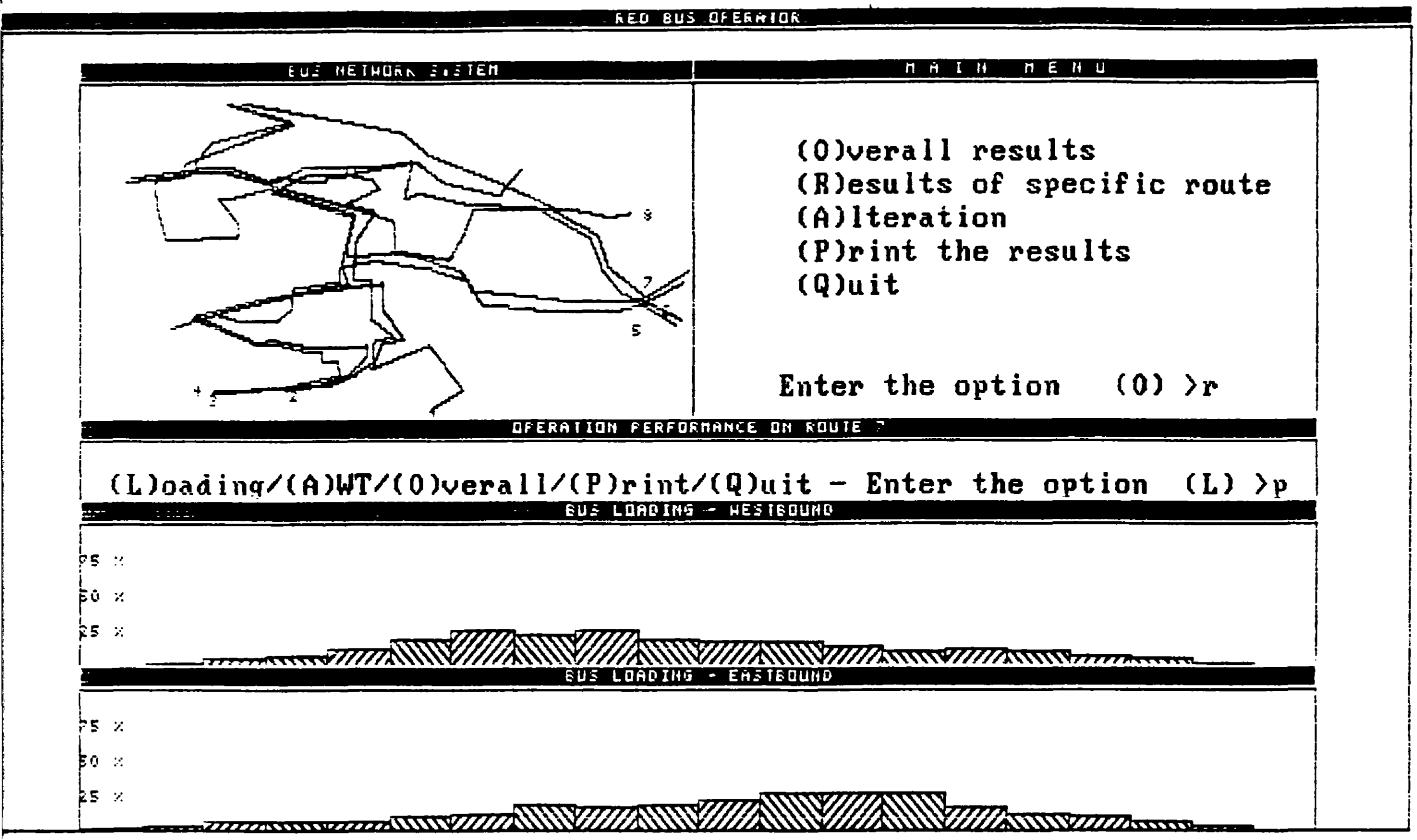
Enter the option (O) >r

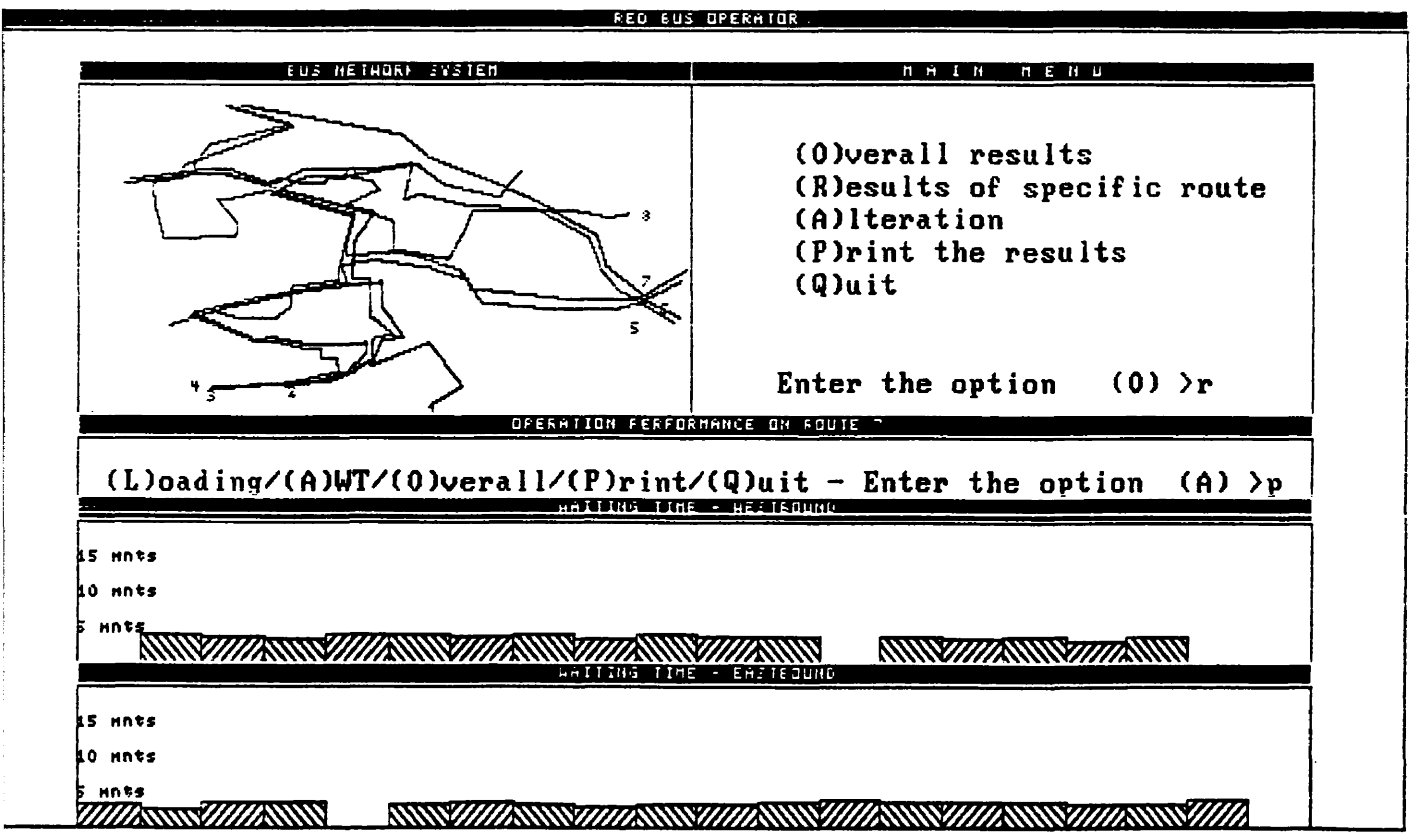
OPERATION PERFORMANCE ON ROUTE 7

(L)oading/(A)WT/(O)verall/(P)rint/(Q)uit - Enter the option (O) >p

OVERALL RESULTS

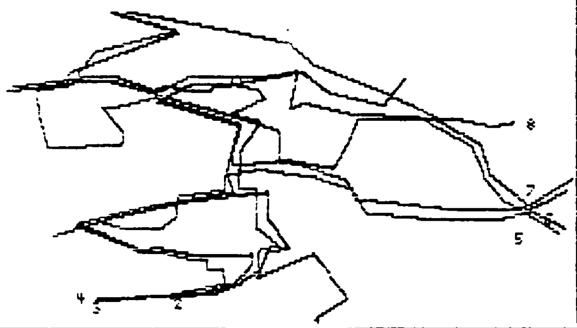
Vehicle type	: Standard	Market share (%)	: 47.3
Capacity	: 45	Occ. rate (%)	: 14.0
Op. Speed (Km/Hr)	: 20.0	Av.wait time (mnt)	: 3.4
System of oprtion	: OPO	Av.fare paid (p)	: 50.0
Fleet size	: 12	Av.Gen Cost (p)	: 67.4
Num. buses oprted	: 12	Tot.Op Cost (£)	: 212380.08
Fare system	: Flat 50p/trip	Tot. revenue(£)	: 178199.52
Num. peak-hr pass	: 807	Profitability (%)	: -16.1


RED BUS OPERATOR
BUS NETWORK SYSTEM
MAIN MENU
(O)verall results
(R)esults of specific route
(A)lteration
(P)rint the results
(Q)uit
Enter the option (O) >r
OPERATION PERFORMANCE ON ROUTE 7
(L)oading/(A)WT/(O)verall/(P)rint/(Q)uit - Enter the option (L) >p
BUS LOADING - WESTBOUND
75 %
50 %
25 %
BUS LOADING - EASTBOUND
75 %
50 %
25 %


RED BUS OPERATOR
BUS NETWORK SYSTEM
MAIN MENU
(O)verall results
(R)esults of specific route
(A)lteration
(P)rint the results
(Q)uit
Enter the option (O) >r
OPERATION PERFORMANCE ON ROUTE 7
(L)oading/(A)WT/(O)verall/(P)rint/(Q)uit - Enter the option (A) >p
WAITING TIME - WESTBOUND
15 mnts
10 mnts
5 mnts
WAITING TIME - EASTBOUND
15 mnts
10 mnts
5 mnts

BLUE BUS OPERATOR

BUS NETWORK SYSTEM | MAIN MENU



(O)verall results
(R)esults of specific route
(A)lteration
(P)rint the results
(Q)uit

Enter the option (Q) >o

OVERALL RESULTS AT THE END OF QUARTER 1

oprt (C)ost/(R)evenue/(A)WT/(P)atronage/pro(F)it/Perfor(M)ance
(O)ccupancy rate/pro(D)uctivity/fleet (S)ize/pr(I)nt/(Q)uit
***** Enter the option ***** (M) >i

SYSTEM PERFORMANCE

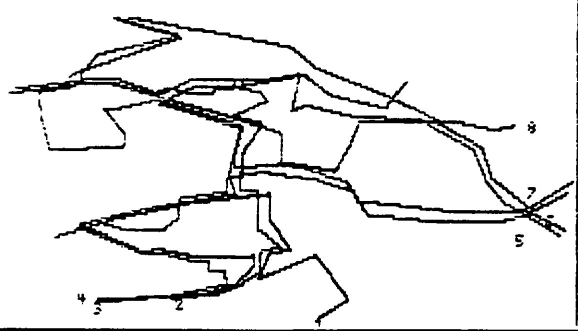
TOTAL PATRONAGE	=	900	TOTAL REVENUE (£) =	131358.51
CASH IN HAND (£)	=	-43698.42	TOTAL OP COST (£) =	175056.93
DEBT TO THE BANK (£)	=	331010.82	TOTAL PROFIT (£) =	-43698.42

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	10	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 492780.84

BLUE BUS OPERATOR

BUS NETWORK SYSTEM | MAIN MENU



(O)verall results
(R)esults of specific route
(A)lteration
(P)rint the results
(Q)uit

Enter the option (O) >r

OPERATION PERFORMANCE ON ROUTE 7

(L)oading/(A)WT/(O)verall/(P)rint/(Q)uit - Enter the option (O) >p

OVERALL RESULTS

Vehicle type	: Standard	Market share (%)	: 52.7
Capacity	: 45	Occ. rate (%)	: 14.9
Op. Speed (Km/Hr)	: 20.0	Av.wait time (mnt)	: 3.4
System of oprtion	: OPO	Av.fare paid (p)	: 33.1
Fleet size	: 10	Av.Gen Cost (p)	: 51.2
Num. buses oprted	: 10	Tot.Op Cost (£)	: 175056.93
Fare system	: Stg 30p/50p/7	Tot. revenue(£)	: 131358.51
Num. peak-hr pass	: 900	Profitability (%)	: -25.0

APPENDIX 3

RESULTS FROM SENSITIVITY TESTS OF THE *COMBO.2* MODEL

APPENDIX 3

SENSITIVITY TEST FOR THE *COMBO.2* MODEL

The following tests were carried out :

1. The sensitivity of the model to the change in the level of fare in one particular route in the network.

2. The sensitivity of the model to the change in the level of service frequency in one particular route in the network.

The values of elasticity of demand were calculated using the following formulae :

$$\xi = \frac{\log(x^o) - \log(x^t)}{\log(y^o) - \log(y^t)}$$

where,

ξ = Elasticity value of demand to variable y.
x^o = The level of demand in the base condition.
x^t = The level of demand in time period t.
y^o = The variable of the level of service (frequency or fare) to be considered in the based condition.
y^t = The variable of the level of service to be considered in time period t.

BASE CONDITION

ROUTE		1	2	3	4	5	6	7	8
Vhcl type	:	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity	:	72	72	72	72	72	72	72	72
Sys Op	:	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz	:	7	10	10	10	8	7	15	6
Bus Oprtd	:	7	10	10	10	8	7	15	6
Fare Sys	:	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage	:	2020	2870	2425	2342	1362	1102	3604	1238
Highest Ld	:	27	25	36	27	15	14	38	9
Occ rate	:	23.1	22.2	25.6	19.0	11.6	13.1	24.7	10.1
M Share	:	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Card Hldr	:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT	:	2.6	2.6	2.4	2.5	2.6	2.2	2.2	1.8
Av Fare	:	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost	:	65.7	65.8	67.5	64.3	63.8	63.8	66.2	59.3
Tot Op C	:	239.56	340.72	352.47	346.43	284.77	250.78	530.18	212.11
Revenue	:	445.59	633.09	534.93	516.62	300.44	243.09	795.00	273.09
Profit	:	206.03	292.37	182.45	170.19	15.67	-7.69	264.82	60.98

TOTAL PATRONAGE = 16963

TOTAL REVENUE (£) = 3741838.24
TOTAL OP COST (£) = 2557019.01
TOTAL PROFIT (£) = 1184819.22

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1101044.97

THE LEVEL OF SERVICE FREQUENCY ON ROUTE 1 WAS REDUCED BY 33 %

ROUTE		1	2	3	4	5	6	7	8
Vhcl type	:	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity	:	72	72	72	72	72	72	72	72
Sys Op	:	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz	:	7	10	10	10	8	7	15	6
Bus Oprtd	:	5	10	10	10	8	7	15	6
Fare Sys	:	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage	:	1897	3057	2500	2313	1475	1041	3439	1208
Highest Ld	:	37	29	33	25	14	14	34	9
Occ rate	:	29.9	23.9	26.6	17.9	12.9	12.5	23.9	9.7
M Share	:	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Card Hldr	:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT	:	3.5	2.6	2.5	2.5	2.7	2.1	2.2	1.8
Av Fare	:	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost	:	68.5	65.3	67.6	65.1	64.6	63.8	66.1	59.2
Tot Op C	:	214.05	344.44	346.58	346.09	281.27	249.76	525.17	209.19
Revenue	:	418.46	674.34	551.47	510.22	325.37	229.63	758.60	266.47
Profit	:	204.41	329.89	204.89	164.13	44.10	-20.13	233.43	57.28

TOTAL PATRONAGE = 16930   TOTAL REVENUE (£) = 3734558.82
TOTAL OP COST (£) = 2516558.79
TOTAL PROFIT (£) = 1218000.03

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1106625.21

THE LEVEL OF SERVICE FREQUENCY ON ROUTE 7 WAS REDUCED BY 33 %

ROUTE		1	2	3	4	5	6	7	8
Vhcl type	:	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity	:	72	72	72	72	72	72	72	72
Sys Op	:	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz	:	7	10	10	10	8	7	15	6
Bus Oprtd	:	7	10	10	10	8	7	10	6
Fare Sys	:	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage	:	2096	2917	2538	2315	1646	1027	3169	1250
Highest Ld	:	32	36	34	26	18	14	43	10
Occ rate	:	25.2	25.1	25.7	17.8	13.8	12.2	31.0	10.0
M Share	:	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Card Hldr	:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT	:	2.7	2.5	2.7	2.3	2.6	2.1	3.2	1.8
Av Fare	:	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost	:	65.4	65.5	68.1	64.3	63.3	63.6	69.7	59.2
Tot Op C	:	245.23	346.35	352.69	351.30	281.12	251.02	448.01	209.06
Revenue	:	462.35	643.46	559.85	510.66	363.09	226.54	699.04	275.74
Profit	:	217.12	297.10	207.16	159.36	81.97	-24.48	251.04	66.68

TOTAL PATRONAGE = 16958   TOTAL REVENUE (£) = 3740735.29
TOTAL OP COST (£) = 2484787.61
TOTAL PROFIT (£) = 1255947.68

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1111127.51

THE LEVEL OF SERVICE FREQUENCY ON ROUTE 8 WAS REDUCED BY 33 %

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	4
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	2019	2961	2395	2310	1429	1032	3576	1154
Highest Ld:	28	37	29	25	14	13	37	13
Occ rate :	23.5	25.5	24.3	17.8	11.9	12.8	24.7	13.2
M Share :	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.5	2.6	2.5	2.3	2.7	2.2	2.1	2.8
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	64.8	65.4	67.5	64.3	64.4	64.2	65.4	61.9
Tot Op C :	245.24	345.24	347.49	342.51	284.41	250.14	529.95	175.02
Revenue :	445.37	653.16	528.31	509.56	315.22	227.65	788.82	254.56
Profit :	200.13	307.92	180.82	167.05	30.81	-22.50	258.88	79.54

TOTAL PATRONAGE = 16876

TOTAL REVENUE (£) = 3722647.06
TOTAL OP COST (£) = 2519997.91
TOTAL PROFIT (£) = 1202649.15

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1106531.39

THE LEVEL OF FARE ON ROUTE 1 WAS INCREASED BY 100 %

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/100p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	1725	3002	2438	2143	1465	1014	3652	1249
Highest Ld:	25	27	32	24	14	14	36	10
Occ rate :	20.3	22.0	26.2	17.4	12.8	12.4	25.0	10.2
M Share :	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.7	2.5	2.5	2.3	2.8	2.1	2.1	1.9
Av Fare :	100.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	115.8	64.9	67.4	64.5	64.7	63.5	66.0	59.7
Tot Op C :	246.18	335.94	355.55	349.24	281.57	249.76	525.38	207.47
Revenue :	761.03	662.21	537.79	472.72	323.16	223.68	805.59	275.51
Profit :	514.85	326.26	182.25	123.48	41.60	-26.08	280.20	68.05

TOTAL PATRONAGE = 16688

TOTAL REVENUE (£) = 4061691.18
TOTAL OP COST (£) = 2551092.27
TOTAL PROFIT (£) = 1510598.91

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1172190.13

THE LEVEL OF FARE ON ROUTE 7 WAS INCREASED BY 100 %

ROUTE		1	2	3	4	5	6	7	8
Vhcl type	:	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity	:	72	72	72	72	72	72	72	72
Sys Op	:	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz	:	7	10	10	10	8	7	15	6
Bus Oprtd	:	7	10	10	10	8	7	15	6
Fare Sys	:	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/100p	F/50p
Patronage	:	2028	3150	2645	2256	1942	1144	2240	1285
Highest Ld	:	27	37	37	22	20	18	22	11
Occ rate	:	22.5	26.8	28.3	17.7	16.5	13.9	14.9	11.2
M Share	:	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Card Hldr	:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT	:	2.7	2.4	2.3	2.5	2.4	1.9	2.0	1.8
Av Fare	:	50.0	50.0	50.0	50.0	50.0	50.0	100.0	50.0
Gen Cost	:	65.3	65.1	67.1	65.2	62.9	63.9	115.1	59.6
Tot Op C	:	243.32	343.47	352.44	347.75	282.43	251.40	527.99	207.33
Revenue	:	447.35	694.85	583.46	497.65	428.38	252.35	988.24	283.46
Profit	:	204.03	351.38	231.02	149.89	145.95	0.95	460.24	76.13

```
TOTAL PATRONAGE      =    16690       TOTAL REVENUE (£) =  4175735.29
                                      TOTAL OP COST (£) =  2556145.14
                                      TOTAL PROFIT  (£) =  1619590.16
VEHICLES             = Mini      Midi     Stdrd     D/Decker
                        0         0         0        73
TOTAL OVERALL GENERALISED COST (Pass.mnts) =    1195920.22
```

THE LEVEL OF FARE ON ROUTE 8 WAS INCREASED BY 100 %

ROUTE		1	2	3	4	5	6	7	8
Vhcl type	:	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity	:	72	72	72	72	72	72	72	72
Sys Op	:	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz	:	7	10	10	10	8	7	15	6
Bus Oprtd	:	7	10	10	10	8	7	15	6
Fare Sys	:	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/100p
Patronage	:	2042	2977	2495	2268	1366	1089	3641	938
Highest Ld	:	26	30	32	23	16	16	36	9
Occ rate	:	22.8	24.8	25.0	17.6	13.1	13.2	24.6	7.9
M Share	:	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Card Hldr	:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT	:	2.7	2.5	2.7	2.4	2.7	2.1	2.1	2.0
Av Fare	:	50.0	50.0	50.0	50.0	50.0	50.0	50.0	100.0
Gen Cost	:	65.8	65.4	67.8	64.4	64.7	63.3	66.1	109.5
Tot Op C	:	241.09	344.58	353.09	348.67	284.23	249.73	525.65	205.76
Revenue	:	450.44	656.69	550.37	500.29	301.32	240.22	803.16	413.82
Profit	:	209.35	312.11	197.28	151.62	17.09	-9.51	277.51	208.06

```
TOTAL PATRONAGE      =    16816       TOTAL REVENUE (£) =  3916323.53
                                      TOTAL OP COST (£) =  2552815.03
                                      TOTAL PROFIT  (£) =  1363508.50
VEHICLES             = Mini      Midi     Stdrd     D/Decker
                        0         0         0        73
TOTAL OVERALL GENERALISED COST (Pass.mnts) =    1140830.48
```

APPENDIX 4

EXERCISE RESULTS OF THE *COMBO.2* MODEL

BUS OPERATION STRATEGIES IN AN URBAN BUS NETWORK

BASE CASE

ROUTE	1	2	3	4	5
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	10	8	3	12	11
Bus Oprtd :	10	8	3	12	11
Fare Sys :	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]
Patronage :	3573	1557	1730	1315	2408
Highest Ld:	68	52	40	51	47
Occ rate :	58.8	36.7	33.3	16.6	31.7
M Share :	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0
AWT (mnts):	6.79	11.40	13.54	5.24	7.77
Av Fare :	50.0	50.0	50.0	50.0	50.0
Gen Cost :	93.3	115.9	104.7	79.7	88.6
Tot Op C :	356.32	288.47	107.21	434.64	394.45
Revenue :	788.16	343.46	381.62	290.07	531.18
Profit :	431.84	54.99	274.41	-144.57	136.73

TOTAL PATRONAGE = 10583 TOTAL REVENUE (£) = 2334485.29
CASH IN HAND (£) = 753394.11 TOTAL OP COST (£) = 1581091.18
DEBT TO THE BANK (£)= 2690382.39 TOTAL PROFIT (£) = 753394.11

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	44

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 286489.01

STAGE FARE WITH FARE OF 35p, 50p AND 70p
FOR SHORT, MEDIUM AND LONG TRIPS

ROUTE	1	2	3	4	5
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	10	8	3	12	11
Bus Oprtd :	10	8	3	12	11
Fare Sys :	S/35/50/70	S/35/50/70	S/35/50/70	S/35/50/70	S/35/50/70
Patronage :	3584	1503	1731	1309	2347
Highest Ld:	63	50	38	50	45
Occ rate :	43.5	35.9	33.2	16.4	30.8
M Share :	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0
AWT (mnts):	6.20	11.50	13.59	5.19	7.77
Av Fare :	56.3	53.5	48.9	47.6	47.0
Gen Cost :	97.8	117.7	104.2	78.4	86.0
Tot Op C :	313.28	288.43	107.29	434.74	394.64
Revenue :	890.07	354.76	373.76	274.92	487.17
Profit :	576.79	66.32	266.48	-159.82	92.53

TOTAL PATRONAGE = 10474

TOTAL REVENUE (£) = 2380686.99
TOTAL OP COST (£) = 1538388.58
TOTAL PROFIT (£) = 842298.41

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	44

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 304957.39

DISTANCE-BASED FARE WITH INITIAL FARE OF 25p AND ADDITIONAL FARE OF 5 p/Km

ROUTE	1	2	3	4	5
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	10	8	3	12	11
Bus Oprtd :	10	8	3	12	11
Fare Sys :	D/25p+ 5	D/25p+ 5	D/25p+ 5	D/25p+ 5	D/25p+ 5
Patronage :	3375	1429	1823	1370	2378
Highest Ld:	70	47	41	52	47
Occ rate :	58.9	34.0	35.1	17.2	31.0
M Share :	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0
AWT (mnts):	6.39	11.37	13.68	5.29	7.80
AV Fare :	48.0	56.3	40.9	40.6	41.6
Gen Cost :	93.9	121.5	96.2	71.6	80.7
Tot Op C :	358.50	288.71	107.10	434.44	394.67
Revenue :	714.83	354.92	328.58	245.22	435.94
Profit :	356.33	66.21	221.47	-189.22	41.28

TOTAL PATRONAGE = 10375

TOTAL REVENUE (£) = 2079493.25
TOTAL OP COST (£) = 1583417.65
TOTAL PROFIT (£) = 496075.59

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	44

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 267183.86

FLAT FARE WITH FARE OF 50p PER TRIP

ROUTE	1	2	3	4	5
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	10	8	3	12	11
Bus Oprtd :	10	8	3	12	11
Fare Sys :	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]
Patronage :	3573	1557	1730	1315	2408
Highest Ld:	68	52	40	51	47
Occ rate :	58.8	36.7	33.3	16.6	31.7
M Share :	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0
AWT (mnts):	6.79	11.40	13.54	5.24	7.77
Av Fare :	50.0	50.0	50.0	50.0	50.0
Gen Cost :	93.3	115.9	104.7	79.7	88.6
Tot Op C :	356.32	288.47	107.21	434.64	394.45
Revenue :	788.16	343.46	381.62	290.07	531.18
Profit :	431.84	54.99	274.41	-144.57	136.73

TOTAL PATRONAGE = 10583

TOTAL REVENUE (£) = 2334485.29
TOTAL OP COST (£) = 1581091.18
TOTAL PROFIT (£) = 753394.11

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	44

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 286489.01

ALLOCATING THE VEHICLES TO THE ROUTES

CASE 1 :To reduce the number of vehicles on the routes with deficit, or on the routes in which the level of occupancies is not too high, and put them onto routes in which the occupancy rate is high.

CASE 2 :To allocate the vehicles to the routes on the basis of the proportion of existing levels of patronage on the routes concerned.

CASE 3 :To reallocate all the vehicles evenly over the network.

CASE 1

ROUTE	1	2	3	4	5
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	17	8	7	5	7
Bus Oprtd :	17	8	7	5	7
Fare Sys :	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]
Patronage :	4320	1448	2836	896	1965
Highest Ld:	72	50	61	32	43
Occ rate :	65.5	35.9	57.3	9.3	23.7
M Share :	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0
AWT (mnts):	4.08	11.33	4.74	16.60	13.77
Av Fare :	50.0	50.0	50.0	50.0	50.0
Gen Cost :	106.0	114.3	79.3	113.6	104.1
Tot Op C :	609.08	288.52	246.87	181.88	251.77
Revenue :	952.94	319.41	625.59	197.65	433.46
Profit :	343.86	30.89	378.72	15.77	181.68

TOTAL PATRONAGE = 11465

TOTAL REVENUE (£) = 2529044.12
TOTAL OP COST (£) = 1578121.81
TOTAL PROFIT (£) = 950922.31

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	44

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 280314.22

CASE 2

ROUTE		1	2	3	4	5
Vhcl type	:	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity	:	72	72	72	72	72
Sys Op	:	TPO	TPO	TPO	TPO	TPO
Fleet Sz	:	15	7	7	5	10
Bus Oprtd	:	15	7	7	5	10
Fare Sys	:	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]
Patronage	:	4159	1363	2837	896	2238
Highest Ld	:	69	72	62	32	45
Occ rate	:	63.7	43.6	58.5	9.5	30.2
M Share	:	100.0	100.0	100.0	100.0	100.0
Card Hldr	:	0.0	0.0	0.0	0.0	0.0
AWT (mnts)	:	4.23	11.23	4.76	16.60	8.94
Av Fare	:	50.0	50.0	50.0	50.0	50.0
Gen Cost	:	87.9	125.0	79.2	113.6	91.4
Tot Op C	:	536.59	252.72	247.06	181.88	358.98
Revenue	:	917.43	300.66	625.81	197.65	493.68
Profit	:	380.84	47.94	378.75	15.77	134.69

TOTAL PATRONAGE = 11493

TOTAL REVENUE (£) = 2535220.59
TOTAL OP COST (£) = 1577229.79
TOTAL PROFIT (£) = 957990.80

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	44

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 280931.88

CASE 3

ROUTE	1	2	3	4	5
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	9	9	8	9	9
Bus Oprtd :	9	9	8	9	9
Fare Sys :	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]
Patronage :	3436	1590	2909	1182	2165
Highest Ld:	66	54	61	44	44
Occ rate :	56.5	39.0	58.2	15.2	26.9
M Share :	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0
AWT (mnts):	7.74	9.61	4.21	7.93	10.03
Av Fare :	50.0	50.0	50.0	50.0	50.0
Gen Cost :	94.7	107.8	78.0	89.1	95.2
Tot Op C :	320.93	324.15	282.54	326.33	323.19
Revenue :	757.94	350.74	641.69	260.74	477.57
Profit :	437.01	26.59	359.15	-65.60	154.38

TOTAL PATRONAGE = 11282

TOTAL REVENUE (£) = 2488676.47
TOTAL OP COST (£) = 1577143.54
TOTAL PROFIT (£) = 911532.93

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	44

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 286453.76

CHOOSING THE TYPE OF VEHICLE

Typesof vehicle to be considered :

1. Double/decker bus	(44 buses)
2. Standard bus	(82 buses)
3. Midi bus	(94 buses)
4. Mini bus	(160 buses)

D/DECKER : VEHICLES ALLOCATED EVENLY OVER THE NETWORK

ROUTE	1	2	3	4	5
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	9	9	8	9	9
Bus Oprtd :	9	9	8	9	9
Fare Sys :	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]
Patronage :	3436	1590	2909	1182	2165
Highest Ld:	66	54	61	44	44
Occ rate :	56.5	39.0	58.2	15.2	26.9
M Share :	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0
AWT (mnts):	7.74	9.61	4.21	7.93	10.03
Av Fare :	50.0	50.0	50.0	50.0	50.0
Gen Cost :	94.7	107.8	78.0	89.1	95.2
Tot Op C :	320.93	324.15	282.54	326.33	323.19
Revenue :	757.94	350.74	641.69	260.74	477.57
Profit :	437.01	26.59	359.15	-65.60	154.38

TOTAL PATRONAGE = 11282

TOTAL REVENUE (£) = 2488676.47
TOTAL OP COST (£) = 1577143.54
TOTAL PROFIT (£) = 911532.93

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	44

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 286453.76

STANDARD BUS : VEHICLES ALLOCATED EVENLY OVER THE NETWORK

ROUTE	1	2	3	4	5
Vhcl type :	Stdrd	Stdrd	Stdrd	Stdrd	Stdrd
Capacity :	45	45	45	45	45
Sys Op :	OPO	OPO	OPO	OPO	OPO
Fleet Sz :	17	16	16	16	17
Bus Oprtd :	17	16	16	16	17
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	4269	2016	4051	1572	3008
Highest Ld:	43	38	34	39	41
Occ rate :	75.5	51.5	59.4	41.3	49.8
M Share :	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0
AWT (mnts):	4.46	4.53	2.46	4.42	4.11
Av Fare :	50.0	50.0	50.0	50.0	50.0
Gen Cost :	97.1	91.6	73.9	75.5	80.3
Tot Op C :	389.40	368.58	360.61	370.80	370.66
Revenue :	941.69	444.71	893.60	346.76	663.53
Profit :	552.29	76.13	532.99	-24.04	292.87

TOTAL PATRONAGE = 14916

TOTAL REVENUE (£) = 3290294.12
TOTAL OP COST (£) = 1860048.53
TOTAL PROFIT (£) = 1430245.59

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	82	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 267713.40

MIDI BUS : VEHICLES ALLOCATED EVENLY OVER THE NETWORK

ROUTE	1	2	3	4	5
Vhcl type :	Midi	Midi	Midi	Midi	Midi
Capacity :	35	35	35	35	35
Sys Op :	OPO	OPO	OPO	OPO	OPO
Fleet Sz :	20	18	18	18	20
Bus Oprtd :	20	18	18	18	20
Fare Sys :	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]
Patronage :	4754	2284	4660	1786	3477
Highest Ld:	33	35	32	35	35
Occ rate :	74.0	58.2	71.6	38.5	60.0
M Share :	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0
AWT (mnts):	3.55	3.47	2.30	3.61	3.82
Av Fare :	50.0	50.0	50.0	50.0	50.0
Gen Cost :	86.5	85.9	74.4	72.1	73.6
Tot Op C :	411.54	351.99	367.30	353.46	418.10
Revenue :	1048.68	503.82	1027.94	393.97	766.99
Profit :	637.14	151.83	660.64	40.51	348.89

TOTAL PATRONAGE = 16961

TOTAL REVENUE (£) = 3741397.06
TOTAL OP COST (£) = 1902388.47
TOTAL PROFIT (£) = 1839008.58

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	94	0	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 257592.60

MINI BUS : VEHICLES ALLOCATED EVENLY OVER THE NETWORK

ROUTE	1	2	3	4	5
Vhcl type :	Mini	Mini	Mini	Mini	Mini
Capacity :	20	20	20	20	20
Sys Op :	OPO	OPO	OPO	OPO	OPO
Fleet Sz :	35	30	30	30	35
Bus Oprtd :	35	30	30	30	35
Fare Sys :	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]
Patronage :	6075	2924	6174	2374	4677
Highest Ld:	20	20	18	18	18
Occ rate :	76.5	63.5	77.2	33.1	64.9
M Share :	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0
AWT (mnts):	2.07	1.87	1.42	1.89	2.53
Av Fare :	50.0	50.0	50.0	50.0	50.0
Gen Cost :	77.1	78.1	66.6	67.3	71.8
Tot Op C :	670.53	506.49	564.86	579.14	636.52
Revenue :	1340.07	645.00	1361.91	523.68	1031.69
Profit :	669.55	138.51	797.05	-55.47	395.17

TOTAL PATRONAGE = 22224

TOTAL REVENUE (£) = 4902352.94
TOTAL OP COST (£) = 2957540.71
TOTAL PROFIT (£) = 1944812.23

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	160	0	0	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 248613.67

STANDARD BUS : VEHICLES ALLOCATED IN PROPORTION TO EXISTING PATRONAGE

ROUTE	1	2	3	4	5
Vhcl type :	Stdrd	Stdrd	Stdrd	Stdrd	Stdrd
Capacity :	45	45	45	45	45
Sys Op :	OPO	OPO	OPO	OPO	OPO
Fleet Sz :	28	12	13	10	19
Bus Oprtd :	28	12	13	10	19
Fare Sys :	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]
Patronage :	5219	1804	3748	1304	3201
Highest Ld:	43	45	36	38	42
Occ rate :	71.0	55.9	61.2	20.7	54.5
M Share :	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0
AWT (mnts):	2.64	6.04	2.93	6.21	4.13
Av Fare :	50.0	50.0	50.0	50.0	50.0
Gen Cost :	97.6	96.7	85.1	80.7	80.7
Tot Op C :	649.93	279.46	295.99	222.90	428.29
Revenue :	1151.25	397.94	826.76	287.65	706.10
Profit :	501.32	118.48	530.78	64.75	277.82

TOTAL PATRONAGE = 15276

TOTAL REVENUE (£) = 3369705.88
TOTAL OP COST (£) = 1876563.72
TOTAL PROFIT (£) = 1493142.16

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	82	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 263052.57

MIDI BUS : VEHICLES ALLOCATED IN PROPORTION TO EXISTING PATRONAGE

ROUTE	1	2	3	4	5
Vhcl type :	Midi	Midi	Midi	Midi	Midi
Capacity :	35	35	35	35	35
Sys Op :	OPO	OPO	OPO	OPO	OPO
Fleet Sz :	32	14	15	12	21
Bus Oprtd :	32	14	15	12	21
Fare Sys :	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]
Patronage :	5687	2043	4199	1475	3536
Highest Ld:	33	35	33	35	35
Occ rate :	75.1	62.9	73.5	32.2	65.7
M Share :	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0
AWT (mnts):	2.09	4.55	2.78	4.43	3.98
Av Fare :	50.0	50.0	50.0	50.0	50.0
Gen Cost :	77.9	89.1	78.1	76.4	75.2
Tot Op C :	669.67	294.43	306.35	254.16	432.26
Revenue :	1254.49	450.66	926.25	325.37	780.00
Profit :	584.82	156.23	619.90	71.21	347.74

TOTAL PATRONAGE = 16940

TOTAL REVENUE (£) = 3736764.71
TOTAL OP COST (£) = 1956868.80
TOTAL PROFIT (£) = 1779895.90

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	94	0	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 256305.26

D/DECKER : VEHICLES ALLOCATED IN PROPORTION TO EXISTING PATRONAGE

ROUTE	1	2	3	4	5
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	15	7	7	5	10
Bus Oprtd :	15	7	7	5	10
Fare Sys :	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]
Patronage :	4159	1363	2837	896	2238
Highest Ld:	69	72	62	32	45
Occ rate :	63.7	43.6	58.5	9.5	30.2
M Share :	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0
AWT (mnts):	4.23	11.23	4.76	16.60	8.94
Av Fare :	50.0	50.0	50.0	50.0	50.0
Gen Cost :	87.9	125.0	79.2	113.6	91.4
Tot Op C :	536.59	252.72	247.06	181.88	358.98
Revenue :	917.43	300.66	625.81	197.65	493.68
Profit :	380.84	47.94	378.75	15.77	134.69

TOTAL PATRONAGE = 11493

TOTAL REVENUE (£) = 2535220.59
TOTAL OP COST (£) = 1577229.79
TOTAL PROFIT (£) = 957990.80

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	44

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 280931.88

MINI BUS : VEHICLES ALLOCATED IN PROPORTION TO EXISTING PATRONAGE

ROUTE		1	2	3	4	5
Vhcl type	:	Mini	Mini	Mini	Mini	Mini
Capacity	:	20	20	20	20	20
Sys Op	:	OPO	OPO	OPO	OPO	OPO
Fleet Sz	:	54	24	26	20	36
Bus Oprtd	:	54	24	26	20	36
Fare Sys	:	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]	F/[50 p/t]
Patronage	:	7182	2628	5790	1951	4706
Highest Ld	:	18	18	18	17	20
Occ rate	:	73.6	61.2	80.7	30.7	69.4
M Share	:	100.0	100.0	100.0	100.0	100.0
Card Hldr	:	0.0	0.0	0.0	0.0	0.0
AWT (mnts)	:	1.28	2.34	1.74	2.14	2.51
Av Fare	:	50.0	50.0	50.0	50.0	50.0
Gen Cost	:	77.7	78.1	68.0	69.3	70.0
Tot Op C	:	1031.59	411.49	490.02	328.88	635.75
Revenue	:	1584.26	579.71	1277.21	430.37	1038.09
Profit	:	552.67	168.21	787.19	101.49	402.34

TOTAL PATRONAGE = 22257

TOTAL REVENUE (£) = 4909632.35
TOTAL OP COST (£) = 2897738.50
TOTAL PROFIT (£) = 2011893.85

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	160	0	0	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 248667.43

APPENDIX 5

EXERCISE RESULTS OF THE *COMBO.2* MODEL

BUS COMPETITION IN AN URBAN BUS NETWORK

BASE CONDITION

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	2051	3048	2271	2293	1323	1000	3728	1225
Highest Ld:	32	36	32	27	13	14	34	10
Occ rate :	26.6	26.2	24.9	19.3	11.6	12.4	25.3	9.8
M Share :	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.6	2.3	2.6	2.2	2.1	2.0	2.1	1.8
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	65.3	64.3	67.9	64.4	62.7	63.2	65.7	59.3
Tot Op C :	245.16	350.79	347.20	345.38	283.32	249.92	517.93	209.46
Revenue :	452.43	672.35	500.96	505.81	291.84	220.59	822.35	270.22
Profit :	207.27	321.56	153.76	160.43	8.52	-29.33	304.42	60.76

TOTAL PATRONAGE = 16939 TOTAL REVENUE (£) = 3736544.12
TOTAL OP COST (£) = 2549158.98
TOTAL PROFIT (£) = 1187385.14

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1102965.58

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	--	--	--	--	--	--
Capacity :	--	--	--	--	--	--	--	--
Sys Op :	--	--	--	--	--	--	--	--
Fleet Sz :	--	--	--	--	--	--	--	--
Bus Oprtd :	--	--	--	--	--	--	--	--
Fare Sys :	--	--	--	--	--	--	--	--
Patronage :	--	--	--	--	--	--	--	--
Highest Ld:	--	--	--	--	--	--	--	--
Occ rate :	--	--	--	--	--	--	--	--
M Share :	--	--	--	--	--	--	--	--
Card Hldr :	--	--	--	--	--	--	--	--
AWT :	--	--	--	--	--	--	--	--
Av Fare :	--	--	--	--	--	--	--	--
Gen Cost :	--	--	--	--	--	--	--	--
Tot Op C :	--	--	--	--	--	--	--	--
Revenue :	--	--	--	--	--	--	--	--
Profit :	--	--	--	--	--	--	--	--

TOTAL PATRONAGE = 0 TOTAL REVENUE (£) = 0.00
TOTAL OP COST (£) = 0.00
TOTAL PROFIT (£) = 0.00

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1102965.58

NEW ENTRANT ENTERED THE MARKET WITH 11 D/DECKER BUSES AND ALLOCATED THEM TO ROUTE 1

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	1047	2644	2235	2299	1393	1034	3704	1244
Highest Ld:	13	33	31	25	14	14	33	11
Occ rate :	12.2	25.7	24.1	19.5	11.6	13.1	25.6	10.2
M Share :	35.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	0.7	2.4	2.5	2.3	2.0	2.0	2.2	1.9
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	58.4	66.0	67.9	64.2	61.8	64.1	66.0	59.7
Tot Op C :	239.54	342.84	354.16	350.82	282.97	251.34	526.86	206.65
Revenue :	231.11	583.24	493.01	507.13	307.28	228.09	817.06	274.41
Profit :	-8.43	240.39	138.86	156.32	24.31	-23.26	290.20	67.76

TOTAL PATRONAGE = 15600

TOTAL REVENUE (£) = 3441330.02
TOTAL OP COST (£) = 2555179.65
TOTAL PROFIT (£) = 886150.36

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1123068.48

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	--	--	--	--	--	--	--
Capacity :	72	--	--	--	--	--	--	--
Sys Op :	TPO	--	--	--	--	--	--	--
Fleet Sz :	11	--	--	--	--	--	--	--
Bus Oprtd :	11	--	--	--	--	--	--	--
Fare Sys :	F/50p	--	--	--	--	--	--	--
Patronage :	1900	--	--	--	--	--	--	--
Highest Ld:	20	--	--	--	--	--	--	--
Occ rate :	15.4	--	--	--	--	--	--	--
M Share :	64.5	--	--	--	--	--	--	--
Card Hldr :	0.0	--	--	--	--	--	--	--
AWT :	0.7	--	--	--	--	--	--	--
Av Fare :	50.0	--	--	--	--	--	--	--
Gen Cost :	58.9	--	--	--	--	--	--	--
Tot Op C :	382.90	--	--	--	--	--	--	--
Revenue :	419.18	--	--	--	--	--	--	--
Profit :	36.28	--	--	--	--	--	--	--

TOTAL PATRONAGE = 1900

TOTAL REVENUE (£) = 419184.69
TOTAL OP COST (£) = 382902.69
TOTAL PROFIT (£) = 36282.00

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	11

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1123068.48

NEW ENTRANT ENTERED THE MARKET WITH 11 D/DECKER BUSES AND ALLOCATED THEM TO ROUTE 2

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	2052	1686	2428	2140	1270	1161	3575	1228
Highest Ld:	30	20	33	24	13	16	42	9
Occ rate :	24.6	15.7	25.8	17.2	11.2	14.3	25.0	10.3
M Share :	100.0	45.8	100.0	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.8	1.0	2.5	2.4	2.3	2.1	2.1	1.7
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	65.8	60.3	68.1	64.4	63.4	63.6	65.9	59.0
Tot Op C :	243.42	344.57	352.75	345.87	283.29	251.20	524.87	211.75
Revenue :	452.65	371.93	535.59	472.06	280.15	256.10	788.60	270.88
Profit :	209.23	27.35	182.84	126.19	-3.14	4.91	263.73	59.13

TOTAL PATRONAGE = 15540

TOTAL REVENUE (£) = 3427956.06
TOTAL OP COST (£) = 2557728.04
TOTAL PROFIT (£) = 870228.02

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1119101.85

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	D/Dck	--	--	--	--	--	--
Capacity :	--	72	--	--	--	--	--	--
Sys Op :	--	TPO	--	--	--	--	--	--
Fleet Sz :	--	11	--	--	--	--	--	--
Bus Oprtd :	--	11	--	--	--	--	--	--
Fare Sys :	--	F/50p	--	--	--	--	--	--
Patronage :	--	1991	--	--	--	--	--	--
Highest Ld:	--	19	--	--	--	--	--	--
Occ rate :	--	16.3	--	--	--	--	--	--
M Share :	--	54.2	--	--	--	--	--	--
Card Hldr :	--	0.0	--	--	--	--	--	--
AWT :	--	1.0	--	--	--	--	--	--
Av Fare :	--	50.0	--	--	--	--	--	--
Gen Cost :	--	60.9	--	--	--	--	--	--
Tot Op C :	--	365.26	--	--	--	--	--	--
Revenue :	--	439.40	--	--	--	--	--	--
Profit :	--	74.14	--	--	--	--	--	--

TOTAL PATRONAGE = 1991

TOTAL REVENUE (£) = 439396.88
TOTAL OP COST (£) = 365257.48
TOTAL PROFIT (£) = 74139.40

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	11

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1119101.85

NEW ENTRANT ENTERED THE MARKET WITH 11 D/DECKER BUSES AND ALLOCATED THEM TO ROUTE 3

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	2011	2533	1929	1676	1396	1089	3467	1229
Highest Ld:	29	24	26	18	16	15	38	10
Occ rate :	24.4	21.0	19.5	14.0	12.4	13.0	24.3	10.1
M Share :	100.0	100.0	46.9	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.3	2.3	1.2	2.4	2.1	2.1	2.1	2.2
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	64.3	64.7	61.9	64.8	62.6	64.4	66.3	60.2
Tot Op C :	247.34	350.64	342.49	349.42	285.53	251.09	529.25	206.48
Revenue :	443.60	558.75	425.55	369.71	307.94	240.22	764.73	271.10
Profit :	196.26	208.11	83.05	20.29	22.41	-10.87	235.53	64.62

TOTAL PATRONAGE = 15330   TOTAL REVENUE (£) = 3381649.07
TOTAL OP COST (£) = 2562253.55
TOTAL PROFIT (£) = 819395.52

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1123136.64

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	D/Dck	--	--	--	--	--
Capacity :	--	--	72	--	--	--	--	--
Sys Op :	--	--	TPO	--	--	--	--	--
Fleet Sz :	--	--	11	--	--	--	--	--
Bus Oprtd :	--	--	11	--	--	--	--	--
Fare Sys :	--	--	F/50p	--	--	--	--	--
Patronage :	--	--	2179	--	--	--	--	--
Highest Ld:	--	--	30	--	--	--	--	--
Occ rate :	--	--	22.4	--	--	--	--	--
M Share :	--	--	53.1	--	--	--	--	--
Card Hldr :	--	--	0.0	--	--	--	--	--
AWT :	--	--	1.2	--	--	--	--	--
Av Fare :	--	--	50.0	--	--	--	--	--
Gen Cost :	--	--	62.9	--	--	--	--	--
Tot Op C :	--	--	372.89	--	--	--	--	--
Revenue :	--	--	480.85	--	--	--	--	--
Profit :	--	--	107.96	--	--	--	--	--

TOTAL PATRONAGE = 2179   TOTAL REVENUE (£) = 480850.93
TOTAL OP COST (£) = 372886.30
TOTAL PROFIT (£) = 107964.63

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	11

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1123136.64

NEW ENTRANT ENTERED THE MARKET WITH 11 D/DECKER BUSES AND ALLOCATED THEM TO ROUTE 4

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	2032	2819	2152	1248	1515	965	3675	1250
Highest Ld:	29	32	29	16	14	15	36	10
Occ rate :	25.3	24.5	24.5	12.0	13.0	11.8	25.3	10.2
M Share :	100.0	100.0	100.0	41.2	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.7	2.5	2.6	1.0	2.4	1.9	2.1	1.8
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	65.1	65.5	68.4	59.6	63.5	63.6	65.8	59.1
Tot Op C :	243.78	347.98	353.06	346.91	281.57	248.15	529.64	211.07
Revenue :	448.24	621.84	474.71	275.49	334.19	212.37	810.66	275.74
Profit :	204.45	273.86	121.64	-71.42	52.62	-35.29	281.02	64.66

TOTAL PATRONAGE = 15656 TOTAL REVENUE (£) = 3453729.03
TOTAL OP COST (£) = 2562172.82
TOTAL PROFIT (£) = 891556.22

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1123088.51

Bl..

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	--	D/Dck	--	--	--	--
Capacity :	--	--	--	72	--	--	--	--
Sys Op :	--	--	--	TPO	--	--	--	--
Fleet Sz :	--	--	--	11	--	--	--	--
Bus Oprtd :	--	--	--	11	--	--	--	--
Fare Sys :	--	--	--	F/50p	--	--	--	--
Patronage :	--	--	--	1780	--	--	--	--
Highest Ld:	--	--	--	23	--	--	--	--
Occ rate :	--	--	--	15.3	--	--	--	--
M Share :	--	--	--	58.8	--	--	--	--
Card Hldr :	--	--	--	0.0	--	--	--	--
AWT :	--	--	--	1.0	--	--	--	--
Av Fare :	--	--	--	50.0	--	--	--	--
Gen Cost :	--	--	--	60.5	--	--	--	--
Tot Op C :	--	--	--	363.37	--	--	--	--
Revenue :	--	--	--	392.67	--	--	--	--
Profit :	--	--	--	29.29	--	--	--	--

TOTAL PATRONAGE = 1780 TOTAL REVENUE (£) = 392668.03
TOTAL OP COST (£) = 363374.12
TOTAL PROFIT (£) = 29293.91

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	11

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1123088.51

NEW ENTRANT ENTERED THE MARKET WITH 11 D/DECKER BUSES AND ALLOCATED THEM TO ROUTE 6

EXISTING OPERATOR

ROUTE		1	2	3	4	5	6	7	8
Vhcl type	:	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity	:	72	72	72	72	72	72	72	72
Sys Op	:	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz	:	7	10	10	10	8	7	15	6
Bus Oprtd	:	7	10	10	10	8	7	15	6
Fare Sys	:	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage	:	2064	2952	2347	2095	1159	759	3554	1213
Highest Ld	:	31	32	31	24	13	8	37	8
Occ rate	:	24.8	25.3	25.1	17.6	10.6	8.2	24.7	9.4
M Share	:	100.0	100.0	100.0	100.0	100.0	41.6	100.0	100.0
Card Hldr	:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT	:	3.0	2.2	2.4	2.3	2.3	0.8	2.1	1.9
Av Fare	:	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost	:	66.0	64.6	67.8	65.1	63.7	58.8	67.7	59.3
Tot Op C	:	242.60	348.30	347.29	348.61	285.91	241.25	524.16	208.21
Revenue	:	455.29	651.18	517.72	462.13	255.66	167.44	783.97	267.57
Profit	:	212.70	302.87	170.43	113.52	-30.25	-73.81	259.81	59.36

TOTAL PATRONAGE = 16143

TOTAL REVENUE (£) = 3560973.96
TOTAL OP COST (£) = 2546334.70
TOTAL PROFIT (£) = 1014639.26

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1114540.27

NEW ENTRANT

ROUTE		1	2	3	4	5	6	7	8
Vhcl type	:	--	--	--	--	--	D/Dck	--	--
Capacity	:	--	--	--	--	--	72	--	--
Sys Op	:	--	--	--	--	--	TPO	--	--
Fleet Sz	:	--	--	--	--	--	11	--	--
Bus Oprtd	:	--	--	--	--	--	11	--	--
Fare Sys	:	--	--	--	--	--	F/50p	--	--
Patronage	:	--	--	--	--	--	1063	--	--
Highest Ld	:	--	--	--	--	--	10	--	--
Occ rate	:	--	--	--	--	--	8.9	--	--
M Share	:	--	--	--	--	--	58.4	--	--
Card Hldr	:	--	--	--	--	--	0.0	--	--
AWT	:	--	--	--	--	--	0.8	--	--
Av Fare	:	--	--	--	--	--	50.0	--	--
Gen Cost	:	--	--	--	--	--	58.3	--	--
Tot Op C	:	--	--	--	--	--	379.22	--	--
Revenue	:	--	--	--	--	--	234.69	--	--
Profit	:	--	--	--	--	--	-144.53	--	--

TOTAL PATRONAGE = 1063

TOTAL REVENUE (£) = 234687.80
TOTAL OP COST (£) = 379215.95
TOTAL PROFIT (£) = -144528.15

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	11

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1114540.27

NEW ENTRANT ENTERED THE MARKET WITH 11 D/DECKER BUSES AND ALLOCATED THEM TO ROUTE 7

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	2241	2448	2330	2208	1142	1067	3102	1314
Highest Ld:	30	28	34	27	13	15	30	11
Occ rate :	26.8	22.9	26.0	19.0	10.0	13.9	21.9	11.9
M Share :	100.0	100.0	100.0	100.0	100.0	100.0	61.7	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.8	2.3	2.7	2.4	1.9	2.2	1.2	1.8
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	65.7	65.3	67.7	65.3	62.2	64.2	62.3	59.2
Tot Op C :	237.99	343.83	345.95	339.31	286.28	251.19	514.13	205.62
Revenue :	494.34	540.00	513.97	487.06	251.91	235.37	684.43	239.85
Profit :	256.35	196.17	168.02	147.75	-34.37	-15.82	170.29	34.23

TOTAL PATRONAGE = 15852 TOTAL REVENUE (£) = 3496926.01
TOTAL OP COST (£) = 2524304.77
TOTAL PROFIT (£) = 972621.23

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1134120.95

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	--	--	--	--	D/Dck	--
Capacity :	--	--	--	--	--	--	72	--
Sys Op :	--	--	--	--	--	--	TPO	--
Fleet Sz :	--	--	--	--	--	--	11	--
Bus Oprtd :	--	--	--	--	--	--	11	--
Fare Sys :	--	--	--	--	--	--	F/50p	--
Patronage :	--	--	--	--	--	--	1925	--
Highest Ld:	--	--	--	--	--	--	26	--
Occ rate :	--	--	--	--	--	--	18.9	--
M Share :	--	--	--	--	--	--	38.3	--
Card Hldr :	--	--	--	--	--	--	0.0	--
AWT :	--	--	--	--	--	--	1.2	--
Av Fare :	--	--	--	--	--	--	50.0	--
Gen Cost :	--	--	--	--	--	--	62.0	--
Tot Op C :	--	--	--	--	--	--	380.57	--
Revenue :	--	--	--	--	--	--	424.69	--
Profit :	--	--	--	--	--	--	44.12	--

TOTAL PATRONAGE = 1925 TOTAL REVENUE (£) = 424691.64
TOTAL OP COST (£) = 380574.87
TOTAL PROFIT (£) = 44116.77

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	11

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1134120.95

NEW ENTRANT ENTERED THE MARKET WITH 11 D/DECKER BUSES AND ALLOCATED THEM TO ROUTE 5

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	2059	2627	2334	2396	910	813	3386	1261
Highest Ld:	31	34	34	29	9	13	33	10
Occ rate :	23.5	25.4	26.0	20.8	8.6	10.0	22.3	10.3
M Share :	100.0	100.0	100.0	100.0	37.4	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.7	2.5	2.3	2.2	0.8	2.4	2.2	1.8
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	65.6	66.1	67.3	64.3	58.2	64.1	66.1	58.9
Tot Op C :	240.91	340.86	356.48	347.06	278.46	247.91	512.16	209.66
Revenue :	454.19	579.49	514.85	528.53	200.76	179.34	746.91	278.16
Profit :	213.28	238.63	158.38	181.47	-77.70	-68.57	234.75	68.50

TOTAL PATRONAGE = 15786 TOTAL REVENUE (£) = 3482228.62
TOTAL OP COST (£) = 2533495.46
TOTAL PROFIT (£) = 948733.16

VEHICLES = Mini 0 Midi 0 Stdrd 0 D/Decker 73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1116553.43

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	--	--	D/Dck	--	--	--
Capacity :	--	--	--	--	72	--	--	--
Sys Op :	--	--	--	--	TPO	--	--	--
Fleet Sz :	--	--	--	--	11	--	--	--
Bus Oprtd :	--	--	--	--	11	--	--	--
Fare Sys :	--	--	--	--	F/50p	--	--	--
Patronage :	--	--	--	--	1520	--	--	--
Highest Ld:	--	--	--	--	10	--	--	--
Occ rate :	--	--	--	--	10.2	--	--	--
M Share :	--	--	--	--	62.6	--	--	--
Card Hldr :	--	--	--	--	0.0	--	--	--
AWT :	--	--	--	--	0.8	--	--	--
Av Fare :	--	--	--	--	50.0	--	--	--
Gen Cost :	--	--	--	--	58.3	--	--	--
Tot Op C :	--	--	--	--	383.65	--	--	--
Revenue :	--	--	--	--	335.49	--	--	--
Profit :	--	--	--	--	-48.15	--	--	--

TOTAL PATRONAGE = 1520 TOTAL REVENUE (£) = 335491.97
TOTAL OP COST (£) = 383645.00
TOTAL PROFIT (£) = -48153.04

VEHICLES = Mini 0 Midi 0 Stdrd 0 D/Decker 11

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1116553.43

NEW ENTRANT ENTERED THE MARKET WITH 11 D/DECKER BUSES AND ALLOCATED THEM TO ROUTE 8

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	2108	2859	2398	2231	1372	995	3702	598
Highest Ld:	33	36	36	26	14	13	36	7
Occ rate :	25.8	24.9	28.2	18.3	11.3	12.9	26.0	5.9
M Share :	100.0	100.0	100.0	100.0	100.0	100.0	100.0	38.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.8	2.6	2.4	2.2	1.9	2.1	2.1	0.7
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	65.9	70.1	68.0	63.6	62.1	64.4	65.8	55.7
Tot Op C :	242.67	345.34	355.93	342.61	285.84	247.25	527.61	205.15
Revenue :	465.00	630.66	528.97	492.13	302.65	219.49	816.62	132.09
Profit :	222.33	285.32	173.04	149.52	16.81	-27.76	289.00	-73.07

TOTAL PATRONAGE = 16263 TOTAL REVENUE (£) = 3587602.83
TOTAL OP COST (£) = 2552409.70
TOTAL PROFIT (£) = 1035193.13

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1113127.21

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	--	--	--	--	--	D/Dck
Capacity :	--	--	--	--	--	--	--	72
Sys Op :	--	--	--	--	--	--	--	TPO
Fleet Sz :	--	--	--	--	--	--	--	11
Bus Oprtd :	--	--	--	--	--	--	--	11
Fare Sys :	--	--	--	--	--	--	--	F/50p
Patronage :	--	--	--	--	--	--	--	977
Highest Ld:	--	--	--	--	--	--	--	6
Occ rate :	--	--	--	--	--	--	--	5.9
M Share :	--	--	--	--	--	--	--	62.0
Card Hldr :	--	--	--	--	--	--	--	0.0
AWT :	--	--	--	--	--	--	--	0.7
Av Fare :	--	--	--	--	--	--	--	50.0
Gen Cost :	--	--	--	--	--	--	--	55.9
Tot Op C :	--	--	--	--	--	--	--	370.69
Revenue :	--	--	--	--	--	--	--	215.56
Profit :	--	--	--	--	--	--	--	-155.13

TOTAL PATRONAGE = 977 TOTAL REVENUE (£) = 215558.94
TOTAL OP COST (£) = 370686.47
TOTAL PROFIT (£) = -155127.53

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	11

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1113127.21

NEW ENTRANT ENTERED THE MARKET WITH 40 MINI BUSES AND ALLOCATED THEM EVENLY OVER THE NETWORK

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	1256	1705	1711	1474	772	769	3050	732
Highest Ld:	20	25	24	19	10	10	29	6
Occ rate :	15.0	16.2	19.0	12.9	7.7	8.8	20.4	6.5
M Share :	49.3	58.8	63.2	61.8	52.4	49.1	77.9	51.2
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	3.3	4.2	4.7	4.1	4.0	3.5	4.6	3.0
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	70.4	73.3	75.8	71.2	70.9	69.1	74.2	64.1
Tot Op C :	236.27	353.49	349.87	343.42	282.00	248.72	526.09	200.33
Revenue :	277.28	376.17	377.58	325.27	170.43	169.83	672.80	161.48
Profit :	41.01	22.68	27.71	-18.15	-111.57	-78.88	146.71	-38.85

TOTAL PATRONAGE = 11469 TOTAL REVENUE (£) = 2530834.03
TOTAL OP COST (£) = 2540175.24
TOTAL PROFIT (£) = -9341.21

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1138368.45

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	Mini	Mini	Mini	Mini	Mini	Mini	Mini	Mini
Capacity :	20	20	20	20	20	20	20	20
Sys Op :	OPO	OPO	OPO	OPO	OPO	OPO	OPO	OPO
Fleet Sz :	5	5	5	5	5	5	5	5
Bus Oprtd :	5	5	5	5	5	5	5	5
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	1293	1193	996	912	701	799	863	698
Highest Ld:	17	18	18	16	10	10	17	7
Occ rate :	63.3	66.5	59.5	46.7	29.8	33.9	57.0	23.3
M Share :	50.7	41.2	36.8	38.2	47.6	50.9	22.1	48.8
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	3.8	4.2	4.7	4.1	4.0	3.5	4.6	3.0
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	65.7	68.4	73.1	74.1	67.4	71.6	66.7	61.1
Tot Op C :	90.46	91.23	88.80	86.06	92.51	90.12	89.44	87.57
Revenue :	285.22	263.32	219.77	201.27	154.72	176.27	190.59	154.18
Profit :	194.77	172.09	130.97	115.22	62.20	86.15	101.14	66.61

TOTAL PATRONAGE = 7455 TOTAL REVENUE (£) = 1645342.44
TOTAL OP COST (£) = 716187.06
TOTAL PROFIT (£) = 929155.39

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	40	0	0	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1138368.45

NEW ENTRANT ENTERED THE MARKET WITH 24 MIDI BUSES AND ALLOCATED THEM EVENLY OVER THE NETWORK

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	1675	1948	2119	1850	975	858	3217	973
Highest Ld:	22	24	31	22	11	11	31	9
Occ rate :	19.7	19.2	22.7	16.0	9.7	11.0	23.1	9.0
M Share :	67.3	64.3	75.2	77.4	63.3	66.6	82.8	69.3
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	4.7	4.7	5.5	4.8	4.9	4.7	5.1	4.0
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	72.0	74.0	78.2	73.4	71.2	72.4	75.9	66.3
Tot Op C :	244.23	353.73	347.89	352.51	284.52	241.05	531.77	211.14
Revenue :	369.68	429.80	467.43	408.25	215.17	189.48	709.79	214.84
Profit :	125.40	76.07	119.54	55.74	-69.35	-51.57	178.02	3.69

TOTAL PATRONAGE = 13615 TOTAL REVENUE (£) = 3004441.87
TOTAL OP COST (£) = 2566886.84
TOTAL PROFIT (£) = 437555.03

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1151624.20

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	Midi	Midi	Midi	Midi	Midi	Midi	Midi	Midi
Capacity :	35	35	35	35	35	35	35	35
Sys Op :	OPO	OPO	OPO	OPO	OPO	OPO	OPO	OPO
Fleet Sz :	3	3	3	3	3	3	3	3
Bus Oprtd :	3	3	3	3	3	3	3	3
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	797	1079	696	539	564	430	668	432
Highest Ld:	26	31	27	20	19	11	28	9
Occ rate :	38.3	58.4	47.8	26.8	28.7	21.3	41.5	17.6
M Share :	32.2	35.7	24.8	22.6	36.7	33.4	17.2	30.7
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	4.7	4.7	5.5	4.8	4.9	4.7	5.1	4.0
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	67.7	95.4	70.7	64.6	78.4	85.5	69.1	66.0
Tot Op C :	58.07	52.83	57.23	57.89	52.84	56.23	58.31	56.01
Revenue :	175.84	238.14	153.75	118.95	124.54	94.85	147.42	95.31
Profit :	117.77	185.31	96.51	61.06	71.69	38.62	89.10	39.30

TOTAL PATRONAGE = 5205 TOTAL REVENUE (£) = 1148793.42
TOTAL OP COST (£) = 449423.48
TOTAL PROFIT (£) = 699369.94

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	24	0	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1151624.20

NEW ENTRANT ENTERED THE MARKET WITH 21 STANDARD BUSES AND ALLOCATED THEM EVENLY OVER THE NETWORK

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	1633	2453	2158	2054	1371	820	3263	1186
Highest Ld:	24	29	31	28	14	12	34	11
Occ rate :	21.8	22.2	23.4	18.3	11.3	10.1	22.9	9.7
M Share :	67.2	79.0	80.9	78.5	78.9	73.3	88.2	84.5
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	1.6	1.8	2.0	1.9	1.3	1.5	1.8	1.7
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	61.5	63.7	66.9	62.8	60.0	62.7	65.2	59.1
Tot Op C :	240.95	349.49	350.02	347.06	285.71	246.06	526.65	199.93
Revenue :	360.35	541.12	476.17	453.14	302.44	180.97	719.95	261.64
Profit :	119.40	191.63	126.16	106.08	16.72	-65.09	193.30	61.71

TOTAL PATRONAGE = 14938 TOTAL REVENUE (£) = 3295780.97
TOTAL OP COST (£) = 2545873.48
TOTAL PROFIT (£) = 749907.49

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1175912.91

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	Stdrd	Stdrd	Stdrd	Stdrd	Stdrd	Stdrd	Stdrd	Stdrd
Capacity :	45	45	45	45	45	45	45	45
Sys Op :	OPO	OPO	OPO	OPO	OPO	OPO	OPO	OPO
Fleet Sz :	3	3	3	3	3	2	2	2
Bus Oprtd :	3	3	3	3	3	2	2	2
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	798	652	508	563	366	290	436	216
Highest Ld:	28	26	23	23	8	14	24	6
Occ rate :	37.0	29.0	27.6	27.9	10.9	18.0	27.1	8.1
M Share :	32.8	21.0	19.1	21.5	21.1	26.2	11.8	15.5
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	1.6	1.8	2.0	1.9	1.3	1.5	1.8	1.7
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	63.2	64.5	66.2	64.2	59.6	63.0	66.2	56.7
Tot Op C :	62.74	59.36	67.04	66.28	66.26	43.40	44.69	41.10
Revenue :	176.12	144.03	112.14	124.36	80.95	64.10	96.23	47.84
Profit :	113.38	84.67	45.10	58.08	14.68	20.70	51.54	6.74

TOTAL PATRONAGE = 3829 TOTAL REVENUE (£) = 845763.14
TOTAL OP COST (£) = 450866.06
TOTAL PROFIT (£) = 394897.08

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	21	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1175912.91

NEW ENTRANT ENTERED THE MARKET WITH 21 STANDARD BUSES AND ALLOCATED THEM TO ROUTE 7

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	2087	2491	2261	2259	1015	978	1964	1254
Highest Ld:	30	31	28	28	12	13	24	10
Occ rate :	26.5	21.0	23.8	18.7	9.0	12.4	15.7	9.3
M Share :	100.0	100.0	100.0	100.0	100.0	100.0	36.4	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.7	2.6	2.5	2.4	2.1	2.1	2.5	1.7
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	65.8	66.0	63.1	64.5	62.4	64.9	67.1	59.1
Tot Op C :	244.00	346.53	350.47	346.33	283.96	250.00	505.23	211.00
Revenue :	460.37	549.49	498.75	498.31	223.90	215.74	433.38	276.62
Profit :	216.37	202.96	148.28	151.98	-60.06	-34.26	-71.85	65.62

TOTAL PATRONAGE = 14309
TOTAL REVENUE (£) = 3156537.69
TOTAL OP COST (£) = 2537499.34
TOTAL PROFIT (£) = 619038.35

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1127691.96

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	--	--	--	--	Stdrd	--
Capacity :	--	--	--	--	--	--	45	--
Sys Op :	--	--	--	--	--	--	OPO	--
Fleet Sz :	--	--	--	--	--	--	21	--
Bus Oprtd :	--	--	--	--	--	--	21	--
Fare Sys :	--	--	--	--	--	--	F/50p	--
Patronage :	--	--	--	--	--	--	3436	--
Highest Ld:	--	--	--	--	--	--	21	--
Occ rate :	--	--	--	--	--	--	27.3	--
M Share :	--	--	--	--	--	--	63.6	--
Card Hldr :	--	--	--	--	--	--	0.0	--
AWT :	--	--	--	--	--	--	2.5	--
Av Fare :	--	--	--	--	--	--	50.0	--
Gen Cost :	--	--	--	--	--	--	71.9	--
Tot Op C :	--	--	--	--	--	--	384.55	--
Revenue :	--	--	--	--	--	--	758.02	--
Profit :	--	--	--	--	--	--	373.48	--

TOTAL PATRONAGE = 3436
TOTAL REVENUE (£) = 758021.13
TOTAL OP COST (£) = 384545.43
TOTAL PROFIT (£) = 373475.70

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	21	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1127691.96

NEW ENTRANT ENTERED THE MARKET WITH 21 STANDARD BUSES AND ALLOCATED THEM TO ROUTE 8

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	2059	2799	2395	2308	1352	1023	3667	335
Highest Ld:	28	31	34	26	15	14	36	6
Occ rate :	24.6	24.1	26.0	18.4	12.3	12.7	26.0	6.6
M Share :	100.0	100.0	100.0	100.0	100.0	100.0	100.0	20.6
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.9	2.7	2.8	2.4	2.4	2.0	2.0	1.6
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	66.0	65.8	68.5	64.7	63.3	63.7	65.7	59.0
Tot Op C :	241.96	338.75	355.76	347.64	282.31	249.69	517.72	185.00
Revenue :	454.19	617.43	528.31	509.12	298.24	226.76	808.90	74.08
Profit :	212.23	278.68	172.55	161.48	15.93	-22.93	291.17	-110.92

TOTAL PATRONAGE = 15943

TOTAL REVENUE (£) = 3517019.80
TOTAL OP COST (£) = 2518828.18
TOTAL PROFIT (£) = 998191.62

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1111989.54

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	--	--	--	--	--	Stdrd
Capacity :	--	--	--	--	--	--	--	45
Sys Op :	--	--	--	--	--	--	--	OPO
Fleet Sz :	--	--	--	--	--	--	--	21
Bus Oprtd :	--	--	--	--	--	--	--	21
Fare Sys :	--	--	--	--	--	--	--	F/50p
Patronage :	--	--	--	--	--	--	--	1296
Highest Ld:	--	--	--	--	--	--	--	4
Occ rate :	--	--	--	--	--	--	--	7.3
M Share :	--	--	--	--	--	--	--	79.4
Card Hldr :	--	--	--	--	--	--	--	0.0
AWT :	--	--	--	--	--	--	--	1.6
Av Fare :	--	--	--	--	--	--	--	50.0
Gen Cost :	--	--	--	--	--	--	--	63.3
Tot Op C :	--	--	--	--	--	--	--	411.35
Revenue :	--	--	--	--	--	--	--	285.92
Profit :	--	--	--	--	--	--	--	-125.42

TOTAL PATRONAGE = 1296

TOTAL REVENUE (£) = 285921.38
TOTAL OP COST (£) = 411345.30
TOTAL PROFIT (£) = -125423.92

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	21	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1111989.54

NEW ENTRANT ENTERED THE MARKET WITH 11 DOUBLE/DECKER BUSES AND ALLOCATED THEM EVENLY OVER THE NETWORK

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	1891	2666	2491	1942	1368	1026	3754	1199
Highest Ld:	29	34	37	26	15	14	37	11
Occ rate :	24.3	24.7	27.8	16.8	12.2	12.6	26.3	10.9
M Share :	74.7	84.0	80.7	90.3	94.9	84.3	97.3	86.6
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.2	2.1	2.3	1.9	2.0	1.6	2.0	2.0
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	63.9	64.0	66.9	63.3	63.2	62.5	65.8	59.5
Tot Op C :	236.53	340.00	345.35	351.65	284.71	249.40	528.72	201.02
Revenue :	417.19	588.21	549.58	428.58	301.81	226.53	828.17	264.64
Profit :	180.66	248.21	204.24	76.93	17.10	-22.88	299.45	63.62

```
TOTAL PATRONAGE      =    16337        TOTAL REVENUE (£) =  3604717.46
                                        TOTAL OP COST (£) =  2537388.25
                                       TOTAL PROFIT  (£) =  1067329.21
VEHICLES             = Mini      Midi    Stdrd    D/Decker
                        0         0        0         73
TOTAL OVERALL GENERALISED COST (Pass.mnts) =    1186972.06
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NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	2	2	2	1	1	1	1	1
Bus Oprtd :	2	2	2	1	1	1	1	1
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	640	507	595	209	73	191	105	185
Highest Ld:	36	31	36	18	5	10	10	9
Occ rate :	25.8	18.2	25.8	10.5	3.0	6.6	2.4	7.1
M Share :	25.3	16.0	19.3	9.7	5.1	15.7	2.7	13.4
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.2	2.1	2.3	1.9	2.0	1.6	2.0	2.0
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	64.2	64.4	67.5	65.4	57.4	63.2	64.4	59.4
Tot Op C :	70.22	70.65	70.93	35.50	36.35	35.90	31.99	35.22
Revenue :	141.34	111.94	131.37	46.12	16.28	42.15	23.30	40.88
Profit :	71.12	41.28	60.44	10.62	-20.07	6.25	-8.69	5.65

```
TOTAL PATRONAGE      =     2505        TOTAL REVENUE (£) =    553370.77
                                       TOTAL OP COST (£) =    386778.12
                                       TOTAL PROFIT  (£) =    166592.65
VEHICLES             = Mini      Midi    Stdrd    D/Decker
                        0         0        0         11
TOTAL OVERALL GENERALISED COST (Pass.mnts) =    1186972.06
```

NEW ENTRANT ENTERED THE MARKET WITH 24 MIDI BUSES AND ALLOCATED THEM TO ROUTE 7

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	2093	2455	2288	2164	999	991	1648	1245
Highest Ld:	32	30	28	25	12	12	20	9
Occ rate :	23.0	22.5	22.9	13.0	8.7	12.3	14.4	9.6
M Share :	100.0	100.0	100.0	100.0	100.0	100.0	30.1	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.7	2.3	2.6	2.1	2.1	2.1	2.2	1.7
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	65.3	66.7	67.3	64.0	62.5	64.5	66.1	58.3
Tot Op C :	241.14	348.26	353.27	356.76	286.53	243.79	503.57	211.07
Revenue :	461.69	541.54	504.71	477.35	220.37	218.60	363.53	274.63
Profit :	220.55	193.28	151.44	120.59	-66.16	-25.18	-140.04	63.56

TOTAL PATRONAGE = 13883

TOTAL REVENUE (£) = 3062427.72
TOTAL OP COST (£) = 2544388.66
TOTAL PROFIT (£) = 518039.06

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1126539.23

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	--	--	--	--	Midi	--
Capacity :	--	--	--	--	--	--	35	--
Sys Op :	--	--	--	--	--	--	OPO	--
Fleet Sz :	--	--	--	--	--	--	24	--
Bus Oprtd :	--	--	--	--	--	--	24	--
Fare Sys :	--	--	--	--	--	--	F/50p	--
Patronage :	--	--	--	--	--	--	3834	--
Highest Ld:	--	--	--	--	--	--	19	--
Occ rate :	--	--	--	--	--	--	32.9	--
M Share :	--	--	--	--	--	--	69.9	--
Card Hldr :	--	--	--	--	--	--	0.0	--
AWT :	--	--	--	--	--	--	2.2	--
Av Fare :	--	--	--	--	--	--	50.0	--
Gen Cost :	--	--	--	--	--	--	71.9	--
Tot Op C :	--	--	--	--	--	--	421.51	--
Revenue :	--	--	--	--	--	--	845.95	--
Profit :	--	--	--	--	--	--	424.44	--

TOTAL PATRONAGE = 3834

TOTAL REVENUE (£) = 845954.63
TOTAL OP COST (£) = 421512.41
TOTAL PROFIT (£) = 424442.23

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	24	0	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1126589.23

NEW ENTRANT ENTERED THE MARKET WITH 24 MIDI BUSES AND ALLOCATED THEM TO ROUTE 8

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	2099	2734	2386	2288	1465	978	3688	274
Highest Ld:	30	36	36	25	16	13	37	5
Occ rate :	24.0	24.6	26.9	19.0	12.2	11.7	25.1	5.2
M Share :	100.0	100.0	100.0	100.0	100.0	100.0	100.0	16.9
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.5	2.5	2.7	2.4	2.1	2.1	2.1	1.4
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	65.1	65.2	68.7	64.8	62.5	64.5	65.9	58.6
Tot Op C :	244.72	350.64	355.03	356.13	280.37	247.57	523.12	186.69
Revenue :	463.01	603.09	526.32	504.71	323.16	215.74	813.53	60.59
Profit :	218.30	252.45	171.30	148.58	42.79	-31.84	290.41	-126.09

TOTAL PATRONAGE = 15912 TOTAL REVENUE (£) = 3510153.22
TOTAL OP COST (£) = 2544262.73
TOTAL PROFIT (£) = 965890.49

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1110755.10

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	--	--	--	--	--	Midi
Capacity :	--	--	--	--	--	--	--	35
Sys Op :	--	--	--	--	--	--	--	OPO
Fleet Sz :	--	--	--	--	--	--	--	24
Bus Oprtd :	--	--	--	--	--	--	--	24
Fare Sys :	--	--	--	--	--	--	--	F/50p
Patronage :	--	--	--	--	--	--	--	1346
Highest Ld:	--	--	--	--	--	--	--	4
Occ rate :	--	--	--	--	--	--	--	9.5
M Share :	--	--	--	--	--	--	--	83.1
Card Hldr :	--	--	--	--	--	--	--	0.0
AWT :	--	--	--	--	--	--	--	1.4
Av Fare :	--	--	--	--	--	--	--	50.0
Gen Cost :	--	--	--	--	--	--	--	64.3
Tot Op C :	--	--	--	--	--	--	--	433.28
Revenue :	--	--	--	--	--	--	--	296.98
Profit :	--	--	--	--	--	--	--	-136.30

TOTAL PATRONAGE = 1346 TOTAL REVENUE (£) = 296979.13
TOTAL OP COST (£) = 433275.54
TOTAL PROFIT (£) = -136296.41

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	24	0	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1110755.10

NEW ENTRANT ENTERED THE MARKET WITH 40 MINI BUSES AND ALLOCATED THEM TO ROUTE 7

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	1966	2295	2333	2088	1056	923	1163	1185
Highest Ld:	36	26	36	26	13	14	15	9
Occ rate :	28.5	20.4	26.7	18.6	9.7	12.3	10.2	9.1
M Share :	100.0	100.0	100.0	100.0	100.0	100.0	22.9	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.8	2.4	2.3	2.5	2.4	2.7	1.7	2.4
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	66.5	64.7	68.6	64.9	63.1	66.4	63.9	60.6
Tot Op C :	239.60	340.71	344.47	351.63	281.44	248.64	495.61	205.93
Revenue :	433.68	506.25	514.63	460.59	232.94	203.60	256.68	261.40
Profit :	194.07	165.54	170.16	108.96	-48.49	-45.04	-238.93	55.47

TOTAL PATRONAGE = 13009 TOTAL REVENUE (£) = 2869766.08
TOTAL OP COST (£) = 2508028.99
TOTAL PROFIT (£) = 361737.09

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1080639.27

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	--	--	--	--	Mini	--
Capacity :	--	--	--	--	--	--	20	--
Sys Op :	--	--	--	--	--	--	OPO	--
Fleet Sz :	--	--	--	--	--	--	40	--
Bus Oprtd :	--	--	--	--	--	--	40	--
Fare Sys :	--	--	--	--	--	--	F/50p	--
Patronage :	--	--	--	--	--	--	3907	--
Highest Ld:	--	--	--	--	--	--	12	--
Occ rate :	--	--	--	--	--	--	34.3	--
M Share :	--	--	--	--	--	--	77.1	--
Card Hldr :	--	--	--	--	--	--	0.0	--
AWT :	--	--	--	--	--	--	1.7	--
Av Fare :	--	--	--	--	--	--	50.0	--
Gen Cost :	--	--	--	--	--	--	67.9	--
Tot Op C :	--	--	--	--	--	--	684.01	--
Revenue :	--	--	--	--	--	--	861.93	--
Profit :	--	--	--	--	--	--	177.92	--

TOTAL PATRONAGE = 3907 TOTAL REVENUE (£) = 861925.09
TOTAL OP COST (£) = 684007.31
TOTAL PROFIT (£) = 177917.79

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	40	0	0	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1080639.27

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	2018	2850	2347	2270	1384	1015	3565	146
Highest Ld:	34	40	41	28	18	14	38	3
Occ rate :	27.7	26.7	27.9	18.9	13.5	13.3	26.3	1.4
M Share :	100.0	100.0	100.0	100.0	100.0	100.0	100.0	10.1
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.6	2.7	3.1	2.8	2.9	2.6	2.5	0.9
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	65.3	66.1	69.8	65.5	65.2	65.4	67.0	56.7
Tot Op C :	238.61	335.90	344.55	343.12	277.55	239.18	513.06	182.14
Revenue :	445.15	628.68	517.72	500.74	305.29	223.90	786.40	32.38
Profit :	206.54	292.77	173.17	157.61	27.74	-15.28	273.34	-149.75

TOTAL PATRONAGE = 15595 TOTAL REVENUE (£) = 3440251.96

TOTAL OP COST (£) = 2474106.88

TOTAL PROFIT (£) = 966145.07

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1096105.66

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	--	--	--	--	--	Mini
Capacity :	--	--	--	--	--	--	--	20
Sys Op :	--	--	--	--	--	--	--	OPO
Fleet Sz :	--	--	--	--	--	--	--	40
Bus Oprtd :	--	--	--	--	--	--	--	40
Fare Sys :	--	--	--	--	--	--	--	F/50p
Patronage :	--	--	--	--	--	--	--	1305
Highest Ld:	--	--	--	--	--	--	--	3
Occ rate :	--	--	--	--	--	--	--	9.6
M Share :	--	--	--	--	--	--	--	89.9
Card Hldr :	--	--	--	--	--	--	--	0.0
AWT :	--	--	--	--	--	--	--	0.9
Av Fare :	--	--	--	--	--	--	--	50.0
Gen Cost :	--	--	--	--	--	--	--	71.8
Tot Op C :	--	--	--	--	--	--	--	652.26
Revenue :	--	--	--	--	--	--	--	287.91
Profit :	--	--	--	--	--	--	--	-364.35

TOTAL PATRONAGE = 1305 TOTAL REVENUE (£) = 287909.81

TOTAL OP COST (£) = 652259.74

TOTAL PROFIT (£) = -364349.93

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	40	0	0	0

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1096105.66

NEW ENTRANT ENTERED THE MARKET WITH 11 D/DECKER BUSES AND ALLOCATED THEM TO ROUTE 8 WITH DISTANCE-BASED FARE SYSTEM

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	2038	2772	2406	2194	1432	1080	3599	383
Highest Ld:	29	36	33	26	18	14	36	3
Occ rate :	23.8	23.3	26.9	18.7	14.0	12.9	26.0	3.5
M Share :	100.0	100.0	100.0	100.0	100.0	100.0	100.0	21.5
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.7	2.6	2.6	2.4	2.7	2.0	2.1	1.2
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	65.8	65.3	69.3	64.9	64.5	63.8	65.3	60.0
Tot Op C :	241.57	345.71	352.49	351.09	279.33	249.57	525.61	197.93
Revenue :	449.56	611.47	530.74	483.97	315.88	238.24	793.90	84.52
Profit :	207.99	265.76	178.24	132.88	36.55	-11.33	268.28	-113.41

TOTAL PATRONAGE = 15904

TOTAL REVENUE (£) = 3508268.68
TOTAL OP COST (£) = 2543308.69
TOTAL PROFIT (£) = 964959.99

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1100744.49

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	--	--	--	--	--	D/Dck
Capacity :	--	--	--	--	--	--	--	72
Sys Op :	--	--	--	--	--	--	--	TPO
Fleet Sz :	--	--	--	--	--	--	--	11
Bus Oprtd :	--	--	--	--	--	--	--	11
Fare Sys :	--	--	--	--	--	--	--	D/25p+ 7
Patronage :	--	--	--	--	--	--	--	1397
Highest Ld:	--	--	--	--	--	--	--	3
Occ rate :	--	--	--	--	--	--	--	7.6
M Share :	--	--	--	--	--	--	--	78.5
Card Hldr :	--	--	--	--	--	--	--	0.0
AWT :	--	--	--	--	--	--	--	1.2
Av Fare :	--	--	--	--	--	--	--	30.0
Gen Cost :	--	--	--	--	--	--	--	36.2
Tot Op C :	--	--	--	--	--	--	--	372.57
Revenue :	--	--	--	--	--	--	--	184.76
Profit :	--	--	--	--	--	--	--	-187.81

TOTAL PATRONAGE = 1397

TOTAL REVENUE (£) = 184756.13
TOTAL OP COST (£) = 372570.90
TOTAL PROFIT (£) = -187814.77

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	11

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1100744.49

NEW ENTRANT ENTERED THE MARKET WITH 11 D/DECKER BUSES AND ALLOCATED THEM TO ROUTE 3 WITH STAGE FARE SYSTEM

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	1989	2397	1420	1594	1282	1213	3482	1140
Highest Ld:	31	25	23	18	15	16	36	10
Occ rate :	26.8	23.4	20.1	13.9	11.9	14.6	25.2	9.8
M Share :	100.0	100.0	32.5	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.9	2.3	2.7	2.1	2.4	2.2	2.3	1.8
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	66.2	65.8	110.1	64.8	63.7	64.1	66.8	59.1
Tot Op C :	244.56	349.81	332.19	340.83	285.56	246.83	525.15	209.84
Revenue :	438.75	528.75	313.44	351.62	282.79	267.57	768.09	251.47
Profit :	194.19	178.94	-18.75	10.79	-2.77	20.75	242.93	41.63

TOTAL PATRONAGE = 14517 TOTAL REVENUE (£) = 3202484.36

TOTAL OP COST (£) = 2534771.96

TOTAL PROFIT (£) = 667712.40

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1109422.24

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	D/Dck	--	--	--	--	--
Capacity :	--	--	72	--	--	--	--	--
Sys Op :	--	--	TPO	--	--	--	--	--
Fleet Sz :	--	--	11	--	--	--	--	--
Bus Oprtd :	--	--	11	--	--	--	--	--
Fare Sys :	--	--	S/35/50/70	--	--	--	--	--
Patronage :	--	--	2945	--	--	--	--	--
Highest Ld:	--	--	36	--	--	--	--	--
Occ rate :	--	--	24.1	--	--	--	--	--
M Share :	--	--	67.5	--	--	--	--	--
Card Hldr :	--	--	0.0	--	--	--	--	--
AWT :	--	--	2.7	--	--	--	--	--
Av Fare :	--	--	37.9	--	--	--	--	--
Gen Cost :	--	--	65.7	--	--	--	--	--
Tot Op C :	--	--	366.75	--	--	--	--	--
Revenue :	--	--	492.86	--	--	--	--	--
Profit :	--	--	126.11	--	--	--	--	--

TOTAL PATRONAGE = 2945 TOTAL REVENUE (£) = 492861.56

TOTAL OP COST (£) = 366752.58

TOTAL PROFIT (£) = 126108.99

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	11

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1109422.24

NEW ENTRANT ENTERED THE MARKET WITH 11 D/DECKER BUSES AND ALLOCATED THEM TO ROUTE 8 WITH STAGE FARE SYSTEM

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	2114	2775	2465	2185	1363	998	3655	272
Highest Ld:	32	32	36	26	14	13	39	2
Occ rate :	26.4	25.1	28.8	17.8	12.2	12.9	27.0	2.7
M Share :	100.0	100.0	100.0	100.0	100.0	100.0	100.0	15.9
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.9	2.3	2.9	2.2	2.6	2.2	2.1	1.3
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	65.9	64.9	69.9	64.1	64.0	64.5	65.6	60.4
Tot Op C :	240.09	342.84	352.10	339.73	279.90	249.29	520.48	200.13
Revenue :	466.32	612.13	543.75	481.99	300.66	220.15	806.25	60.13
Profit :	226.24	269.29	191.65	142.25	20.76	-29.14	285.77	-140.00

TOTAL PATRONAGE = 15827   TOTAL REVENUE (£) = 3491379.61
TOTAL OP COST (£) = 2524566.84
TOTAL PROFIT (£) = 966812.77

VEHICLES = Mini 0, Midi 0, Stdrd 0, D/Decker 73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1107079.96

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	--	--	--	--	--	D/Dck
Capacity :	--	--	--	--	--	--	--	72
Sys Op :	--	--	--	--	--	--	--	TPO
Fleet Sz :	--	--	--	--	--	--	--	11
Bus Oprtd :	--	--	--	--	--	--	--	11
Fare Sys :	--	--	--	--	--	--	--	S/35/50/70
Patronage :	--	--	--	--	--	--	--	1444
Highest Ld:	--	--	--	--	--	--	--	8
Occ rate :	--	--	--	--	--	--	--	8.4
M Share :	--	--	--	--	--	--	--	84.1
Card Hldr :	--	--	--	--	--	--	--	0.0
AWT :	--	--	--	--	--	--	--	1.3
Av Fare :	--	--	--	--	--	--	--	35.4
Gen Cost :	--	--	--	--	--	--	--	47.5
Tot Op C :	--	--	--	--	--	--	--	371.44
Revenue :	--	--	--	--	--	--	--	225.36
Profit :	--	--	--	--	--	--	--	-146.08

TOTAL PATRONAGE = 1444   TOTAL REVENUE (£) = 225364.02
TOTAL OP COST (£) = 371444.34
TOTAL PROFIT (£) = -146080.33

VEHICLES = Mini 0, Midi 0, Stdrd 0, D/Decker 11

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1107079.96

NEW ENTRANT ENTERED THE MARKET WITH 11 D/DECKER BUSES AND ALLOCATED THEM TO ROUTE 3 WITH DISTANCE-BASED FARE SYSTEM

EXISTING OPERATOR

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck	D/Dck
Capacity :	72	72	72	72	72	72	72	72
Sys Op :	TPO	TPO	TPO	TPO	TPO	TPO	TPO	TPO
Fleet Sz :	7	10	10	10	8	7	15	6
Bus Oprtd :	7	10	10	10	8	7	15	6
Fare Sys :	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p	F/50p
Patronage :	1975	2030	1440	1459	1152	1259	3496	1152
Highest Ld:	33	25	26	18	14	16	36	9
Occ rate :	27.0	21.1	23.0	12.1	10.5	15.4	25.4	9.8
M Share :	100.0	100.0	28.4	100.0	100.0	100.0	100.0	100.0
Card Hldr :	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AWT :	2.6	2.1	2.6	2.0	2.3	2.0	2.1	1.8
Av Fare :	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Gen Cost :	65.7	66.4	109.6	63.4	63.4	63.7	66.6	59.4
Tot Op C :	245.40	346.01	340.21	348.34	283.12	246.50	522.45	212.49
Revenue :	435.66	447.79	317.71	321.84	254.12	277.72	771.18	254.12
Profit :	190.26	101.78	-22.50	-26.51	-29.00	31.22	248.72	41.63

TOTAL PATRONAGE = 13963 TOTAL REVENUE (£) = 3080136.22
TOTAL OP COST (£) = 2544530.43
TOTAL PROFIT (£) = 535605.79

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	73

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1098576.62

NEW ENTRANT

ROUTE	1	2	3	4	5	6	7	8
Vhcl type :	--	--	D/Dck	--	--	--	--	--
Capacity :	--	--	72	--	--	--	--	--
Sys Op :	--	--	TPO	--	--	--	--	--
Fleet Sz :	--	--	11	--	--	--	--	--
Bus Oprtd :	--	--	11	--	--	--	--	--
Fare Sys :	--	--	D/25p+ 7	--	--	--	--	--
Patronage :	--	--	3627	--	--	--	--	--
Highest Ld:	--	--	45	--	--	--	--	--
Occ rate :	--	--	31.7	--	--	--	--	--
M Share :	--	--	71.6	--	--	--	--	--
Card Hldr :	--	--	0.0	--	--	--	--	--
AWT :	--	--	2.6	--	--	--	--	--
Av Fare :	--	--	34.8	--	--	--	--	--
Gen Cost :	--	--	57.5	--	--	--	--	--
Tot Op C :	--	--	372.61	--	--	--	--	--
Revenue :	--	--	556.22	--	--	--	--	--
Profit :	--	--	183.62	--	--	--	--	--

TOTAL PATRONAGE = 3627 TOTAL REVENUE (£) = 556223.87
TOTAL OP COST (£) = 372605.14
TOTAL PROFIT (£) = 183618.73

VEHICLES =	Mini	Midi	Stdrd	D/Decker
	0	0	0	11

TOTAL OVERALL GENERALISED COST (Pass.mnts) = 1098576.62