INCOME DISTRIBUTION AND THE EVALUATION OF USER BENEFITS FROM CHANGES IN TRANSPORT SYSTEMS

by

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ABSTRACT

Transport policies usually affect specific social groups in different ways. Nevertheless, distributional issues have not formed part of the mainstream of research on modelling in transport planning and evaluation.

Traditionally economists have thought in terms of redistribution between income groups, often with the implicit assumption that the marginal utility of income is greater for the poor than for the rich. Nevertheless, the assumption of constancy or near constancy for the marginal utility of income has often served as a basis for using Marshallian consumer's surplus as a measure of user benefits from transport systems.

In this study, a framework is developed in order to estimate the benefits provided to specific income groups under alternative investment scenarios. The commonly accepted assumptions concerning household and personal incomes in transport demand modelling are reconsidered, and alternative measures of user benefits based on the trade-off between goods and leisure are examined. One of these, the compensating variation, is compared with the traditional measure of consumer's surplus for each income category.

Hypothetical but realistic scenarios are constructed for analysis. These are based on matrices of journeys and travel costs by different transport modes between over two hundred districts covering Greater London. The matrices resulted from modelling exercises relating to alternative investment policies considered in a set of studies that had been carried out in the late 1980s.

When applied to these scenarios, the framework demonstrated clear differences between the policies in terms of distribution of benefits across the income spectrum. Differences were also found between the estimates of travellers' monetary valuation of changes in utility level as given by the compensating variation and consumer surplus. The results are presented separately for each income category and are discussed in terms of their distributional implications in the evaluation of transport changes in large urban areas.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

Financing transport infrastructure and operation is one of the predominant issues of government policy. Transport represents one of the major items of public expenditure and it plays an essential role on the development of urban systems and economic activities. At the same time, public investments, which represent the bulk of transport financing, are subject to various budgetary policies and the influence of political and social ideologies embedded in government thinking.

Transport policies usually affect specific social groups in different ways. They may generate benefits to a substantial part of the society at large, while failing to increase accessibility or even to reduce travel costs to specific social groups. For the urban poor, transport facilities are particularly important as the improvement of accessibility can enhance their employment prospects, reduce money and time spent getting to jobs, reduce the cost of inputs and so on.

Moreover, public expenditure is generally financed by user charges, taxation and public debt. The mix of financing affects the total social cost of any project and should therefore influence the choice among projects. Furthermore, it will also influence the incidence of costs among different social groups.

Despite all their significance, distributional issues have not formed part of the mainstream of research on modelling in transport planning and evaluation.

Traditionally economists have thought in terms of redistribution between income groups, often with the implicit presumption that the marginal utility of income is greater for the poor than for the rich. Nevertheless, it is the assumption of constancy or near constancy for the marginal utility of income which has often served as a basis for using Marshallian consumer's surplus as a measure of welfare change.

In this research, a framework has been developed in order to estimate user benefits provided to specific income groups under alternative investment scenarios. The commonly accepted assumptions concerning household and personal incomes in transport demand modelling are reconsidered, and alternative measures of user benefit have been examined. These are compared with the traditional measure of consumer's surplus for different income groups separately.

The framework has been applied to a data set which resulted from modelling exercises relating to alternative investment policies considered in the London Assessment Studies, including a 'do-minimum' policy and rail and highway investment policies. These policies have been tested by the London Transportation Studies Model, and their output matrices of journeys and travel cost by different transport modes form the basis on which hypothetical but realistic alternative scenarios have been constructed for analysis.

Although the data used for this work have been provided by the Department of Transport (DTp) from modelling work for London, the aim of this research is to investigate some of the implications associated with transport provision, evaluation and income distribution. It is not the objective here to carry out a study of London's distinctive situation, but to investigate the methodological issues and their potential practical implications in a realistic but notional situation.

Changes in the transport system would also result in benefits to non-users including environmental improvements, contribution to economic development, job creation and land use regeneration. These benefits in turn, would have different social distributions. Furthermore, the source used for financing such projects would have different incidence on the various income groups. Finally, the outcome of economic evaluation of investment in transport infrastructure will be critically affected by the pricing policy adopted, as well as the institutional and political structure in which complementary and competing services operate. These related issues, though important, are not addressed in this research.

Even if one accepts that there is a potential redistributive case for transport investment, one still needs to ensure that precise instruments chosen are capable of achieving the distributional objectives pursued. In any case, any distributional impact will depend on the relative importance of particular income groups in the use of, and benefits derived from, that service or facility in which the investment is made, in comparison with their importance as contributors to the taxes which finance the service.

Income distribution policies, whether directly through the fiscal system or through individual projects, are ultimately the sole responsibility of public agencies and decision makers, and therefore generally influenced by the political process. It is nevertheless in the general interest if implicit judgements, and their implications across the various social groups, are made clear, and this is one of the objectives of this research.

1.1 Outline of this thesis

This thesis is divided into seven chapters.

Following this chapter, **Chapters 2** and **3** provide the theoretical support which forms the basis of this research.

Chapter 2 examines different methods for evaluating transport infrastructure and operation. In particular, the rational and welfare foundations of cost-benefit analysis are presented, together with the underlying value judgements and their implications for redistributive policies. Although concepts of economic efficiency provide an important starting point for evaluation, they may be inadequate for capturing many aspects associated with transport provision. Given the apparently single-dimension analysis embodied in the core of cost-benefit analysis, alternative methodologies for the evaluation of transport projects are also examined.

In **Chapter 3**, the concept of consumer surplus is discussed within the neo classical theories of welfare and microeconomics. Consumer surplus is a central concept in transport evaluation. In particular user benefits are estimated by an aggregated measure of changes in price and quantity supplied. A comprehensive account of some of the applications of the concept in the context of transport evaluation is also given. Furthermore, a framework is presented in which the measures of user benefits are derived from the theory of trade-off between goods and leisure.

Chapter 4 describes and defines the source of data used in this research. In this respect, the London Assessment Studies are briefly presented together with the specifications of the highway and rail investment policies and the general requirements for the London Transportation Studies Model forecasts. Their output matrices provided the basis in which final alternative scenarios are constructed. Hence, the London Transportation Studies Model which generated those matrices and the Greater London Transportation Survey of 1981 used for calibration of the London Transportation Model and in the construction of the scenarios, are also introduced, with relevant features considered in this research highlighted.

In **Chapter 5** income distribution is estimated for the trips in each cell of the various output matrices. Albeit that the objective of the work described was to construct alternative scenarios for comparison, it provided an opportunity to investigate new approaches for estimating income distribution, as well as to obtain further insights for the evaluation carried out subsequently.

Chapter 6 compares the different measures of user benefits estimated to accrue to each income group as a result of changes in the transport system. In this respect, benefits derived from the rail and highway investment scenarios are each contrasted with a 'do-minimum' situation and the results are presented concisely.

Finally, **Chapter 7** discusses the results in the ways envisaged previously and in terms of their distributional implications in the evaluation of transport changes in large urban areas. Conclusions are finally drawn together with suggestions for further research.

CHAPTER 2
EXISTING EVALUATION PROCEDURES

2.1 Introduction

This chapter examines different methods for evaluating transport infrastructure and operation. The aim is not to give a comprehensive list, but instead to focus on the most important techniques applied to transport projects in the United Kingdom.

Despite this, many of the concepts discussed in this chapter are neither exclusively associated with the transport sector nor with developed countries. Indeed many of the theoretical and applied contributions to theory of analysis of costs and benefits came from projects in a number of sectors financed by foreign agencies in the Third World.

Similarly, the basic notions are equally valid for the evaluation of public or private transport as such. There are however, some distinct features in the evaluation of highway and public transport investments which are also addressed in this chapter.

The chapter starts by discussing the more general notions behind the theory of Cost Benefit Analysis. As noted by Mishan (1975), "since cost-benefit analysis is an application of the theory of resource allocation, itself a subject at the core of welfare economics, the rationale of such analysis can be understood and vindicated only by reference to propositions at the centre of welfare economics" . Thus, its rationale and welfare foundations are examined first. The use of variable weights has been perhaps the most controversial issue in cost-benefit analysis. This is question is addressed next. A brief account of externalities, the value of time and accident costs is also given.

Cost-Benefit Analysis (CBA) should be looked as a guide, an aid to decision-making. It gives an approximation of what 'society' (as a collection of individuals) would, under certain assumptions, prefer. It does not follow though that what 'society' wants is good for society (itself a subjective question), nor that CBA has valued all the factors the decision-maker wished to take into account. By looking at the matter in this way, one may shift the domain of discussion to, perhaps an even more important one, which is concerned about what role CBA should play in the decision-making process. This is definitely outside the scope of the present discussion, but given the apparently single dimension analysis embodied in the core of CBA, alternatives methodologies for the evaluation of transport projects are examined in **Section 2.3**, namely, Planning Balance Sheet, Goals Achievement Matrix and the 'SACTRA' approach.

The evaluation of public transport improvements has captured considerable attention during the 1970s and most of the succeeding decade. The effects of changes in fares and the level of service on government allocation of resources have been extensively investigated. More recently, there has been an increasing interest in establishing the extent to which investment in public transport can be realised under existing government policies introduced with the 1985 Transport Act. These issues are addressed in **Section 2.4.**

Some concluding remarks are giving in the final section.

Although concepts of economic efficiency provide an important starting point for evaluation, they may be inadequate for capturing many aspects associated with transport provision. These include for instance questions of equity and distribution. Furthermore, there are the issues of transport need and accessibility which may not be accurately expressed in terms of market demand, as well as planning and the attainment of multiple objectives. When appropriate, these issues are also briefly addressed throughout this chapter.

2.2 Social Cost Benefit Analysis

Cost Benefit Analysis (CBA), although it is a relatively newly applied technique, is subject to an extensive literature and fierce controversy.

According to Dasgupta and Pearce (1972), the idea of measuring the net advantages of capital investment projects in terms of society's net gain in utility originated with Dupuit's paper 'On the Measurement of the Utility of Public Works' (Dupuit, 1844). Despite refinements to the concept and theory of consumers' surplus by Marshall, Hotelling and Hicks (see next chapter), the practical application of the theory to public investments was not resurrected until the 1950s, with the formal advent of CBA.

The United States Flood Control Act of 1936 enunciated the principle that a project be declared feasible if 'the benefits to whomsoever they may accrue, are in excess of the estimated costs'. The Act however, was purely concerned with construction costs and did not embrace the wider idea of a cost as any loss of welfare (Pearce, 1983). Many other questions were left unresolved until 1950, when the U.S. Federal Inter-Agency River Basin Committee attempted to formalise the procedures for valuing costs and benefits. The result document, known as the 'Green Book'(U.S. Government, 1950), was immediately superseded by U.S. Bureau of Budget's 1952 Budget Circular A-47 (U.S. Government, 1952), which produced a further endeavour in the formalisation of valuation procedures (Dasgupta and Pearce, 1972). Academic interest in appraisal technique had also grown, and in 1958 three different works attempted to lay down benefit-cost criteria, on the basis of theory of welfare economics, as they related to water resource projects. (Eckstein, 1958; McKean, 1958; Krutilla and Eckstein, 1958). The Harvard Water Resource Program (Maass et al, 1962) was the result of further development of a reasonably integrated theory of CBA, which forged closer linkages with the underlying welfare theory.

Ironically, the theory of welfare economics (which provides the rationale for CBA), had been subject to severe criticism. (Baumol, 1952; Graaff, 1957). Precisely the same problems that faced welfare economics face CBA, particularly in respect of the distributional consequences of projects. Nonetheless, CBA continue to flourish and evolve, although subject to considerable controversy.

In the United Kingdom the earliest application dates back to 1960 carried out by the Road Research Laboratory to Britain's first motorway (Beesley et al, 1960). Since then, the main application has been concentrated to transport projects; Foster and Beesley (1963; 1965) for the Victoria Underground Line; Ministry of Transport (HMSO, 1963) for the Channel link; the Roskill commission (HMSO, 1971) for the Third London airport among others. For a rather old, although quite comprehensive survey of practical applications in the United Kingdom of CBA in transport, see Barrell and Hills (1972).

Later in the 1960s it was extended to developing countries with the publication of a 'Manual of Industrial Project Analysis' (Little and Mirrlees, 1968). In fact much of the contribution to theory and application of CBA came from projects financed by foreign agencies to third world countries. Dasgupta, Marglin and Sen (1972) consolidated many of the early contributions from the development economics literature and the theory of taxation. Little and Mirrlees (1974) developed this approach even further in a rather special and highly influential way, which became the basis for the World Bank guidelines (Squire and van der Tak, 1975).

2.2.1 The rationale and welfare foundations of Cost Benefit Analysis. Pearce (1983) defines CBA as a procedure for:

(i) Measuring the gains and losses to individuals, using money as the measuring rod of those gains and losses;

(ii) Aggregating the money valuations of the gains and losses of individuals and expressing them as net social gains or losses.

If therefore, he argues, "CBA involves the aggregation of individuals' assessment of the costs and benefits to them of a given action, policy, project or programme, it will, if properly derived, reflect individuals preferences. If CBA is then an input to the procedure of deciding what a decision-maker ought to do, then CBA is itself normative and rests on at least one value judgement or normative statement, namely that it is a good thing that individuals' preferences should count".

Similarly, by looking at the role that money actually play in the measure of preferences, it is apparent that market places operate on the basis that those with more money have more say than those without. If we are to leave the aggregated preferences in the market place unadjusted, it follows that they will reflect the structure of market power, or to put it another way, the distribution of income. Thus, if we accept the role of CBA in the decision making procedure, then we must add a second value judgement, namely that the distribution of income used to weight the preferences of individuals is in some sense acceptable.

Two independent normative judgements emerge therefore from this definition:

i. Individual preferences should count;

ii. Those preferences should be weighted by the existing distribution of income.

Judgement (i) is the basic requirement of democratic sensitivity, or as it is best known in economics, consumer sovereignty. The second judgement is the one about which economists have disagreed. What is clear is that we do not have to accept it in the particular form stated here, and this is where the debate has concentrated. In short, CBA requires therefore two normative (value) judgements. The first states that preferences count, while the second state how these preferences are to be weighted.

Similarly, Ray (1984) maintained that the mainstream of the traditional criterion of cost-benefit analysis measures the net benefit of a project as its net effect, over time, on the path of total real consumption (aggregated over individuals) in the economy. Since consumption and savings (private and public) are equally valued in the traditional analysis, the criterion can be restated in terms of real income, rather than consumption. The net effects on real income are measured as the equally weighted sum of consumer and producer surpluses and losses.

In an analogous way, two issues arise in this process: the valuation of the gains and losses accruing to an individual, and their aggregation across individuals, both at a point in time and over a period, even over succeeding generations. The valuation of gains to some individuals is thought to be important (this is addressed in the next chapter) but most of the controversy arises over distribution weights in the aggregation process. This is discussed next.

2.2.2 The use of distribution weights in the economic analysis. The use of variable weights on gains and losses to different income groups has been the most controversial issue in CBA. It is often suggested that the use of distribution weights in economic analysis introduces a political and arbitrary judgement about basic values from which such analysis should be kept free (see Hargberger, 1978 and 1982).

If, for instance, government values all income equally, regardless of its distribution - either between the public and private sectors or within the private sector - the need for distribution weights disappears. The weights themselves, as from the normative judgements implicit in the CBA definition, only apparently disappear; in reality they are still there, but the implicit value judgements made are such that the social cost of each resource transfer, as incurred by the losers, should be regarded as offset by the resulting social benefit accruing to the gainers.

In addition, if governments, through their fiscal policies, are able to redistribute income costlessly, then there is no need to include distribution weights in project evaluation. Project selection should under such circumstances aim to maximize income and allow other instruments to redistribute it. However, in general redistribution cannot be costless and a 'deadweight' loss will always be associated with.

The least controversial welfare criterion in economics is the Pareto criterion, (or Pareto unanimity rule) which states that society is made better off if at least some of its members are made better off and no one is made worse off. Thus, a project must be desirable if nobody loses and at least one person gains. Clearly, this is highly restrictive in real life, since projects tend to involve gains to some and losses to others. The most celebrated attempt to allow for non-unanimity while retaining the concept of Pareto optimality was the 'compensation principle' formulated in slightly different ways by Kaldor (1939) and Hicks (1939, 1940).

According to the Hicks-Kaldor compensation criterion, a project should be regarded as a potential Pareto improvement if it improved the welfare of some people, even though others might lose, provided that those who gained could compensate those who lost and still have some benefit left over (note that this is not affected by the numbers of people in the different groups, nor is anything said about who the groups are, e.g. rich, poor. Also, it does not require actual compensation).

Provided the initial environment is Pareto efficient, Dasgupta and Pearce (1972) argue that it is just this principle which underlies cost-benefit analysis. "If the monetary valuation of benefits exceeds the monetary valuation of the costs, then the gainers (those who receive the benefits) can hypothetically compensate the losers (those who bear the costs) and still have some gains left over. The excess of gains over the required compensation is equal to the 'net benefit' of the project".

Nevertheless, compensation in theory may induce a paradox. A project sanctioned by the Hick-Kaldor criterion could give rise to a subsequent situation in which those who had lost could now 'compensate' those who had gained for moving back to pre-project state. That this could happen arises from the fact that the project may change the distribution of income and hence the pattern of relative prices. At the initial set of prices the project is judged worthwhile, but at the new set of prices emerging after the project is undertaken we can hypothesise a project involving a move back to the initial position and this project may be sanctioned by the very same test used to justify the move away from the initial position. This was first demonstrated by Scitovsky (1941). For a formal demonstration see Dasgupta and Pearce (1972), Pearce (1983), Layard and Walters (1978) among others.

Moreover, even where the money value of benefits does outweigh the money value of losses, the compensation criterion provides an inadequate link between the benefit-cost maximand and welfare maximisation as long as the compensation is not actually paid. The problem is that income will be redistributed if losers are not compensated. If interest lies only in efficiency, the increase in real resources is an adequate measure of project benefit and the problem simply disappears. Nevertheless, if there is interest in income distribution as well, the distribution of resources among different groups in society must be also be examined. Given that a redistribution of income does result from undertaking projects, there is a number of options, and indeed controversy, concerning the way the distribution of resources should be examined.

The first option, and the one which underlies most CBA, is to argue that the redistribution is not significant (Krutilla, 1961; Eckstein, 1958) or in other words, that the effect of the redistribution on prices is not significant and the Scitovsky paradox will not arise. Arguments against this view are concerned with uncertainty over future cost-benefit analysis which may have noticeable redistributional consequences; the cumulative effects of many investments; and the change in real income being valued explicitly in terms of ruling prices, which in turn reflects the existing income distribution.

A second line of support for ignoring redistributional consequences rests on the ground that their incorporation would involve apparently subjective (ascientific) considerations. Dasgupta and Pearce (1972) argue that this view is difficult to accept. Since, they maintain, "CBA involves one major explicit value judgement - that individual preferences should count - why then ignore society's preferences about the distribution of income? The problem, would be to find out what kind of income distribution society approves".

A third position is to make an explicit attempt to allow for the distributional consequences of a policy either by trying to observe social preferences concerning distribution, or by other means. The resources accruing to each group can then be weighted in accordance with an appropriate concept of social welfare and summed to obtain the measure of the project's social worth. There are several possibilities.

First, economists can indicate the consequences for distribution and allow the decision-maker to apply his own 'weights' to the gains and losses of the various sections of the community. A second approach would be to observe the weights implicit in past government decisions (Weisbrod, 1968; Maass, 1966). A variant on this approach has been suggested (Krutilla and Eckstein, 1958) which involves the use of marginal rates of taxation as weights.

Another approach to the distribution problem is to impose an explicit value judgement on the social utility (or welfare) function. One simple approach is to scale down higher incomes and scale up lower incomes to 'equalise' their influence on the cost-benefit outcome. Foster (1966) has suggested an approach whereby gains and losses are weighted by the ratio of the average national personal income to the individual's income. Squire and van der Tak (1975) have demonstrated how both interpersonal and intertemporal distribution weights may be derived from an explicitly specified welfare function. The basic assumption underlying the utility function in their work, is that the utility derived from an increment of consumption is less, the higher the existing level of consumption; that is the marginal utility of consumption decreases as the level of consumption increases. Finally, some attempt could be made to estimate weights by assessing the likely shape and elasticity of a marginal utility of income function.

The case for using unequal weights has been demonstrate rather simply by Ray (1984). He has shown that as long as the 'deadweight' loss of making a transfer is positive, either the appropriate welfare weights on income must be regarded as unequal or transfers from the rich to the poor must be regarded as undesirable (in fact any transfer would be regarded as undesirable). Governments usually do not have the ability to make costless transfers to control the distribution of income. If transfers from the rich to the poor are still considered desirable, a prima facie case for using unequal weights emerges (Ray, 1984).

Mishan (1975), points out though that even considering distributional weights a project may still be accepted which make a richer person richer and a poorer person poorer.

2.2.3 Externalities, the value of time and accident costs. Some of the most frequent criticisms (or perhaps misconceptions) of CBA come from planners. Probably one of the most popular is that CBA is confined to 'economic' applications, and therefore not to be thought as part of the planning analysis. However, in the cost-benefit framework, the evaluation should include all the social advantages and disadvantages of wide ranging planning proposals. Any decision which effects individual welfare is ultimately the subject matter of CBA irrespective of the label which may be conveniently attached to it

(Lichfield et al, 1975).

Another frequent misconception is that CBA is limited to items in which monetary values are readily obtainable. As much as possible, measurement in money values is sought, yet no respectable CBA will omit discussion of the alternatives in terms of unquantified costs and benefits. The principles by which incommensurable and intangible items should be handled are no different from those which could be evaluated in monetary terms. Lichfield (1975) argues that "it would be helpful to see unquantified costs and benefits in perspective by referring to the way they might be assessed were sufficient evidence available. Because in the past, some of the effects of planning proposals have not been capable of quantification in common units the possibility of obtaining sufficient evidence is not ruled out". As McKean (1968) put it: "Critics frequently confuse (a) the logical possibility of valuing an intangible outcome, (b) the empirical possibility of evaluation, and (c) the morality of the value if one is derived" (McKean, 1968 pp 135-6).

Most incommensurable items are of an aesthetic nature. Although the aesthetic problem cannot be completely solved, the difficulties it presents can be overcome (or at least reduced) in many different ways. The fact that items exist which cannot be expressed in common units (and in this particular case money is used as the measuring rod) does not invalidate the approach but only limits its usefulness, given the current state of the art.

Another criticism might be to suggest that economic evaluation deals only with market forces and that it is the proper job of other disciplines (e.g. planning) to correct the effects of such forces. Clearly, this is a fallacious criticism since CBA gives a prominent position to the measurement of externalities and the estimation of public and community costs represents a high percentage of the work involved.

Externalities or external effects are either benefits caused for which no payment is received or disbenefits caused for which no payment has to be made. They may arise either because of the absence of law defining property rights (given the difficulties involved in defining such rights) or because of the difficulty of enforcing such laws.

Confusion sometimes arises over the distinction between technological (or real) and pecuniary externalities. The former are the ones normally understood as externalities (e.g. noise, pollution, environmental externalities in general). Pecuniary ones are those involving increased or decreased profits or income due to an activity. The distinction is important for the use of appropriate measures. Pecuniary effects of proposals may be significant in making some individuals better or worse off, but do not always measure adequately changes in welfare. Those gains or losses may be better measured directly; as a rule including them would involve double counting. Moreover, some pecuniary effects are alterations in the distribution of wealth rather than addition to it, and therefore unless distributional considerations are important they may be ignored.

The economic evaluation of transport projects involves the estimation of values for items which were previously regarded as intangibles, such as travelling times or accidents. In addition, common environmental externalities may include reductions in noise, pollution and congestion levels. These together with the more straightforward items, such as government expenditures and vehicle operating costs, can be used for detailed evaluation of the operational consequences under consideration.

The valuation of time savings is perhaps one of the most important aspects of appraisal in the transport sector. It represents one of the major source of benefits of both highway and public transport projects. In particular it has been argued that 80% of quantified benefits of Trunk Road Appraisal are due to time savings (MVA et al, 1987). Time values are also used in modal choice; the investigation of the consequences of technological development in transport; land use planning and other fields. In project evaluation explicitly converting amounts of time into money units is a necessity if true returns on investment are to be calculated.

As an economic good, the unique quality of time is that it cannot explicitly be bought or sold in the market place. Each person has the same number of hours to consume each day and all that an individual can do is to determine the activity content of his or her time. Moreover, the value of time as a resource per se should be determined not by the amount of work required in its production but by its scarcity.

Until 1987, existing practice for time valuation in transport projects relied essentially on the document by McIntosh and Quarmby (1970), normally referred to as MAU note 179. The authors recognize that there are three separate function to be fulfilled by generalized cost, and accordingly they distinguish three types of cost. The behavioural cost is those cost which when used in appropriate models give the best empirical fits to observed behaviour. The second type of cost relates to the change in benefit as perceived by society, consequent on the transport system change. Finally the third, referred as resource cost, relates to the change in real resources consumed as a result of the change in the system. Each cost is composed of a money cost, plus a number of time components, weighted by appropriate values of time. Implicit in the notion of the generalised costs, was the suggestion that they could be converted to a common currency, as required for CBA.

The recommended time components are in-vehicle, walking and waiting/transfer. While it is possible to envisage circumstances in which the opposite it is true, it appears generally reasonable to expect in vehicle-time to be perceived as less onerous than walking or waiting times. Accordingly, there is a general consensus that walking time should be valued twice as high as in-vehicle time. Although, the same weight is normally applied to waiting times, the same consensus is not generally found.

The notion behind the value of time is the opportunity cost. This is a rather established issue in the valuation of time savings. There are however, two different lines of enquiry, whether individual employee's or employer's own valuation should be used as the representation of the social value. Therefore, in the estimation of value of time a further differentiation is made between working and non-working time.

For working time it is assumed a priori that the corresponding value of time to the employer (and by some further assumptions to society) is equal to the wage rate (plus employment taxes, other compulsory contributions and allowance for overheads), and then further assumed that the individuals will in fact behave as if they personally accepted this valuation (MVA et al, 1987). The underlying assumption is that time should be valued on the basis of the marginal cost to the employer (i.e. wage rate plus overheads) and such cost will reflect the marginal productivity of the employer, itself a good measure of the value to the society. Even if these assumptions were uncontroversial, such valuation practice would only be acceptable if time savings were converted into working time, as opposed to simply being transferred to the employee's leisure time for instance.

In the DTp COBA 9 manual (DTp, 1989a) values of working time are given for different types of vehicle occupants. An addition of 36.5% is made to the gross wage rate to represent National Insurance and pension contributions. The same values applies to all aspects of travel - waiting, walking and travel in vehicle.

The value of non-working time is derived from statistical analysis about individuals preferences in choice situations. The behavioural approach in the analysis of how people behave in choice situations and the estimation of value on the basis of their revealed preferences requires the existence of free choice, knowledge of the alternatives and some time lag for actual adjustment of the traveller to the situation, given their particular circumstances and their incomes. It follows that estimates of the value of particular time savings will vary considerably depending on both the physical and personal circumstances.

McIntosh and Quarmby (1970) suggested that non-working time be valued at 19% of the gross household income, taken over a 2000 hour year. They have also maintained that the value of time should be valued at 25% of the wage rate. This notion was supported a priori by the common perception that the value of time saving is likely to be somewhat less than what the individual might earn in the same time. Empirical evidence, however, suggests that this relation is weak, and determining it has not been assisted by many of the assumptions about the average hours worked, tax rates, etc, which have been used to convert gross annual income into hourly rates. This implies that values of time will be proportional to income, rather than the wage rate.

A more recent study however, carried by MVA (MVA et al, 1987) has suggested that values of time fall as a proportion of gross income as that income rises, and that the countervailing effect of higher taxation rates is not sufficient to restore the proportion to constancy. In this comprehensive study, they have extended the neo-classical model of consumer theory to include the time dimension, and establish the link between the theoretical basis and that of discrete choice models, which provides a basis for the empirical measurement of values of time. Thus, in this microeconomic framework, consumer are expected to maximize a utility function (itself a function of a vector of commodities plus a vector of time spent in various activities) subject to both time and budget constraint. Further constraints also requires a minimum number of working hours and that each time element has associated with it a minimum.

In conjunction with the above theory, a market segmentation approach is proposed which allows variations in values of time to be related to characteristics of the traveller and the circumstances of travelling. The analysis has suggested that there is a considerable variation in the value of time due to a number of factors including income, mode, household size and employment status.

The microeconomic theory presented in the study however, did not itself imply any direct relation between values of time and the wage rate, and, according to the authors, "one plausible reason for anticipating a positive relationship between the value of time and income is the declining marginal utility of income" (MVA et al, 1987).

In addition, consistent effects were also found for person and household type. There is a general impression that values of time fall with increasing household size, which is consistent with the rationalization of income on a per head basis (possibly after allowing for different allocation among household members). Retired people and students were concluded to have values of time respectively 25% and 20% lower than other persons, for a given household income level. Employed persons working 'variable' hours were found to have values, other things being equal, some 20% higher. In many ways, the mode effect on the value of time cannot be separated from the travelling population and the circumstance of travel. Because there is an interaction between mode and income effects, the implications are that base values should be differentiated by mode as well as by income.

A table of recommended values of time is given by the study, stratified by income and mode, with recommendations on the appropriate weighting for the other effects. The work recommended that the values of time for households with annual income over £20000 (1985 prices) should be between 40% and 100% higher than those with annual income below £5000, with interpolation between these two for intermediate cases.

These are however, as stressed throughout the study, behavioural values of time. These represent the money an 'individual' would be wiling to pay to save a unit of time for himself. On the other hand, for evaluation purposes what is required in principle is the amount of money that a public agency would be prepared to pay to save a unit of time for an individual. The authors have noted that "these are likely to be different, wherever it is proper for public agencies to take into account elements in the valuation which are outside the scope of the individual, or vice versa. Among the elements to which this applies are: misperception by the individual; taxation or subsidies such that the cost affecting the individual is not a true resource cost; a difference in tine horizon (for example if individual values are all short run, but transport policy includes long run considerations)". (MVA et al, 1987 pp 166).

The principles of welfare economics suggest however, as discussed previously, that if the underlying income distribution is considered equitable, then willingness to pay is the correct criterion for judging the appropriateness of public sector investment, in which case any revealed variation in travellers' value of time should be taken into account. Such an approach will result though in favouring projects which translate large proportion of benefits to travellers with higher values of time, which in turn bear at least some relation to high income travellers. It was to avoid this that an equity (standard) non-working value of time was adopted. Ultimately, the choice between an income related and a standard (equity) value of time is political, although if the evaluation is to serve the social interest, the implicit judgement and its implications should be made clear.

Since the MVA (1987) study, the value of non-working time has been revised, and is now valued at 43% of the average hourly earnings of full time adult employees, which is equivalent to 40% of the mileage weighted hourly earnings of commuters (DTp, 1987).

The value of non-working time adopted by the DTp in their COBA 9 manual (DTp, 1989a) applies to all non-work journey purposes, including commuting by all modes of travel. The standard appraisal value is recommended to be used in all COBA appraisal, and most appraisals for the Department. The value of waiting, cycling and walking time is double the value of in-vehicle time. In addition, COBA assumes for the 30 years evaluation period, that 14% of car mileage is by trips during the course of work and 86% in non-working time.

Another substantial source of benefits in the economic appraisal of transport projects relate to accident costs. These can be divided into three kinds: direct resource costs, which include damage to vehicles and other property, medical and assistance costs, and legal costs; indirect resource costs, of which the main one is the loss of output of the dead or injured person; and non-resource cost, which include the loss of life as such, suffering and grief and the fear of risk of accident.

The measurement of direct resource costs is straightforward. Indirect resource costs however may present some problems, and the main question is whether future consumption of a person killed should be included. Disagreement prevails however concerning the measure of non-resource costs. For an example where disagreement have be seen to prevail, see for instance Thomas (1978) and the comments by Ziderman (1981).

Mishan (1975) discusses some of the possible ways put forward for measuring the loss of life. The most common way of calculating the economic worth of a person's life is that of discounting to the person's expected earnings. An alternative, or perhaps more refined, is that of calculating the present discounted value of the losses over time accruing to others only as a result of the death of this person at a certain age. Another method approach the problem from a 'social' point of view. Since society, through its political processes, does in fact take decisions on investment expenditure that occasionally increase or reduce the number of deaths, an implicit value of human life can be calculated. The existence of an insurance market could provide some information on the value a person sets on his or her own life. Finally, Mishan (1971) transform the question of the valuation of life into one concerned with valuing changes in the probability of loss of life, based on consumers' willingness to pay.

Clearly all of this methods have deficiencies (or inadequacy) either on its conception or valuation. Whatever the method of valuation of life the resource costs of accidents should be included in any overall valuation of accident costs.

The question of value of accidents and, the value of life in particular, opens the debate towards safety expenditures. Again different views prevail with respect to the amount of expenditure devoted to transport safety.

Standard values are produced by the DTp (1990) for use in valuing the savings of accidents from road improvements and road safety measures. The current values are based on a mixture of methods of estimation, but the intention is to increase the use of methods based on willingness to pay - so far applied only to fatalities.

2.3 The multicriteria evaluation

Despite the fact that Cost-Benefit Analysis has been increasingly employed in the evaluation of alternative transport projects, criticism with respect to its welfare and economic foundations has not ceased.

Further objections have also been advanced to its effectiveness for evaluating plans in terms of their broad array of community objectives. In particular, as long as traditional cost-benefit analysis requires the translation of both costs and benefits of a transport improvement into monetary terms, the net result may distort the relative importance to the community of the different impacts. In fact the intangible costs and benefits may be as significant for the community under consideration. Furthermore, the expression of some costs and benefits in monetary terms and the restriction of the evaluation process to an economic analysis may lead to a deficient decision since the essence of particular costs and benefits may be lost through their conversion in monetary terms (Hill, 1967).

The apparently single dimension analysis embodied in the core of CBA has prompted the development of alternative methodologies for the evaluation of transport investments and/or improvements. Perhaps the best known are the Planning Balance Sheet (Lichfield, 1970; Lichfield et al, 1975) and the Goal-Achievement Matrix (Hill, 1967; Hill, 1968; Sager, 1981).

2.3.1 Planning Balance Sheet. This was devised by Lichfield as a generally applicable aid to reaching decisions on urban and regional planning proposals. In essence, it is a particular framework within which the methodology of social cost-benefit analysis could be applied and thus much of its rationale will be similar to the cost-benefit approach. Notwithstanding this similarity, Lichfield thought it was necessary to adapt social CBA as then generally practised, to urban and regional planning proposals.

The need for adapting CBA, according to Lichfield et al (1975) was twofold. First, CBA has typically been applied to investment projects in a single sector (e.g. water resources, highways, etc) and thus, estimated costs and benefits have largely been related to the particular "system" of the which the project forms a part. The analysis has therefore focused mainly on the costs and benefits falling directly on those who produce and operate the project and those who consume the goods and services it generates. In contrast the multi-dimensional characteristic of urban and regional planning proposals makes evaluation an even more difficult task, if not weakening its application. A greater number of groups will be affected, the repercussion of proposals being far more wide-ranging, and the number of imponderable factors present will tend to be much greater. Thus, because of the multi-sectoral nature of proposals, greater regard will have to be paid than in conventional applications of CBA to those items which cannot be quantified or measured in common units. Therefore, the Planning Balance Sheet (PBS) includes a statement of intangible and incommensurable items in the same table as those for which valuations can be established.

The second reason for adapting conventional CBA is the importance of equity considerations in urban and regional planning. The PBS allows the analyst to set down the items of cost and benefit against each group who will experience the consequences of the option, and to trace the ultimate incidence of gains and losses. Hence, in the analysis, an attempt is made, if practicable, to determine the incidence of gains and losses on groups within the community.

Over the years, the PBS itself has been developed largely through practical application to a range of studies (see for example Lichfield, 1966a; 1966b; 1969; 1971). Although advances have been made in techniques of quantifying costs and benefits, the basic framework and approach of the analysis have remained the same since the initial studies in the 1960s.

The first task is to identify sectors within the community and to differentiate them between "producers/operators" and consumers. Each producer/operator, listed vertically in balance sheet form, is as far as possible, paired with the appropriate groups of individuals who will be consuming the goods and services generated by the projects. Each linked, or associated, pair of producers and consumers is considered to be engaged in either a notional or a real "transaction", whereby the former produces services "for sale" to the latter. These transactions are not confined to goods and service exchanged in the market, but they would extend, for example, to include visual intrusion imposed upon residential occupiers by the builders of a motorway, pollution caused by car users and etc. The impacts expressed monetarily are aggregated as in conventional cost benefit analysis and a decision is finally made judgementally by weighting the net monetary cost or benefit against the spectrum of other impacts and their distribution. For a full description of PBS analysis, see Lichfield (1970) or Lichfield et al (1975), among others.

The generality of many planning studies, especially at the sub-regional or regional scale, and their inevitably complexity, has meant that in practice analysis using the PBS may not achieve full documentation of all transactions among all groups affected, but the framework exists for extending the analysis if study resources allow.

2.3.2 Goal Achievement Matrix. The Goal Achievement Matrix (GAM) was developed as an alternative from the early experiences of PBS and some of the theoretical advancements of the subject.

The term goal is used for a principal objective of the scheme and should, as far as possible, be measurable. Hill (1967) outline a hierarchical goal system. The goals of a planned action may be categorized on the basis of specificity as ideals, objectives and policies. Typical objectives of transport projects are: increase of accessibility; reduction of noise, air pollution and accident rates; more equitable income distribution; and reduction of community disruption. Hill (1967) defines another category of values, requisites, which are not specific goals of plans but which enable the planner and decision maker to set guidelines. Requisites set limits to objectives and the policies by which objectives may be realized, and they enter into consideration primarily at the time the alternative plans are generated and developed. Typical examples are feasibility, immediacy and interdependence.

The essence then is to establish separate accounts for impacts generated by different schemes as they bear against each important goal and upon each of several groups within society. In this analysis, costs and benefits are always defined in terms of goal achievement. Where the goal can be and is defined in terms of quantitative units, the costs and benefits are defined in terms of the same units. Where no quantitative units are applicable, benefits indicate progress toward the qualitative states that the objective describes while costs indicate retrogression from these objectives. Note that this interpretation of costs and benefits differs from the traditional conception.

Weights are introduced into the analysis which reflect the community's valuation of the various objectives. Therefore, both the achievements towards each goal and impacts against (incidence) each social group are given weights on judgemental basis. The weights are applied irrespective of the units in which the achievement of the objectives is measured.

Those levels of goal achievement (multiplied by their appropriate weight) which are in commensurable units are combined, leaving a reduced but still multidimensional array to be reviewed in reaching a final decision. In rare cases where all costs and benefits for all objectives are in like units, a grand summation can take place. The final matrix can then be presented for each alternative plan to the decision makers, either in an unmodified form or an aggregated manner giving each plan a relative score.

The approach to decision-making by means of goal-achievement analysis relies heavily on obtaining the correct weightings both for community groups and for objectives. Hill (1967) sets out some methods for determining these weights:

(i) The decision-makers may be the only people responsible for weighting objectives and their relative importance for particular activities, locations, or groups in the urban area.

(ii) A general referendum may be employed to elicit community valuation of objectives.

(iii) A sample of persons in affected groups may be interviewed concerning their relative valuation of objectives.

(iv) The community power structure may be identified and its views on the weighting of objectives and their incidence can be elicited.

(v) Well-publicized public hearings devoted to community goal formulation and valuation can be held.

(vi) The pattern of previous allocations of public investment may be analyzed in order to determine the goal priorities implicit in previous decisions on the allocation of resources.

The determination of community objectives and relative valuation may be subject to similar arguments to the distributional weights in CBA. Nevertheless, some of the procedures mentioned above have been performed in different studies (for references see Hill, 1967).

Hill (1967) proposed a set of measures and definitions for determining the extent of achievement of three objectives: reduction of accident rates, reduction of community disruption and reduction of air pollution. By means of goal-achievement analysis, many of the intangible effects associated with certain objectives could be measured and considered simultaneously with costs and benefits measured in a more concrete manner.

Finally, supporters of the GAM argue that despite the fact that the approach is complex and costly and requires the determination of "arbitrary" weights, it does make explicit the incidence of costs and benefits and considers both quantifiable and non-quantifiable objectives.

2.3.3 Evaluation of trunk road proposals in Britain: the SACTRA approach. In the late 70s the Department of Transport established an Advisory Committee (the Advisory Committee on Trunk Road Assessment, ACTRA) to undertake a review of the methods employed to assess proposals for new trunk roads. They concluded that while the system was generally sound, there was a need to ensure that the assessment was not dominated by factors susceptible to evaluation in money terms (essentially cost of construction, vehicle operating cost, travel time and at least some accident costs). They also consider that it was inadequate to rely on a simple checklist (introduced by Jefferson in 1975) to comprehend environmental factors.

The committee advocated that a comprehensive framework should be used as the basis for assessment, considering all factors included. ACTRA also recommended that a framework approach might be helpful in comparing investments in alternative forms of transport.

After the publication of the report, known as the Leitch report (DTp, 1977), the Department experimented with the framework for different schemes and at different stages in the design process. Similarly, different forms of framework had been tested.

The Standing Advisory Committee on Trunk Road Assessment (SACTRA), which was formed in 1979, has paid particular attention to the experiences of those who had used the framework experimentally since the ACTRA report. Samples of the framework prepared at different stages of design were examined. The degree of use of the framework had varied from scheme to scheme according to its nature and complexity.

The experience gained reassured the SACTRA that the framework does have a role to play in the trunk road assessment. It can provide an intelligible means of presenting comprehensive information to the public, and can help them to identify how the different groups will be affected. It can also provide a basis for the designers and decision makers to reach rational judgement on schemes, taking into account the full range of benefits and disbenefits. They considered however, how the framework approach should be completed and used in order to take the maximum advantage of its potential.

For instance, it would not be necessary to present great details to the public consultation about the route, and it is reasonable to omit some of the alternatives and modify the most promising ones (in the light of consultation) for presenting to the Minister for decision about the route to be taken by the road. However, a more comprehensive framework with greater detail would be required for final public enquiry.

The effects of each option are grouped under six headings: travellers; occupiers; users of facilities; effects on policies for conserving and enhancing the area; effects on transport, development and economic policies. These are essentially the same as ACTRA suggested except that 'non road users directly affected' has been split into 'occupiers' and 'users of facilities'. This has the advantage of separating the impacts on people tied to an area and on visitors and those who have a choice as to whether they remain affected or not (DTp, 1979).

Hence, SACTRA suggested that the framework approach should be developed in three different stages, since the degrees of complexity, problems and nature varies for every stage of the trunk road assessment.

FIRST STAGE - Initial framework for consideration at the public consultation

At the first stage of design where the alternatives are identified, it would be helpful to collate the information in framework form until enough data is available to select the most promising options for public consultation.

The objects of the public consultation stage are to inform the public that a new road is under consideration, to seek information from local people about the importance to them of various factors, and to seek their opinion about which of the options is the best.

The main vehicles for providing information is normally a leaflet containing a map showing the routes and a brief indication of the main impacts. There might be also a public exhibition showing more details of the scheme.

The framework would be available to anyone interest in it.

SECOND STAGE - A summary framework drawing out the significant factors for the consideration of the Minister, and with recommendations as to which route is the best.

For the second stage the designers must prepare their information (including any new information gained from consultation) in a form for the Minister to consider.

A summary framework should be prepared portraying the main advantages and disadvantages of each route, and making a recommendation which is the best route.

The submission to the minister should continue to reflect the balance between the quantified and non-quantified factors built into the framework.

After the selection of a preferred route, the design has to be worked out in full detail . It may be possible at this stage to improve the preferred route by small decisions (i.e, shifting the alignment, introducing noise barriers) involving trade-offs of benefits and losses. The decisions should be taken with the framework in mind.

THIRD STAGE - A more comprehensive framework, based on more detailed designs and analysis for consideration at a public enquiry.

At this stage the framework will be prepared in more detail than at the public consultation stage, but will even so only be a summary. More detailed will be available in plans and drawings, and in consultant's report.

The framework has to be as comprehensive as possible and should provide all necessary information how impacts have been assessed and what assumptions been made.

Normally a public enquiry follows and if a new alternative is form according to new proposals the department may prepare a new draft and present to a second public enquiry before the final choice is reached.

The methodology developed by SACTRA was further extended, with some modifications, to urban road appraisal in 1986 (see DTp, 1986a).

2.3.4 **Comments.** Many of the criticisms of CBA have been partially overcome by PBS and GAM. Both methods however, have been developed differently in practice. As indicated, PBSA has been matured through practical applications to a wide range of planning problems and in further theoretical advancements by its author and others. In contrast Hill, has carried out no substantial applications of the GAM, although he has developed selected aspects in the literature, notably indices of measurement and the application of scaling techniques (Lichfield et al, 1975). The development of both methodologies has contributed to their refinement. In particular, Hill argued that in the PBSA costs and benefits were treated as if they did not depend for their 'existence' and validity upon the achievement of particular objectives; that is, as if they possessed independent value (Lichfield et al, 1975). The point that objectives should made explicit in evaluation was accepted by Lichfield as a valid criticism in relation to early applications of his method. Later, objectives of various sectors of the community were explicitly introduced into the Cambridge Study in 1962-64 (Lichfield, 1966a), and the role of objectives in his method was stressed further in a study following of planning proposals for Swanley, Kent (Lichfield, 1966b).

A critical comparison of the PBS with the GAM is given by Lichfield et al (1975). The methods are contrasted in relation to central issues, identified by Lichfield, that have to be faced in evaluation. These are: scope of the analysis and its relation to decision-taking; formulation of the relevant set of objectives by which to compare alternatives; measurement of the achievement of the objectives; and incorporation of equity considerations.

Note that these two, together with CBA, are not the only methods currently used or proposed for evaluation of urban and regional plans. For a comprehensive review of these and other methods see Lichfield (1970).

The evaluation of trunk road proposals in Britain follows a comprehensive framework developed in three different stages. Additional to the assessment of quantified and non-quantified factors, it also include the identification of the impacts in different groups as well as public consultation and enquiry.

2.4 Evaluating public transport improvements and investment

In general public transport operators and/or government officials have, to a certain extent, the opportunity to control fares and service levels in order to achieve their objectives (which may for example be to achieve highest social welfare or maximum profit). In particular, the impact of these factors on the demand for public transport have significant implications for public transport policies.

Information on the effect of fares on public transport patronage is normally exists. This is partly because of the direct relationship between fares and revenue, coupled with the financial records normally retained by operators, and partly in planned and regulated operating environments because fare-system is normally operated network-wide so that when fares change the new fare levels affect the whole operation at the same time (TRRL, 1980).

In the mid 70s, for instance, some public transport operators were directed to run their services so as to maximise the total number of passenger miles they sell, subject to an overall subsidy constraint. This strategy was actually adopted as a corporate objective for London Transport in 1975 (London Transport, 1975).

Glaister and Collings (1978) examined this by comparing and contrasting (in theoretical terms) the implications of using these objective with those of 'classical' marginal cost pricing alternatives. They also demonstrate that under certain assumptions it is possible to define a simple procedure for weighting passenger miles so that maximisation of weighted passenger miles would be equivalent to maximisation of net social benefits. Alternative weighting systems are also examined in order to encourage congestion relief (through modal split), income redistribution or economic efficiency. The arguments are illustrated with numerical calculations using London Transport data.

The distributional effects of maximisation of passenger miles are further explored by Bös (1978). Using the same set of data, the author concluded that maximisation of passenger miles would have provided positive distributional effects of London Transport bus and rail pricing for any exogenously given amount of deficit or profit for the enterprise.

On the other hand, given the particular nature of attributes, changes in service levels (for instance, travel time, waiting time, and comfort) are much more difficult to assess, although their relevance to public transport demand and/or operator's objectives may be of even more significance.

In addition, in the assessment of both fares and service levels it is difficult to provide conclusive answers (specially with regard to social welfare) since distinct social groups will perceive differently the various attributes. An association with the concept of marginal utility of income is immediate.

In an attempt to explore the balance between fares and service level with regard to the degree of subsidy, a model has been developed for the Department of Transport (1982).

The model has been used to evaluate the effects of changes in subsidy, represented by changes in fares and level of service. This is measured in terms of generalised cost to public transport users and the congestion effects on other road users (both in terms of time and vehicle operating cost variations in response to alterations in traffic speed). The public transport operators also face changes in operating costs if service levels are changed.

All evaluations are carried out relative to some 'base' situation, assuming a demand function of the form:

$$x_i(p,u) = x_i^{(b)} e^{\sum_{m=1}^{M} a_{im} g_m}$$

where: x_i(**p**,**u**) is the demand for mode i following a change in the vector of money travel cost **p** and the vector of user cost, or service quality variables, **u**

$x_i^{(b)}$ is the demand for mode i in the base

a_{im} are constants and

g_m are the generalised cost of using mode m.

The generalised cost is expressed in terms of the differences in money travel component and user cost variables. The money travel component is simply the ordinary fares in the case of public transport and the operating cost (itself a function of vehicle speeds) divided by the vehicle occupancy for private vehicle travel. It follows that for public transport $\partial g_m/\partial p_m = 1$. The user cost variable is a function of waiting time, time spent in the vehicle whilst stationary and time spent in the vehicle whilst moving, each converted in money terms using average values of time.

Waiting times incorporate a simple function of vehicle headways and a factor to represent the increasing probability that users, while at stops, will encounter full vehicles as the average load factor increases. A further penalty for increasing levels of discomfort is also included. Times spent in vehicles are determined by general road traffic speeds, itself a function of speed/flow relationships. For a full description of the assumptions behind waiting time, vehicle speed and operating cost see Department of Transport (1982).

The formulation of the demand function (semi-log linear) used here has the property that own price elasticities of demand are directly proportional to fare levels. Indeed, it is clear that a_{im} is the elasticity of x_i with respect to p_m, divided by p_m. This can be shown by taking the derivative of x_i with respect to p_m and further dividing by x_1 and multiplying by p_m. Since a_{im} are constants the demand elasticities are all proportional to their respective prices and henceforth, if fares increases the fare elasticity increases in the same proportion.

The evaluation of the effects of changes in fares or service levels are estimated from the standard consumer surplus theory. Although the method for evaluation was derived from the rigorous microeconomic (and welfare) theory at the individual level, in practice it is common to assume that the formula is equally valid for aggregate (or market) demand functions (DTp, 1982). Further assumptions are embodied in the application. First, the demand relations actually used are not compensated (for a discussion on the difference between compensated and Marshallian demand functions see next chapter). Moreover, the aggregate demand functions are not formally derived and there is no guarantee that the symmetry conditions required of the individual's function will be satisfied. Therefore the integrals will, in general, depend upon the path of integration. Second, in most studies (see for instance DTp, 1982) the values of time used are estimated from independent sources and, although they vary across markets (because they comprise different kinds of individuals) they are assumed to be constant during each integration.

The model has been applied to assess the effects of subsidy to public transport operators in the main conurbations of England (DTp, 1982). The study covered London, Greater Manchester, West Midlands, Merseyside, West Yorkshire and South Yorkshire. The following modes were considered: bus, commercial vehicle, car, British Rail and Underground (in the case of London).

The purpose of the study was, according to the Department, "to explore two main questions:

(1) For a given level of subsidy in each conurbation how can fare and service levels be set to give the greatest benefit?

(2) How do subsidy levels for different conurbations compare in terms of value for money?" (DTp, 1982).

A change in fare structure and/or service level will normally involve a change in degree of subsidy to the public modes. Subsidy by itself, since provided from government revenue, implies some tribute, either on the part of alternative use of the revenue or a change in income which individuals forego in the form of taxation (DTp, 1982). Therefore, in the evaluation carried out, change in subsidy was subtracted from the measure of consumer surplus to obtain the net social benefit. Additionally, the net benefit has been divided by the change in subsidy. The result of the evaluation therefore, is expressed in terms of the marginal net social benefit per £ of subsidy. This shows the additional social benefit resulting from a marginal £ of subsidy, after netting out the subsidy itself.

A further calculation reveals the extra net social benefit that would be earned at margin by using £1 extra subsidy to change each one of the policy variables (fares and service level), holding the other constant. These "shadow prices" are essential to the assessment of the optimal balance between fares and services, the balance of expenditure levels between authorities and the rate of return to subsidy in general (Glaister, 1987).

The results of the evaluation have been discussed at some length by the Department of Transport (1982) and by Glaister (1987).

It is clear from the outset that the social cost benefit framework developed by Glaister concentrates on the financial (changes in revenues and operating costs) and consumer surplus implications. Glaister (1987) recognizes that there are a number of other important effects that are not included explicitly. At present, the model does not cover the effect of different subsidy levels on accidents; the longer term effects of subsidy on changes in land use; the effects of increased subsidies on labour productivity and wage costs; any energy considerations that are not captured adequately in the various vehicle operating cost calculations; and environmental implications. Furthermore, issues regarding transport 'needs' (indeed, a very significant issue in most debates on subsidy) are not taken into account; nor are other questions concerning the existence of distortions elsewhere in the economy; the alternative uses that the funds would have had; or the efficiency cost of raising the finance through taxation. Finally, perhaps one of the most prominent issues of all is the distributional aspects of the subsidy.

The legislative framework for public transport in Great Britain however, has undergone considerable changes with the introduction of the 1985 Transport Act, which effectively extended deregulation to all bus services outside London, and created a competitive market.

The demand for public transport was argued to be better served by mobilizing the resources - financial and skills - of the private sector with a regime of targeted incentives and reduced control. Such a policy was intended, among other things, to reduce the need for public expenditure, thereby contributing to macro-economic objectives, and to increase the effectiveness of any subsidy provided.

More recently, there has been an increasing interest in establishing the extent to which investment in public transport can be realised under existing government policies. The main concerns have been with urban areas, where public transport investment by local authorities with financial support from central government, may be justified under Section

56 Transport Act 1985 according to Guidelines issues by the DTp (1989b).

The essential principles established by the Government were that revenue contributions from those directly benefit from the scheme should be maximized. Government itself, will support schemes that meet the Section 56 Guidelines, if there is enough evidence that the scheme will generate considerable benefits to non-users, or society at large, and then only as a last resort.

These principles have changed the focus of appraisal of schemes submitted for grant. The appraisal will in particular need to show that the scheme is the most cost effective way from the point of views of the public sector of achieving the desired objectives; that the present value of the total scheme cost is covered by revenue from passengers and contributions from that other beneficiaries such as developers, direct savings in other areas of public expenditure, plus the other benefits that will accrue to non-users; that the scope for pricing mechanisms has been explored, with a view to finding the option which minimizes the requirement for public sector support; that, where schemes are likely to bring benefits to developers through land use enhancements, the possibility of the developers making an appropriate contribution to the cost has ben fully explored; and finally that the external benefits to non-users exceed in value the whole of the public sector contribution (Halcrow Fox, 1991).

In short the guidelines are designed to result in projects where public policy objectives are achieved through the contributions of the private sector and eventually the public sector only where sufficient external benefits are generated.

Therefore, the cost of the scheme, (capital, operating and replacement costs) are to be covered by three sources of income: fare revenues, contribution from land owners/developers, and government grant payable in respect to external benefits.

In some cases it may be possible that fares revenues exceed operating cost, but are unlikely to provide a significant contribution to capital costs. In addition other sources of revenue (advertising, retail concessions, etc) will not contribute considerably to capital costs. Development contributions, except in unusual cases, are unlikely to exceed 5% of the capital costs. Ultimately, the capital cost will have to be met largely from grant, justified on the basis of external benefits - which must become the focus of project appraisal.

Of the external benefits, road congestion relief has much the most prominent role in scheme appraisal. It will normally be required to justify a substantial proportion of the scheme's capital cost. Environmental benefits and accident reduction are another source of possible benefits, although less prominent.

A number of other external benefits may be generated through the introduction of new public transport infrastructure. In particular, it could lead to economies of scale through improved access by activities to the labour supply. Also, for some schemes, some constraint on regional development could be reduced, creating an impetus for future growth. Changes in land use may also generate benefits, although it is difficult to apportion these effects between investments in transport and other initiatives. Finally, the impact of new transport schemes on achievement of local objectives for areas that receive inner city or regional support needs to be added to the estimation of total benefits accruing from transport improvements.

A research program developed for the Passenger Transport Executive Group and the DTp by Halcrow Fox (1991), has operationalised these broad guidelines, laying out approaches to setting revenue-maximising fares and to estimating the revenue potential of projects; to estimating the scale of, and to capture, development gains; to quantifying, as far as possible, the external benefits, in respect which government Section 56 grant may be made available.

2.5 Concluding Remarks

This chapter has examined different methods for evaluating transport infrastructure and operation.

In Great Britain, the evaluation of transport projects has relied essentially on Cost-Benefit Analysis. This involves the aggregation of individuals' assessment of the costs and benefits to them of a given action, policy, project or programme, and it will, if properly undertaken, reflect individuals' preferences. If we are to leave the preferences reflected in the market place unadjusted, it follows that they will also reflect the structure of market forces, or to put it another way, the distribution of income.

Two value judgements are therefore implicit in this technique: that individual preferences should count; and that those preferences should be weighted by the existing distribution of income.

This second value judgement is the one about which economists have often disagreed. Indeed, the use of variable weights on gains and losses to different income groups has been the most controversial issue in CBA.

If interest lies only in efficiency, the increase in real resources is an adequate measure of project benefit and the problem simply reduces to one of relative valuation of resources of different kinds. If, however, there is interest in income distribution as well, the distribution of resources among different groups in society must be also examined. Given that a redistribution of income does result from undertaking projects, there is a number of options, and some controversy, concerning the way the distribution of resources should be examined.

The economic evaluation of transport projects involves the estimation of values for items which were previously regarded as intangibles, such as travelling time or accidents. Also, common environmental externalities may include reductions in noise, pollution and congestion levels. These together with the more straightforward items, such as government expenditures and vehicle operating costs, can be used for detailed evaluation of the operational consequences under consideration.

In relation to distributional issues, the valuation of time savings is one of the most important aspects of appraisal in the transport sector. The principles of welfare economics suggest that if the underlying income distribution is considered equitable, then willingness to pay is the correct criterion for valuing resources when judging the appropriateness of public sector investment, in which case any revealed variation in travellers' value of time should be taken into account. Such an approach will result though in favouring projects which translate large proportion of benefits to travellers with higher values of time, which tend to be high income travellers. It was to avoid this that an equity (common) value of non-working time was adopted in British practice. Ultimately, the choice between an income-related and a common value of time is political, although if the evaluation is to be understood, the implicit judgement and its implications should be made clear.

Although concepts of economic efficiency provide an important starting point for evaluation, they may be inadequate for capturing many aspects associated with transport provision. These include, in addition to questions of equity and distribution, issues of transport need and accessibility which may not be accurately expressed in terms of market demand, as well as planning and the attainment of multiple objectives.

These issues have prompted the development of alternative methodologies for the evaluation of transport investments and/or improvements. In Great Britain, the evaluation of trunk road proposals follows a comprehensive framework developed in three different stages. In addition to the assessment of quantified and non-quantified factors, it also includes the identification of the impacts on different groups. The whole process is subject to public consultation and enquiry.

In the case of public transport, the legislative framework has undergone considerable changes with the introduction of the 1985 Transport Act. Since then, there has been an increasing interest in establishing the extent to which investment in public transport could be realised under the prevailing institutional environment.

The demand for public transport was argued to be better served by mobilizing the resources - financial and skills - of the private sector with a regime of targeted incentives and reduced control. Such a policy was intended, among other things, to reduce the need for public expenditure, thereby contributing to macro-economic objectives, and to increase the effectiveness of any subsidy provided. It was also argued that government grants for public transport investment should still be required (at least in the conurbations), as long as it generates sufficient external benefits - which became the focus of project appraisal.

Although distributional issues are an established part of the economic theory, they have been a subject of fierce controversy. In many ways, the evaluation techniques current in Britain for highway and public transport investment are inconsistent, and furthermore neither of them makes more than a limited attempt to address distributional issues.

CHAPTER 3
CONSUMER'S SURPLUS AND THE MEASUREMENT OF WELFARE CHANGES

3.1 Introduction

The concept of consumer's surplus is probably one of the most important in the measurement of social benefits. Yet, it is perhaps the most controversial of widely used economic concepts, subject to fierce criticisms (Samuelson, 1947; Little, 1957). Nevertheless, the concept itself, albeit simple in principle, is not always fully understood and the large existing literature does not help to illuminate some of the fundamental queries.

Consumer's surplus is a central concept in public policy evaluation. In particular transport investments and/or improvements have their benefits estimated by an aggregated measure of changes in price (or 'generalised cost') and quantity supplied.

Dupuit (1844) gave the first description of the notion that Marshall later referred as consumer's surplus. Marshall (1920) defined consumer's surplus as "the excess of the price which [the consumer] would be willing to pay rather than go without the thing, over that which he actually does pay". Despite being the most popular measure of welfare changes it is perhaps the least rigorous and its use implies some fundamental value judgements which often serve as the basis for criticism.

On the other hand, it is widely held by economists that the correct quantities to be measured are: either the amount the consumer would pay or would need to be paid after the changes to be just as well off as he was before; or alternatively the amount which would have to be given to or taken from the consumer when he faces the initial conditions to make him as well off as he would be when facing the new conditions. This corresponds to the Hicks' (1956) compensating variation (CV) and equivalent variation (EV) respectively. Likewise, the measurement of both CV and EV encounters many problems.

This chapter, within the framework established by the neo-classical theories of welfare and microeconomics, presents the concept of consumer's surplus. Some of the criticism and drawbacks of the different measures of welfare changes are also briefly discussed. An account of some applications of the concept in the context of transport evaluation is also given.

Following the work by Train and McFadden (1978) and Jara-Diaz and Farah (1987) two different frameworks are presented in which the measures of both users benefit and value of time are derived from the theory of trade-off between goods and leisure. The usually accepted assumptions on the role of income in transport demand modelling have been reviewed and an advanced new specification for the measurement of users' benefit is proposed to be tested. Although they are not discussed in great detail, some of the limitations and drawbacks of this theoretical account are also pointed out.

3.2 Theoretical Background

The starting point is the theory of consumer choice. This approach views the individual as choosing quantities of goods and services so as to derive the maximum utility subject to a constraint on his overall expenditure. The problem of preference maximization can then be written as:

$$\text{Max } u(\mathbf{x}) \qquad \text{subject to } \mathbf{p}.\mathbf{x} \leq I$$

where:

I is the fixed amount of money available to a consumer

$\mathbf{p} = (p_1,p_2,...p_k)$ is the vector of prices of goods 1,2,..k.

$\mathbf{x} = (x_1,x_2,...x_k)$ is the bundle, or vector of amounts of goods consumed.

$u(\mathbf{x})$ is the utility of the bundle $\mathbf{x}$ to the consumer.

and:

the solution $\mathbf{x} = \mathbf{x}^*(\mathbf{p},\mathbf{I})$ is the demand function

the optimum $u[\mathbf{x}^*(\mathbf{p},\mathbf{I})] = V(\mathbf{p},\mathbf{I})$ is the indirect utility function.

An important property of the indirect utility function is the Roy's identity:

$$x_i(p,I) = -\frac{\frac{\partial V(p,I)}{\partial p_i}}{\frac{\partial V(p,I)}{\partial I}}$$

The demand function may thus be obtained through the derivatives of the indirect utility function with respect to price and income.

The dual approach views the individual as minimizing the expenditure in order to attain a predetermined level of utility. The expenditure minimization problem is therefore:

$$\text{Min } \mathbf{p.x} \qquad \text{subject to } u(\mathbf{x}) \geq u$$

and:

the solution $\mathbf{h}=\mathbf{h}(\mathbf{p},u)$ is the compensated demand function

the optimum $\mathbf{p.h}(\mathbf{p},u) = e(\mathbf{p},u)$ is the expenditure function

The expenditure function derived in this way gives the minimum cost of achieving a fixed level of utility. The partial derivative of the expenditure function with respect to the price of good is the compensated (or Hicksian) demand function:

$$\frac{\partial e(p,u)}{\partial p_i} = h_i(p,u)$$

This term comes from viewing the demand function as being constructed by varying prices and income so as to keep the consumer at a fixed level of utility. Hence, the income changes are arranged to 'compensate' for the price change.

Hicksian demand functions however, are not directly observable since they depend on utility which is not directly observable. Only the demand functions expressed as a function of both prices and income are observable; generally these are called Marshallian demand functions. The difference between compensated and Marshallian demand functions lies in the income effects of a price change. This can be illustrated in a simple case of two goods **1** and **2**, by altering their relative prices.

The overall demand change, as a result of changes in prices of a good, can be decomposed in two components. A fall in p_1 without any changes in p_2, for instance, does two things:

(i) It changes the relative prices facing the consumer.

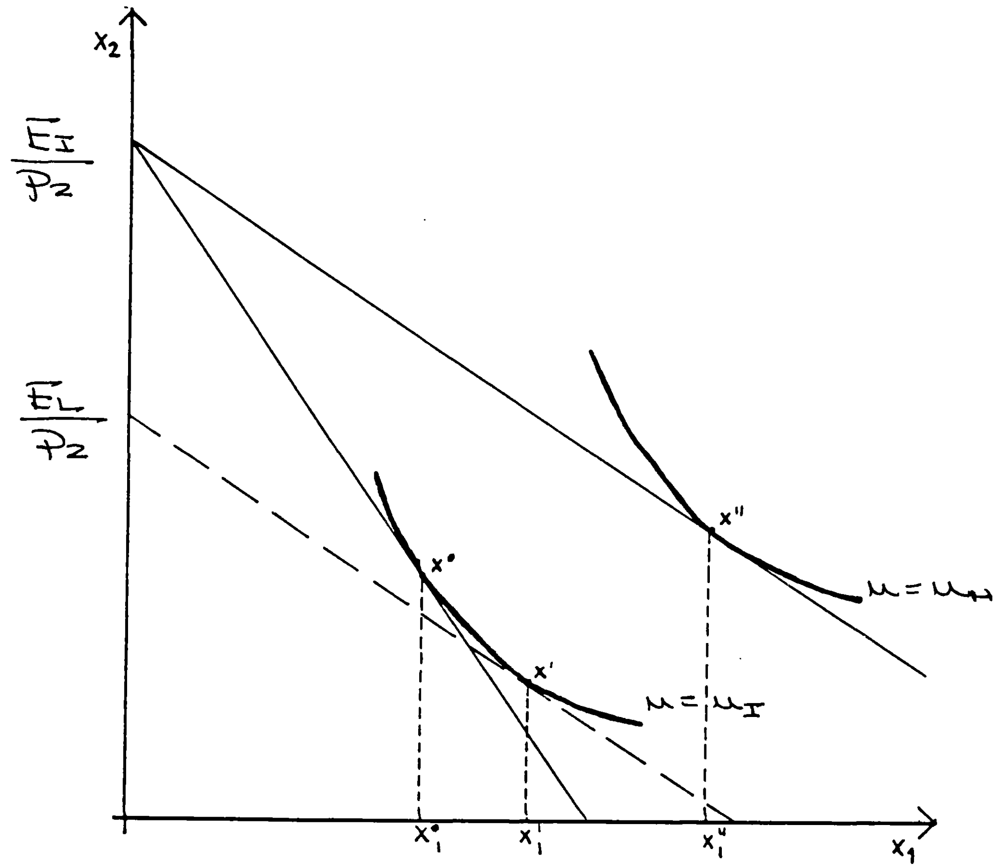
(ii) It reduces the expenditure required to achieve the initial utility level u_I from an initial level E_I to a lower level E_L. Thus a higher utility level u_H can be achieved with the initial expenditure. It represents an increase in the consumer's real income.

In **figure 3.1.** the change in the demand for x_1 is broken, in accordance with the above, into:

(a) own substitution effect, which results solely from the change in p_1 with real income held constant.

(b) income effect, which is the change resulting solely from the change in real income, with the relative prices held constant.

Figure 3.1 The effects on the demand of changes in relative prices



The difference between **x°** and **x'** is due to a change in relative prices with real income (utility) held constant. The difference between **x'** and **x"** is due to the change in real income with relative prices held constant at their new level.

(i) $x_1' - x_1^o$ is the own substitution effect;

(ii) $x_1'' - x_1'$ is the income effect; and

(iii) $(x_1' - x_1^o) + (x_1'' - x_1') = x_1'' - x_1^o$ is the total price effect.

The Slutsky equation relates the two demand functions by decomposing the overall demand changes induced by a price change into this two separate effects:

$$\frac{\partial x_j(p,I)}{\partial p_i} = \left.\frac{\partial h_j(p,u)}{\partial p_i}\right|_{u=V(p,I)} - \frac{\partial x_j(p,I)}{\partial I} . x_i$$

3.3 The measurement of welfare changes.

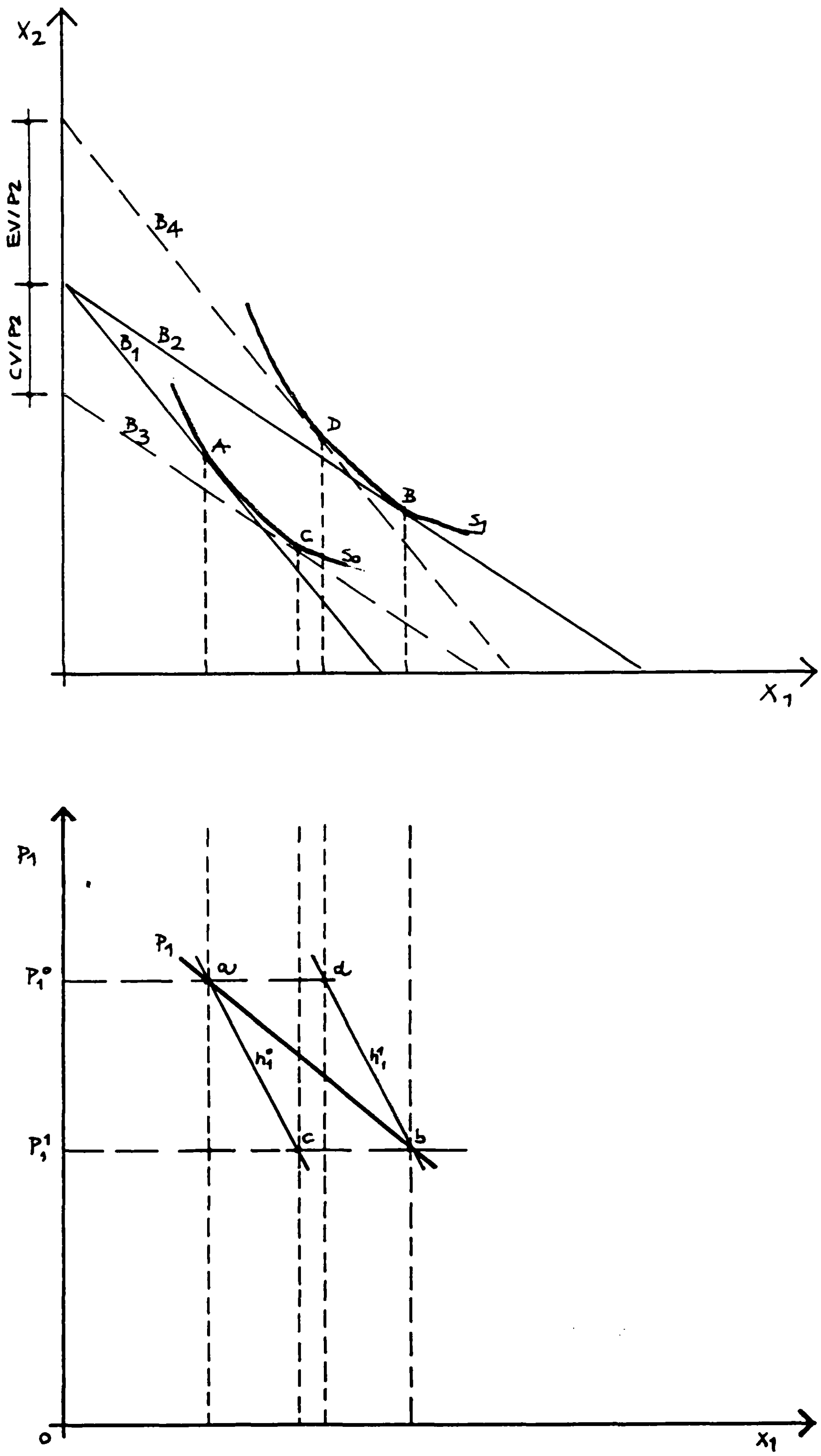
3.3.1 The Compensating and Equivalent Variation. A number of public policy issues require the estimation of the effects of a change in the price of a commodity on the consumers' welfare. Specifically, in transport one wishes to measure the benefit of changes in fares, level of service, travel time, and so on.

One possibility is to measure the changes in the utility level of the consumer. However, this approach suffers from a number of drawbacks. Firstly, it is not implementable, in that we cannot observe utility levels. Secondly, because the utility function is only unique up to a positive monotone transformation, a utility measure would be affected by the choice of utility function used to represent the consumer's preferences. This means that a utility measure would be essentially arbitrary. Moreover, any utility measure would not be comparable amongst individuals and we could not add utility differences for a measure of aggregate benefits to all consumers.

A measure which could at least avoid some of these problems is the consumer's own monetary valuation of the price change. Since the measure is expressed in terms of money, individual measures are at least commensurable and could be added to form a measure of aggregate benefit to all consumers of that good. This latter however, would require a fundamental assumption that an extra £1 of benefit to an individual has the same social significance whichever individual it accrues to. This has important implications for standard cost benefit analysis when some individuals gain and others lose as a result of particular decisions. The distributional issue is particularly relevant in developing countries, where the implementation of different policies might have substantial impacts on distinct social groups with very widely differing incomes.

Figure 3.2. illustrates the effect of a fall in the price of good 1 from p_1^o to p_1^1, with the price of good 2 and money income held constant.

Figure 3.2 **The effects on the demand and the measure of welfare of changes in relative price**



As illustrated there are two plausible measures which could represent the consumers' monetary evaluation of the change in his utility. The compensating variation (CV) and the equivalent variation (EV).

Hicks (1956) defines the CV as the minimum amount by which a consumer would have to be compensated after a price change in order to be as well off as before. The EV, on the other hand, is the amount of money which would have to be given to the consumer when he faces the initial price to make him as well off as he would be by facing the new price (lower in this particular case) with his initial income.

The distinction between EV and CV may be made clearer by using the indirect utility function:

$$V(p^0,I^0) = V(p^1,I^0-CV) = u^0$$

$$V(p^0,I^0+EV) = V(p^1,I^0)$$

One way to measure both CV and EV without a detailed knowledge of individual preferences is by using the expenditure function.

$$CV = e(p^0,u^0) - e(p^1,u^0)$$

which is the same as:

$$CV = e(p^0,u^0) - e(p^1,u^0) = \int_{p_1} \frac{\partial e}{\partial p_1} dp_1$$

but, as:

$$\frac{\partial e(p,u^0)}{\partial p_1} = h_1(p,u^0)$$

$$CV = \int_{p_1} h_1(p,u^0) dp_1$$

where $h_1(\mathbf{p},u^o)$ is the constant utility demand function for x_1 and $\mathbf{u}=\mathbf{u}^o$, and therefore the CV is the area between the p_1 axis, the price lines p_1^o and p_1^1 and the compensated demand curve h_1^o i.e. $x_1 = h_1(p_1, p_2^o, u^o)$ (see **Figure 3.2.**).

Similarly, EV can be expressed:

$$EV = e(p^0, u^1) - e(p^1, u^1)$$

$$EV = \int_{p_1} h_1(p, u^1) dp_1$$

where h_1^1 is the constant utility demand curve for $u=u^1$, i.e. $x_1 = h_1(p_1, p_2^o, u^1)$ and EV is the area under the h_1^1 and between the price lines p_1^o, p_1^1 (this is also illustrated in **figure 3.2.**).

The consumer's market demand curve for x_i is not however his constant utility demand curve, but rather his constant money income demand curve. Both curves will coincide though, if and only if, the income effect is zero, and thus in this case the CV can be measured. If the income effect is non-zero then what can be measured (the area under the consumer's market demand curve between the price lines) will not be equal to CV. This brings us to the concept of the Marshallian consumer's surplus (MCS).

3.3.2 The Marshallian Consumer's Surplus. Marshall (1920) defined consumer's surplus as "the excess of the price which [the consumer] would be willing to pay rather than go without the thing, over that which he actually does pay".

The intuitive rationale for Marshall's idea is clear enough. From the first-order conditions for utility maximization,

$$\frac{\partial u(x)}{\partial x_i} = \lambda p_i$$

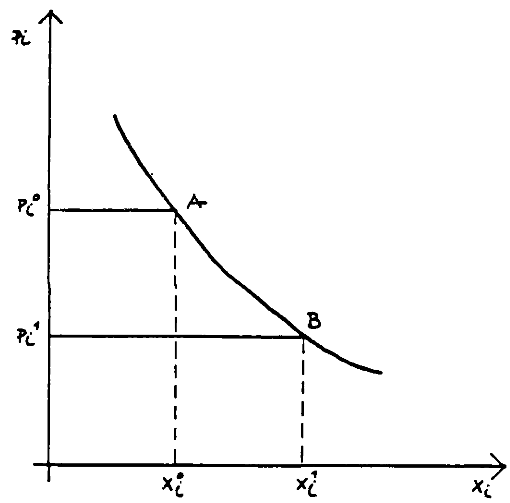
where λ is the marginal utility of income.

The total differential of utility can be written:

$$du = \sum_i \lambda p_i dx_i$$

If it can be assumed that λ is constant, and if we think of p (the price the consumer is prepared to pay for a marginal unit) as a function of x, then we can integrate utility changes over the interval x^o to x^1 to give the gross welfare change as λ times the sum over all goods of the area $x_i^o ABx_i^1$ illustrated in **figure 3.3.** From this, the change in MCS can be deduced by subtracting the difference between the total expenditures at the new and old prices.

Figure 3.3 The measure of consumer's surplus



Alternatively we could start from the indirect utility function and Roy's identity, where:

$$-\lambda x_i = \frac{\partial V(p,I)}{\partial p_i}$$

with:

$$\lambda = \frac{\partial V(p,I)}{\partial I}$$

In this case we would integrate the differential $du=-\sum\lambda x_i dp_i$ over the interval p^o to p^1, taking x as a function of p, and again assuming λ to be constant. This would give λ times the sum over all goods of the areas like $p_i^o ABp_i^1$ in the above figure. Hence, if the price of a good varies from p_i^o to p_i^1 then the MCS changes is expressed by:

$$\Delta MCS = -\int_{p_i^0}^{p_i^1} x_i dp_i$$

Thus the assumption of constancy or near constancy for the marginal utility of income, which has often served as a basis for using Marshallian consumer's surplus as a measure of welfare change. Deaton and Muellbauer (1980) pointed out, that almost 90 years previously Pareto (1892) had realized that the constancy of λ is impossible since it would imply for instance, that maximum attainable utility be independent of prices.

It turns out whether we integrate over the price or over the quantities, the only circumstance in which either the area $p_i^o AB p_i^1$ or the area $x_i^o AB x_i^1$ is a valid measure of welfare change is if preferences are homothetic[1].

In addition, if for instance, x_1 is a normal good ($\partial x_1/\partial I>0$) then x_1 will exceed h_1^o for all $p_1<p_1^o$ and be less then h_1^1 for all $p_1>p_1^1$, and the MCS will exceed CV but is less than the EV. The opposite holds if x_1 were an inferior good.

The magnitude of the individual income effects will depend upon the size of the price change and the importance of x_1 in the consumer's budget. For small price changes, and for goods which account for a small proportion of the consumer's expenditure, the area between the price lines and the market demand curve will provide a reasonably accurate measure of the benefits from the price change.

The same procedure as that just outlined can be used to measure the benefits of a price change for more than one price. Hotelling (1938) provided a generalization of the consumer's surplus measure to variations in more than one price, proposing a line integral

[1] Preference are said to be homothetic, if, for some normalization of the utility function, doubling quantities doubles utility. Drawing analogy with production theory, preferences are said to be homothetic if utility can be produced under constant returns to scale (Deaton and Muellbauer, 1980).

$$\Delta MCS = -\int_{p_i^0}^{p_i^1} \sum_i (p,I) dp_i$$

However, the measure of total benefit from multiple price change should be path-independent: because the prices may actually change simultaneously, the order in which we change them to calculate the benefit should not affect the total benefit figure. This will hold if and only if:

$$\frac{\partial x_i}{\partial p_j} = \frac{\partial x_j}{\partial p_i}, \; i \neq j$$

i.e. the cross effect of price changes on demand are equal. Typically the cross price effects are the sum of the income effects and the cross-substitution effect. Note that, since in the measurement of both CV and EV the former effect was assumed zero, the cross price effect consist solely of the cross-substitution effects, which are in fact equal. This can also be shown by:

$$\frac{\partial h_i(p,u)}{\partial p_j} = \frac{\partial(\partial e/\partial p_i)}{\partial p_j} = \frac{\partial^2 e}{\partial p_j \partial p_i} = \frac{\partial^2 e}{\partial p_i \partial p_j} = \frac{\partial(\partial e/\partial p_j)}{\partial p_i} = \frac{\partial h_j(p,u)}{\partial p_i}$$

The problem so far is therefore that the correct measurement of welfare changes relies on the Hicksian demand functions. Neither utility nor compensated demand functions can be observed. Several studies for instance (Burns, 1973; Seade, 1978; Willig, 1976), provide formulas for the maximum error involved in approximating CV and EV by the Marshallian measure. Willig (1976) shows that the relative error is given by $\eta \Delta MCS/2I$, where η is the income elasticity of demand. This shows that ΔMCS may be a good approximation as a benefit measure, provided price variations are small and the consumption of the corresponding goods and services are relatively insensitive to income level. Moreover, there are methods of calculation for CV and EV based on the knowledge of uncompensated demand functions (Vartia, 1983).

More recently, Jara-Diaz and Videla (1990) have presented an approach to calculation of the Hicksian measures of welfare changes (CV and EV) directly from market demands.

Their derivation starts from the definition of CV (and EV) expressed as differences in the expenditure function, where:

$$CV=e(p^0,u^0)-e(p^1,u^0)$$

The expenditure function $e(p^1, u^o)$ can be approximated through a second order Taylor expansion from $e(p^o, u^o)$:

$$e(p^1,u^0)\approx e(p^0,u^0)+\sum_i \left.\frac{\partial e(p,u^0)}{\partial p_i}\right|_{p^0}\Delta p_i+\frac{1}{2}\sum_i\sum_j \left.\frac{\partial^2 e(p,u^0)}{\partial p_j \partial p_i}\right|_{p^0}\Delta p_i \Delta p_j$$

where $\Delta p_i = p_i^1 - p_i^o$. Using the derivative property $\partial e/\partial p_i = h_i$ then:

$$CV\approx -\sum_i h_i(p^0,u^0)\Delta p_i-\frac{1}{2}\sum_i\sum_j \left.\frac{\partial h_j(p,u^0)}{\partial p_i}\right|_{p^0}\Delta p_i \Delta p_j$$

The Slutsky equation relates the Hicksian and market demands and is given by:

$$\frac{\partial x_j(p,I)}{\partial p_i}=\frac{\partial h_j(p,u)}{\partial p_i}-\frac{\partial x_j(p,I)}{\partial I}x_i(p,I)$$

Therefore CV can be expressed by in terms of the market demand by substituting by the Slutsky equation and, given that $h_i(p^o,u^0)=x_i(p^o,I^0)$, then:

$$CV\approx -\sum_i x_i(p^0,I^0)\Delta P_i-\frac{1}{2}\sum_i\sum_j \left.\frac{\partial x_j(p^0,I^0)}{\partial p_i}\right|_{p^0}\Delta p_i \Delta p_j$$

$$-\frac{1}{2}\sum_i\sum_j \left.\frac{\partial x_j(p^0,I)}{\partial I}\right|_{I^0} x_i(p^0,I^0)\Delta p_i \Delta p_j$$

This last equation is then proposed to be an approximation to CV after a price change, expressed only in terms of market demands, including the income effect.

They have also shown that the first two terms of the equation represent an approximation of ΔMCS (derived from Hotelling's line integral), provided second order effect of prices on demand are negligible and the Jacobian matrix of the vector of market demands evaluated at $\mathbf{p}^o$ is symmetrical (Jara-Diaz and Videla, 1990). Thus, they argue, that the approximated measure of CV has two components: the traditional welfare measure that would be used if income effect was not taken into account, and they term an income-induced welfare impact given by the last term in the equation.

A similar result can be obtained for the EV, by expanding the expenditure function around $(\mathbf{p}^1, \mathbf{u}^1)$.

3.4 The evaluation of user benefits in transport systems

3.4.1 The rule-of-half. The evaluation of user benefits in transport projects relies essentially on the rule-of-half measure. Nevertheless, is also one of the most controversial of all applications of the concept of consumer's surplus.

The notion was supported, at first, on a purely intuitive argument. There are many way of looking to the concept. The most obvious way is by dividing users in two classes: those travelling between the two zones (by the same mode), both before and after changes in cost have taken place, and the 'new' users (assuming that the change is a reduction in cost).

In order to illustrate let T^0 and T^1 denote the number of trips between a given pair of zones, by a certain mode at some initial and final situations represented by superscripts 0 and 1 respectively. Let C^0 and C^1 be the corresponding unit cost of those trips. As before let us arbitrarily assume that $C^1 < C^0$ (i.e. there is a reduction in cost) and therefore $T^1 > T^0$.

The number of travellers who continue making the same trip, T^0, will experience a benefit equal to the overall changes in cost. This is given by $T^0(C^0 - C^1)$. 'New' users, ($T^1 - T^0$ in number), however, cannot perceive a benefit greater than those ($C^0 - C^1$), nor less than zero. Then if a linearity assumption is made for the individual benefit of 'new' user's, the total consumer surplus variation can be written as:

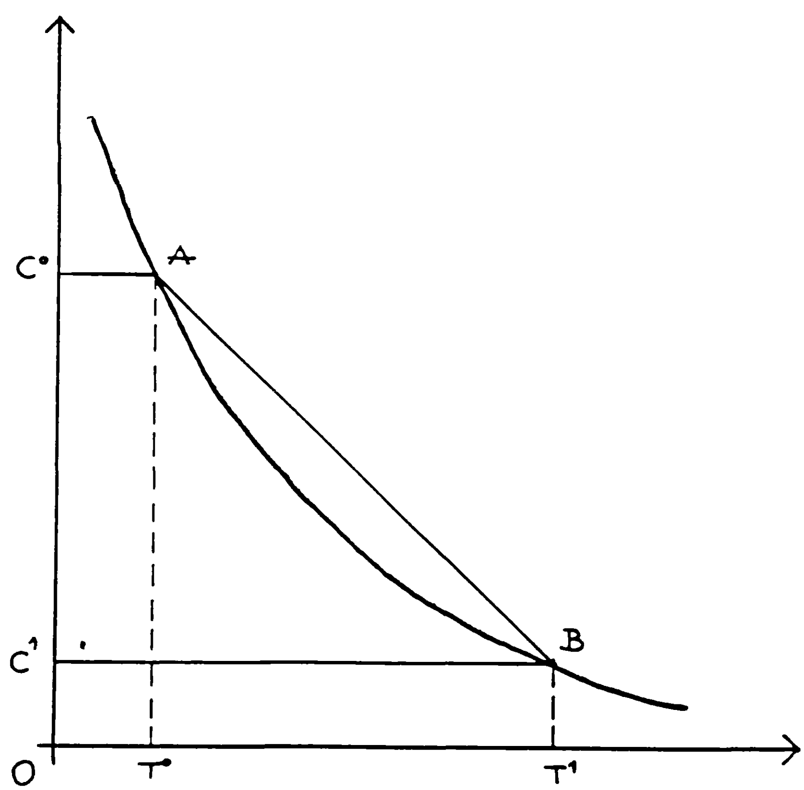
$$\Delta MCS = T^0(C^0 - C^1) + (T^1 - T^0)\frac{1}{2}(C^0 - C^1)$$

which simplifies gives the expression of the rule-of-half for one pair of origin-destination zone and a single mode:

$$\Delta MCS = \frac{1}{2}(T^0 + T^1)(C^0 - C^1)$$

This is illustrated in **figure 3.4.**

Figure 3.4 Rule-of-half: changes in costs, willingness to pay and consumer's surplus for an individual traveller



A different rational may be applied to this concept by referring to the idea of willingness to pay.

In practice one may refer to the maximum value an individual is prepared to pay for the journey as the worth of the journey to that individual, or the willingness to pay for that journey. As the price falls, more people are prepared to pay, and those who were actually prepared to pay a higher price get more of a bargain (i.e. the surplus, the difference between what they are willing to pay and the cost they are actually paying. Note the similarity with Marshall's definition earlier in this chapter).

This is also illustrated in the previous figure. The area under the curve to the left of the vertical line at T^0 is equal to the total worth (or the total willingness to pay) within the system at the initial price. Moreover, it is clear that the area of the rectangle to the left of that vertical line and below the horizontal line at C^0 (OC^0AT^0) is equal to the total cost of the journey made within the system (i.e. T^0 C^0).

When there is a price change, consumer surplus can be calculated by the changes in willingness to pay and the changes in cost within the system. This is the intuition behind the Marshal's definition.

Changes in number of travellers willing to pay costs of travel in the system as a result of reduction in prices, will come entirely from the contribution of 'new' travellers (a change in prices will not alter the willingness to pay of old travellers, but simple their surplus). Because they are 'new' they must be willing to pay for the journey less than its 'before' price (otherwise they would have travelled before) and not less than the 'after' price (or they would not be travelling now). The total they are willing to pay is given by the area T^0ABT^1. On average they can reasonably be supposed to value it at the mean of the old and new price. Change in willingness to pay is then given by:

$$\Delta WTP \approx (T^1 - T^0)\frac{(C^0 + C^1)}{2}$$

and the changes in cost by:

$$\Delta C = T^1C^1 - T^0C^0$$

With that, the rule-of-half is easily obtained by subtracting the changes in willingness to pay and the changes in cost within the system. Hence, the formula is reproduced:

$$\Delta MCS = \frac{1}{2}(T^{0} + T^{1})(C^{0} - C^{1})$$

The same concept can be extended the one-journey analysis to a multi-journey analysis for different modes **m** and income categories **k**, where the rule-of-half is obtained by:

$$\Delta MCS = \sum_{i}\sum_{j}\sum_{m}\sum_{k}\frac{1}{2}(T^{1}_{ijmk} + T^{0}_{ijmk})(C^{1}_{ijmk} - C^{0}_{ijmk})$$

The main reason for estimating separately changes in cost is that it identifies the changes in consumption that takes place. This has direct implication for non-users, as for example a reduction in fares may increase or decrease expenditure on public transport (i.e. revenues) depending on the particular elasticity of demand and hence the operating surplus or deficit of the system. These changes in turn will represent both part of the benefit to users and part of the cost to non-users, in opposite direction. Beardwood and Swain (1989) also advocate that there are a few advantages of looking at the differences in willingness to pay and costs separately, since cost may be perceived and unperceived, as well as they may represent resource and non-resource cost according as to whether resources are or are not consumed when the costs are incurred. In addition, as they argue, "money has differing values to different people. In particular, to the consumer of goods subject to some (average) tax rate the spending power of money is effectively reduced by the rate".

The formula for the rule-of-half is though equally obtained by aggregating benefits of 'old' and 'new' users or by subtracting changes in cost from changes in willingness to pay. Nevertheless, as it is stated by Jara-Diaz and Farah (1988), "all of these developments and reasoning contribute to give a sounder theoretical base to the rule-of-half, but to date, it still retains most of the intuitive base of its beginning".

Williams (1976) brought strictness to the derivation. Williams' derivation starts from Hotelling's line integral. Since the measure of total benefit from multiple price change should be path independent, Williams first assume that the cross effects of a price change for two different origin-destination pairs are equal. Provided that this integrability condition hold, one can arbitrarily choose an integration path, because the value of Hotelling's integral would be unique.

The derivation is reproduced by Jara-Diaz and Farah (1988). It is indicated that the rule-of-half is favoured as good approximation of user benefits by the absence of second (or higher) order effects of fares on demand, and by smallness of variations of fares or perceived user costs.

The rule-of-half as a measure of user benefit in most strategic transport planning models has, however, been subject to constant reappraisal.

Williams (1977) argued for instance that "the rule-of-half measure used to determine user benefit is not only computationally inefficient, but also its marginal basis renders it inappropriate for assessing the economic value of large numbers of transport systems which involve the introduction of new facilities. In contrast to the common method of extracting user benefit after the forecasting process, the composition of optimality which underpins the behavioural model allows the economic evaluation measures to be extracted directly from the calculations performed during model implementation. For urban transport planning models this distinction is between the assessment of benefits at the trip generation stage rather than after the assignment sub-model. The resultant measure lays emphasis on quantities commonly interpreted as accessibility indices or rents rather than on movement costs in the conventional measure" (Williams, 1977).

More recently, Beardwood (1990) looks at the measure of user benefit in constrained and congested situations. She argues that much travel takes place in situations of limited capacity and, certainly in the assumptions of those modelling them, with constraints on the numbers of travellers who end their journeys in each of the destination areas. A simple example of this occurs when easier travel into (but not out of) a district forces those living there to make longer journeys than before without themselves receiving any increased benefit. Current practice associated with four-stage transport models, attributes more benefit to those 'unwilling' travellers than to those genuinely advantaged by the changes. In this circumstances she suggests that the use of traditional benefit formula can lead to several anomalies.

Using a simplified system consisting of two centres, within each of which travel is 'unimpeded', i.e. occurs at zero cost, and trip distributions calculated using a doubly constrained gravity model, Beardwood shows that changes in the number of travellers willing to pay will always be greater by those not enjoying the actual reduction in cost. This is shown using both the 'rule-of-half' and the Hotelling line integral.

In this respect she proposed a method of measuring the changes in the modified accessibility of a location in a way which reproduces the overall change in willingness to pay in a uniform situation and which satisfies commonsense requirements when constraints operate.

In summary, the rule-of-half can be seen as a simple and operational tool, since it can be applied even without the knowledge about the underlying demand function. However, the rule-of-half either intuitively or strictly, is derived directly as an approximation to the least rigorous form of money valuation of utility: the Marshallian Consumer Surplus. Thus its validity requires the assumptions behind the MCS i.e. that the marginal utility of income is constant across the population and that cross effect of price changes on the market demand are equal.

3.4.2 An alternative approach. Alternatively, assuming that a demand model has been estimated at the level of distribution or modal split or a combination of both, then many possibilities for the calculation of user benefit arise. It is clear that the calculation of user benefits, will depend not only on the strictness behind the derivation of welfare measures, but also on the quality of the demand model itself. Of course, one can always choose the rule-of-half formula, using the demand model only to predict equilibrium states.

A second possibility is to use direct integration, i.e.:

$$\Delta MCS = \sum_{i=1}^{I} \sum_{j=1}^{J} \int_{0}^{1} T_{ij}(\sigma)(C_{ij}^{1} - C_{ij}^{0}) d\sigma$$

This requires the value of the line integral version of ΔMCS to be unique, and then the linear path of integration yield the desired results.

Another possibility is to look for an indirect utility function V which satisfies Roy's identity:

$$T_{ij} = -\frac{\partial V}{\partial C_{ij}} \bigg/ \frac{\partial V}{\partial I}$$

From the indirect utility function, the expenditure function can be obtained, from which measure of welfare such as CV and EV can be derived.

The actual form to be chosen for valuing user benefits will depend upon the form, assumptions and derivation of the demand model. Nevertheless, since the early stages of transportation planning process, demand models have evolved considerably. The fundamental limitations of traditional demand models and the framework within which they are applied have being subjected to considerable reappraisal and constant criticism. Williams (1977) for instance, argued that "models used in transportation studies are, without exception, inconsistent with the theory of choice, and are thus subject to mispecifications errors".

Transport demand models can now take different forms and specification. A widely used method of generating travel demand and activity location models is that proposed by Wilson (1967, 1970) based on the concept of entropy, in which the most probable distribution of trips, is determined subject to any known constraints. The model, embodied in many strategic transport model, may be written in a form such as:

$$T_{ijn} = A_{in} O_{in} B_j D_j e^{-\alpha_n c_{ijn}}$$

and it is obtained by maximizing an objective function of the following structure, or a monotonic transformation of this expression:

$$G = -\sum_{n=1}^{N}\sum_{i=1}^{I}\sum_{j=1}^{J} T_{ijn}\left[\ln\frac{T_{ijn}}{O_{in}D_j} - 1\right]$$

subject to the trip end constraints

$$\sum_{j=1}^{J} T_{ijn} = O_{in}$$

$$\sum_{n=1}^{N}\sum_{i=1}^{I} = D_j$$

and the cost constraints

$$\sum_{i=1}^{I}\sum_{j=1}^{J} T_{ijn} c_{ijn} = C_n$$

where T_{ijn} is the number of trips between zones **i** and **j** by person of type **n**, usually categorised by car-ownership. This is a model for distribution of trips by people of different types experiencing different costs, without estimating modal split. Further elaboration enables modal split to be incorporated.

The parameter α_n is the Lagrange multiplier associated with the cost constraint and can be viewed as the population sensitivity of people of type **n** to transport cost. Further lagrange multipliers or dual variables associated with the trip end constraints will be denoted by ϕ_{in} and γ_j. They do not appear explicitly in the model formulation, but can be interpreted in terms of user benefit.

The methodology, which may be applied with equal validity at various levels of spatial aggregation, is characterised by the lack of assumption made concerning the decision making process at the level of the individual.

During the 1970s there was a considerable interest in the derivation of user benefit measures from the gravity type travel demand models such as the one just described. Neuberger (1971) derived a non-marginal benefit measure for the singly-constrained gravity model. The result was further extended to a general class of spatial interaction and modal split models by Williams (1976), who showed that to a good approximation, under an assumption of fixed α_n, the change in user benefit between situations denoted by the superscripts **0** and **1**, and differing only in respect to of the costs c_{ijn} is given by:

$$\Delta MCS = \sum_n \frac{1}{\alpha_n} \sum_i O_{in}(\phi_{in}^1 - \phi_{in}^0) + \frac{1}{\bar{\alpha}} \sum_j D_j(\gamma_j^1 - \gamma_j^0)$$

when demand is given by the double constraint gravity model outlined above. α may be taken as the weighted mean:

$$\bar{\alpha} = \frac{\sum_n \alpha_n \sum_i O_{in}}{\sum_n \sum_i O_{in}}$$

The equation is an exact result when the parameters α_n are equal.

Williams also showed that the rule-of-half to be a an approximation to the result, the latter being valid for arbitrary changes in transport cost matrix.

The result indicates that specification of transport supply in terms of costs of the appropriate form allows extraction of the benefit measure from a high level in the model - in this case from the accessibility or balancing factors of the distribution model rather than after the assignment stage. This, as he argues, "is not an indication that the assignment stage is superfluous to the evaluation process. What is assumed is that the dual variables are computed with level-of-service variables appropriate to the state in which demand and supply are in equilibrium. Note also that here the calibration and implementation of the model in the forecasting phase, proceed from the route choice model to the generation stage rather than the reverse" (Williams, 1977).

The result was further generalised by Champernowne et al (1976) who have shown that the measure of benefit may be given by:

$$\Delta MCS = \frac{1}{\alpha}(G^1 - G^0) + (C^1 - C^0)$$

which implies that the change in total surplus is equal to the total cost change to all types of people plus the difference, scaled to money units by α, between the objective function G evaluated in the initial and final cost states (Champernowne et al, 1976), which, as they have also shown, reproduces Williams results.

These expressions links the entropy concept with consumer surplus, assuming that the dual variable α does not depend on costs (c_{ijn}) as is usually done.

The entropy concept is attractive from the point of view of demand estimation. The probability distribution obtained by maximizing entropy is nevertheless, as Wilson (1970) has pointed out, that which makes the weakest assumption consistent with what is known and reflected in the constraints. The method can be viewed as a statistical aggregation procedure, and trip variability may be considered to arise from a number of different sources (for a good description of a number of sources variability that have considerable influence on, and implication for, the formulation of travel demand models and their forecasting ability see Williams (1977)). However, in terms of user benefits the entropy formulation does not fit easily into the idea of choice and utility presented previously.

At the early development stages of the transportation planning process it was recognized that trip behaviour, when aggregated to the level of the zone (or other spatial unit), showed discernable patterns which bore statistically significant correlative relations with land-use, socio-economic and transport system level-of-service variables. It therefore seemed not unreasonable to base forecasts on trip group pattern rather than to deal directly with the large amount of variability associated with the behaviour of individuals or households. Williams (1977) argued that "the aggregate approach, while generating deceptively good results in terms of conventional goodness of fit statistics when applied to zonal data, frequently resulted, through loss of information arising from grouping, in models with poor explanatory power and forecasting ability.

3.4.3 Disaggregate approaches. In principle, a forecast of the demand at the macrolevel may be established by constructing a model at the microlevel and performing an aggregation process. Indeed, the family of discrete choice models represent a further area where estimates of the user benefits can be derived. There are however, two distinct approaches to the introduction of probabilistic choice mechanism: constant utility and random utility.

In the constant utility approach it is assumed that the values of utility are deterministic, but that the decision-making process is of a probabilistic nature. The probability measure may be interpreted as the proportion of a population, whose choice is characterized by the same vector of observable attributes, selecting the alternative, as a frequency of choice from repeated trials by a single person. The essential feature is that the decision making varies probabilistically over the population or for each trial.

In random utility theory each individual in the hypothetical population is assumed to select that alternative which offers him maximum net utility or surplus. If each choice were endowed with the same surplus value then the same alternative would be chosen by all members of the population. However, in general, the benefits and costs of available choices will be perceived differently. Because some of the attributes of any individual are unobserved, and because the valuation of observable attributes may be nonuniform, it is not certain which alternative will be selected by that individual. In short, this approach is characterised by a deterministic selection mechanism but the utility and/or cost of each alternative are regarded as random variables.

The uncertainty here is associated with the observer who attributes random components to the utility and cost functions - the traveller himself is, in theory, capable of rational choice, considered to choose optimally and consistently within his or her own frame of reference.

The computation of a consumer surplus measure of benefit which is fully consistent with the model generated within the random utility approach, has been expressed by Williams (1977) in terms of the change in the expectation of the value of the surplus.

The basic microeconomics behind disaggregate transport demand models is essentially the same as presented in **Section 3.2.** Following Jara-Diaz and Farah (1987), the problem of maximizing an utility function subject to some constraints should now however be solved in two steps. The first step is conditional on mode choice.

$$Max\ \ u(x_1,x_2,...x_n,x_d)$$

subject to

$$\sum_i p_i x_i \le I - c_d$$

with $x_i \geq 0$, and where x_d represents travel by a mode d that can be described by its characteristics $\mathbf{q}_d$, and $\mathbf{c}_d$ is the cost of using that mode.

The solution to the problem is now a vector of conditional demand functions $\mathbf{x}=\mathbf{x}^*(\mathbf{p},\mathbf{I}-\mathbf{c}_d,\mathbf{q}_d)$ which can be replaced in the utility function yielding a conditional indirect utility function.

$$u[x^*(p,I-C_d,q_d)] = V(p,I-c_d,q_d)$$

As the mode should be chosen from a given finite set M, for the second step the individual maximizes utility choosing $\mathbf{b} \in$ M such that:

$$V(p,I-c_b,q_b) > V(p,I-c_d,q_d)\ \ \forall d \neq b\ ;\ d \in M$$

It should be noted that Roy's identity also holds for the discrete goods represented by travel by the various modes where:

$$x_b(c_b,I) = -\frac{\dfrac{\partial V}{\partial c_d}}{\dfrac{\partial V}{\partial I}} = \begin{cases} 1 & \text{if } d=b \\ 0 & \text{if } d\neq b \end{cases}$$

which is the individual market demand (i.e. indicates of use or non-use) for mode b (1) and for other modes (0).

The conditional indirect utility function V_i can be expressed as the sum of function u_i of the observed variables c_i and $\mathbf{q}_i$, and a random error term ε_i. Thus, the probability of choosing mode d is given by the probability of $u_d + \varepsilon_d$ being greater than $u_b + \varepsilon_b$, $\forall b \neq d$. The actual form taken by that probability is dependent on the distribution assumed in the random error term.

Different measures of user benefits have been derived on the same basis (Williams, 1977; Small and Rosen, 1981; Sasaki, 1982). These measures have been discussed further by Jara-Diaz and Farah (1987), leading on to the advances described in **Section 3.5.**

3.5 The goods-leisure trade-off and the valuation of user benefits

In disaggregate work trip mode choice models the wage of the worker often enters as explanatory variable. Conceptual and methodological problems arise, however, concerning the use of wage rates as explanatory variables. First, it is not immediately evident that wage should be allowed to enter as explanatory variable. In the neo classical theory of consumer behaviour, wage rates are used as constraint parameters on the utility maximization not in the utility function itself. Second, if wage is to enter the model, how should it be incorporated. Often, the cost of travel is divided by the worker's wage, representing the way which travellers perceive their costs. In other cases however, travel time is multiplied by the worker's wage reflecting the presumption that workers with higher wage are more concerned with travel time savings.

Train and McFadden (1978) analyzed the use of wage in mode choice models, and showed how different assumptions regarding the worker's indifference mapping between goods and leisure lead to different method of entering wage.

Work trip mode choice models are derived from the neo-classical theory of trade-off between goods and leisure. The problem can be stated in terms of an individual who chooses the consumption of goods (G) and available time or leisure (T_a) subject to constraint on his overall income and time availability (the same notation used by Jara-Diaz and Farah (1987) is adopted here). More formally, it may be expressed for a given choice of mode **i** for travel to work as:

$$Max \quad U(G,T_a)$$

subject to

$$G+B.c_i=w.W+E$$

$$T_a=T-W-B.t_i$$

where:

T time period

W is the working hours in period T.

w the individual's wage rate

E unearned income

B number of trips to work in period T.

and c_i and t_i are the cost and time of a trip to work by mode i.

The number of hours worked played a key role in the analysis since both G and T_a can be expressed in terms of W from the constraints; utility is then a direct function of the variables which are presumably under the control of the individual i.e. the number of hours worked and transport mode. Then the overall maximization may be solved in two steps:

$Max_i\{Max_W U[G(W,c_i),T_a(W,t_i)]\}$

Three forms of the utility function $U(G,T_a)$ for an individual are presented by Train and McFadden, the Cobb-Douglas function $U=K.G^{1-\beta}T_a^{\beta}$ being the most general. Note that the Cobb-Douglas function is in practice very restrictive and implies a unit elasticity of substitution between goods and leisure.

The first maximization yields:

$$U_1 = K((1-\beta)^{1-\beta}\left[w^{-\beta}(E-B.c_i) + w^{1-\beta}(T-B.t_i)\right]$$

which is the conditional indirect utility function, to be maximized through modal choice.

The individual will choose the mode which maximizes utility (i.e. $U_i \geq U_j$ for all $j=1,2...n;\ j\neq i$) and only terms in c_i and t_i differ between modes, so that the maximand is proportional to:

$$V_i = -w^{-\beta}.c_i - w^{1-\beta}.t_i \quad for\ 0\leq\beta\leq 1$$

$$V_i = -c_i - w.t_i \quad for\ \beta\rightarrow 0$$

$$V_i = -\frac{c_i}{w} - t_i \quad for\ \beta\rightarrow 1$$

In other words, when β approaches 0, time is multiplied by wage, whereas when it approaches 1, cost is divided by wage. For values of β between 0 and 1, the choice is an empirical issue[2].

More general mode choice models can be derived from the above solution. These are presented in Train and McFadden (1978) and will not be discussed here in great detail.

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[2] Work trip mode choice models were estimated to obtain the value of the β parameter of the Cobb-Douglas function. Empirical work suggested a value between 0.7 and 1 (see Train and McFadden, 1978).

The results however, as presented by the authors, are straightforward:

(i) Different components of time and cost can enter the 'representative' utility function with different coefficients. Each weighted time component is multiplied by $w^{1-\beta}$, and each weighted cost component is divided by w^{β}.

(ii) Socio-economic variables and mode specific constants can enter the 'representative' utility function. These variables are to be interpreted as proxies for unobserved cost or time components.

(iii) An error term can be introduced into the analysis so that the model is probabilistic.

The methodology presented can be used to obtain more rigorous forms of valuation of users' benefit at individual level. The equivalent variation EV was defined in **Section 3.3.1** as the amount of money which would have to be given to the consumer when he faces the conditions prevailing before an improvement is made to make him as well off as he would be by facing the improved condition with his initial income. Formally,

$$U(wW+E-B.c_{d1},T-W-B.t_{d1})=U(wW+E-B.c_{d0}+EV,T-W-B.t_{d0})$$

where d0 and d1 represent the mode chosen before and after the improvements respectively, and the values of EV relates to the period T.

Solving for EV,

$$EV=B(c_{d0}-c_{d1})+w.B(t_{do}-t_{d1})$$

The EV is thus equal the money savings plus the time savings multiplied by the wage rate (value of time). Therefore, the EV is directly given by the change in V_i and is independent of β (the elasticity of the utility with respect to time).

The methodology presented however, makes two basic assumptions, namely that income is endogenously determined (i.e. that the individual chooses how many hours to work depending on his wage rate) and that the marginal utility of income is constant across individuals. As argued by Hausman (1981), it is supposed constancy or near constancy of the marginal utility of income which has often served as a basis for using Marshallian consumer's surplus as a measure of welfare change. This though, will only provide a reasonably accurate measure of benefits for marginal price changes and if transport expenditures represent a small proportion of the consumer's expenditure. These assumptions nevertheless, may not hold in most developing countries and hence some of the arguments may easily be contested.

The basic framework has been reconsidered by Jara-Diaz and Farah (1987). The usually accepted assumptions on the role of income in transport demand modelling have been changed, in order to better account for the reality within developing countries. Firstly, income (I) is treated as exogenous - neither are working hours under the individual's control, nor is additional salary possible - and secondly, the proportion spent on transport is not negligible.

If $U(G,T_a)$ is assumed to take the generalized Cobb-Douglas form, the problem can be stated:

$$Max \quad U(G,T_a) = K.G^{1-\beta}T_a^{\beta}$$

subject to

$$G = I - B.c_i$$

$$T_a = T - W - B.t_i$$

The overall indirect utility function is therefore obtained:

$$U^*(c_d,t_d,I) = K(I - B.c_d)^{1-\beta}(T - W - B.t_d)^{\beta}$$

where (c_d,t_d) are the characteristics of the selected alternative. Note that since I (and therefore W) are assumed to be fixed the first optimization is no longer necessary.

Since the indirect utility function is monotonically increasing in income while the expenditure function is monotonically increasing in utility, either one can be inverted to derive the corresponding function. The expenditure function can therefore be expressed:

$$e(c_d,t_d,U)=\left(\frac{U}{K}\right)^{\frac{1}{1-\beta}}(T-W-B.t_d)^{-\frac{\beta}{1-\beta}}+B.c_d$$

The exact measures of individual welfare changes may be derived through the expenditure function. By definition:

$$EV=e(c_{d0},t_{d0},U_1)-e(c_{d1},t_{d1},U_1) \quad and$$

$$CV=e(c_{d0},t_{d0},U_0)-e(c_{d1},t_{d1},U_0)$$

and hence:

$$EV=(I-B.c_{d1})\left[\frac{T-W-B.t_{d1}}{T-W-B.t_{d0}}\right]^{\frac{\beta}{1-\beta}}+B.c_{d0}-I$$

$$CV=I-(I-B.c_{d0})\left[\frac{T-W-B.t_{d0}}{T-W-b.t_{d1}}\right]^{\frac{\beta}{1-\beta}}-B.c_{d1}$$

Expressions for the value of time (VT) and the marginal utility of income (λ) may also be derived:

$$VT=\frac{\partial U_i}{\partial t_i}\bigg/\frac{\partial U_i}{\partial c_i}=\frac{\beta}{1-\beta}.\frac{I-B.c_i}{(T-W-B.t_i)}=\frac{\beta}{1-\beta}.\frac{G}{T_a}$$

$$\lambda=\frac{\partial U_i}{\partial I}=K(1-\beta)\left[\frac{T-W-B.t_i}{I-B.c_i}\right]^{\beta}=K(1-\beta)\left(\frac{T_a}{G}\right)^{\beta}$$

The implications of the expressions above may be summarized:

(i) In the valuation of user benefits, time savings act now as a 'multiplier' of disposable income (I - $B.c_i$) instead of entering as an additive way. Note also that β plays an explicit role.

(ii) The value of time is negatively correlated with travel costs and positively with travel time. The value is related to $I/(T - W)$ rather than I/W.

(iii) As expected the marginal utility of income decreases with income, whereas it increases with available time. Assuming λ independent of travel time and travel cost is roughly consistent with this expression only if both of these variables are relatively small with respect to (T - W) and I respectively.

The approaches of Train and McFadden and Jara-Diaz and Farah have both been used in disaggregate work trip modal choice models. The reformulation of modal utility to make it income-sensitive as proposed by Jara-Diaz, has been applied in empirical work and led to the specification of the expenditure rate, which is defined as income divided by non-working hours or disposable time. (see Jara-Diaz and Ortuzar, 1989).

Empirical studies carried in Santiago, Chile have shown that expenditure rate models completely dominate the wage rate specification, both in statistical and economic interpretation. This indicates that income should not be treated as a proxy for wage rate or taste, but as (exogenous) purchasing power (Jara-Diaz and Ortuzar, 1989).

In addition, Jara-Diaz and Videla (1989) have developed a methodology to detect the presence of income effect in mode choice from model estimation. In their analysis, they have expanded (through Taylor approximation) the usual linear specification (which is independent of income) of the utility function in terms of cost and travel time, introducing a square-in-cost term. In this specification the marginal utility of income is a function of income. Modal choice models were estimated separately for each income category using the same set of data from Chile. The results show that mode choice does depend on the level of individual income. Estimated coefficients were not only significant but had the expected signs and, in absolute values, decreased with incomes. Moreover, as expected, the marginal utility of income decreases in the ratios 6:3:1 while income increases in the ratios 1:2:3 (Jara-Diaz and Videla, 1989).

Finally, Jara-Diaz and Videla (1989) have compared different measures of user benefits from discrete modal choice models using two different models derived from the data. One of the models follows the framework derived from Train and McFadden and modal utility is specified by:

$$V_i = \alpha_i + \beta \frac{c_i}{w} + \gamma t_i$$

where the individual wage rate (w) is used to represent the way travellers perceive their journey cost. The second model correspond to the reformulation proposed by Jara-Diaz. The specification, where g is the expenditure rate, is given by:

$$V_i = \alpha_i + \beta \frac{c_i}{g} + \gamma t_i$$

Both models were estimated using the three components of travel time (in-vehicle, walking and waiting) and the socioeconomic variables sex and number of cars per licensed driver in the household. Different measures of user's benefit for the two models were also derived based on approximations of the ΔMCS and CV.

Comparisons were made for changes in cost for a single mode and simultaneous changes in cost for the various modes. In the case of changes of cost for a single mode, estimated benefits with the non-income sensitive models are lower for the modes associated with low income users. Nearly identical outcomes resulted for the MCS estimated for the expenditure rate model and the measures of CV calculated through the expenditure function.

With simultaneous changes in costs however, it was found that the various measures of MCS and CV can yield large differences in values. In particular, even differences in sign may be observed for MCS and CV estimated with the wage rate model.

The main conclusion is that the MCS measure applied to mode choice models that are not sensitive to income appears to underestimate the benefits caused by projects which particularly favour low income users. It appears that when income is better accounted for even the Marshallian measure indicates benefits more properly (Jara-Diaz and Videla, 1989).

3.6 Conclusion

This chapter has examined in the context of transport provision one of the most controversial economic concepts, namely consumer's surplus. A theoretical account of the subject is given, within the framework established by the neo classical theories of welfare and consumer choice. Drawbacks associated with the measurement of welfare changes, as well as the assumptions behind it have also been discussed.

Most of the applied work in transport project appraisal relies on the 'rule-of-half' as an adequate measure of changes in welfare. Nevertheless, as stated by Jara-Diaz and Farah (1988), the rule-of-half is born either intuitively or strictly, directly from the least rigorous form of money valuation of utility: the Marshallian consumer's surplus. A general departure from the rule-of-half leads to more rigorous forms of user benefit calculation, which consider a demand model explicitly in their derivation, thus including the information provided by the different elements involved in the economic phenomenon of transport demand. Furthermore, explicit derivation of such rigorous welfare measures permits a better interpretation of benefits in terms of demand parameters and their underlying meaning. However, except in isolated experiments the rule-of-half has not been sufficiently compared with its alternatives.

On the other hand, exact or rigorous welfare measures cannot be better than the underlying demand model. Thus, demand specifications which do not reflect the actual process of choice may yield results which are as inadequate as those obtained directly from approximations.

Finally, aggregation of demand may well be a necessary step in travel forecasting, but aggregation of benefits for project evaluation will always carry with it implicit value judgements, since the (money equivalent) utility of various individuals or groups of individuals has to be added. For practical purposes, reporting user benefits in a disaggregated fashion seems to be an adequate compromise, whether user benefits are approximated by the rule-of-half or whether they are calculated more rigorously.

In this respect, two different frameworks have been presented in this chapter, in which the measures of both user benefits and the value of time are derived from the theory of trade-off between goods and leisure. The results of using these measures are investigated in the research described in this thesis, where aggregate measures of CV, EV and the standard consumer surplus are calculated for realistic scenarios based on data for London, and the estimates of welfare benefits associated with each income group according to each of the measures proposed are compared. Moreover, the ratios of marginal utility of income and their implications as weighting factors for obtaining an aggregate measure of welfare benefit are also examined.

CHAPTER 4
SOURCES OF DATA FOR THIS RESEARCH

The objective of this chapter is to define and describe the data set used throughout this research. The main source of this data is output matrices of journeys and travel costs under alternative policies tested in the London Assessment Studies from the London Transportation Studies Model.

The London Assessment Studies were a collection of studies commissioned by the Secretary of State for Transport to investigate transport-related problems in some of the busiest part of London. The studies have examined extensively different transport investment proposals, including highway and rail improvements. Some of the result of the studies have led to the specification of general requirements and modelling inputs for testing three alternative policies by means of the Interim London Transportation Studies (LTS) Model (MVA, 1987b).

The LTS Model is a conventional four stage transport model of the kind that evolved from land-use and transport planning studies undertaken in the 1960s. Outputs from the LTS Model have provided much of the basis of objective examinations of implications of transport policy for the Greater London area over the past two decades.

The Model was calibrated using the Greater London Transportation Survey of 1981 (GLC, 1985a). This was the third in a series of interview surveys carried out since the 1960s to assess changes in travel behaviour and the effect of transport policies within the Greater London area. It is a comprehensive source of information, which provides a data base often used for transport modelling and evaluation.

The main features described in this chapter are as follows.

Initially the general background of the Survey is described, as it has provided the basic information on income distribution and trip patterns. The main intention throughout has been to provide the information about this extensive data set that is required for the present study, without going into a more detailed description.

The main features of the LTS Model are given in **Section 4.2**. The objective of this section is threefold. First, to provide a broad understanding of the model itself; second, to highlight specific features which should be considered for the construction of the scenarios required for this research; and third to understand the underlying demand models which have generated the output matrices used in the evaluation of user benefits. The author does not have direct experience with the model, and this description is generally based on a technical audit prepared for the Department of Transport by the MVA Consultancy (1987a) and the report on the Interim Model (MVA, 1987b). The LTS Model is being maintained by MVA, and they are constantly incorporating enhancements to the specification. Nevertheless this description relates to the State the model was in by the time the tests of policies from the London Assessment Studies were carried out.

Finally, the London Assessment Studies are briefly described in the last section, together with the specifications of general requirements for the LTS model forecasts for 'do-minimum', highway, and rail investment policies.

4.1 The Greater London Transportation Survey of 1981

The Greater London Transportation Survey (GLTS) of 1981 comprised a set of surveys conducted by the Greater London Council to assess person and vehicle movement within Greater London and Districts around its periphery.

The home interview is one of these surveys, covering a representative sample of 38573 households in the area. The data resulting from the home interview survey is organized in four different hierarchical files as follows:
(i) the **household** file contains one record for each household from which a response was obtained. The record contains information for the household including home location, size, number of employed members, income, car ownership and expansion factors;

(ii) the **person** file holds all the individual information such as working status, season tickets, and type of work. It contains one record for each person in each household and comprises a representative sample of 91935 persons;

(iii) journey characteristics are included in the **journey** file. Whilst each record in all the other files is constructed directly from one record in the survey data, the journey file is derived by a process termed 'trip linking'. Essentially this combines recorded stages into journeys, a journey being defined as a set of stages where neither the first origin purpose nor the final destination purpose is 'change mode'. The file contains one record for every journey recorded by each person in each household and amounts to 266618 journeys;

(iv) the **stage** file comprise one record for each stage of every journey.

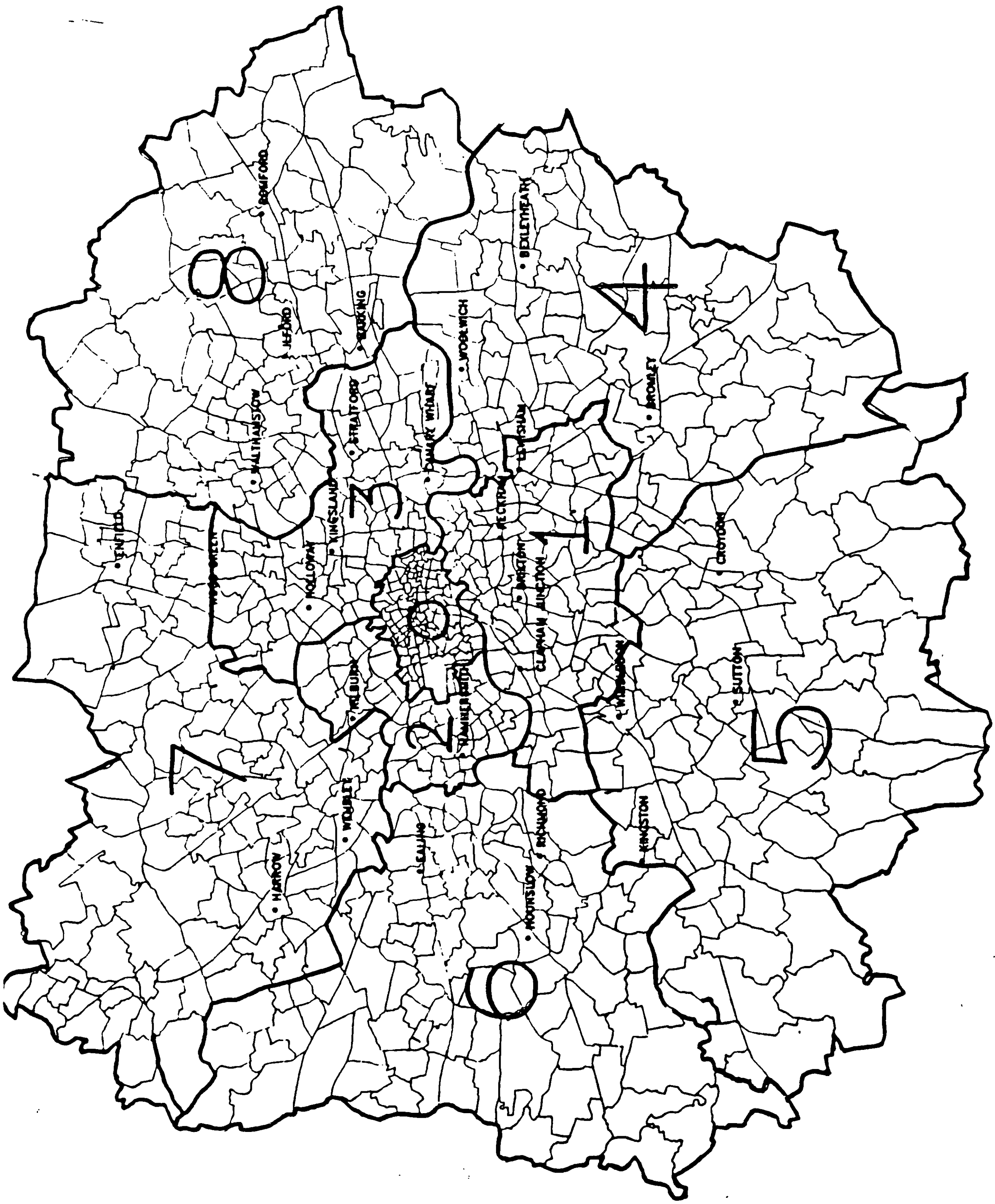
A hierarchical zoning system is employed by the Survey, which divides the GLTS area into 925 zones, 227 traffic districts and 9 sectors. The sectors are further grouped into central, inner and outer areas comprising Sector 0, Sector 1-3, Sector 4-8 respectively as illustrated in **Figure 4.1**.

The data has been expanded to 2764626 households, 6810868 persons and 19905484 journeys. Hence, the sampling fraction was almost 1.5% for all categories taken together.

Various expansion factors were calculated in the survey. Expansion is the term used to describe the procedure that factors sampled household interview records to the population from which they were drawn (Stroud, 1974). A first round of expansion factors were calculated from the ratio of the number of private households present in the census and the number of successful interviews. For this purpose, Census Comparison Areas (CCA) were defined as the smallest area for which unique reference codes exist for both Census Wards and Sampling Wards, and an expansion factor was calculated for each CCA. These were then validated with both population and employment information from the Ward Library. The final expansion involves the calculation of adjustment factors (to correct for response bias) which are used to weight single interviews. For a description of the methodology, results and problems of expanding the 1971 survey see Stroud (1974).

Figure 4.1 The Greater London Transportation Survey Area

(Figure supplied by MVA)



In order to determine household and person characteristics for every reported journey within the survey area, all these three files were linked (matched), so that for each journey, information was provided on, for example, household income, car ownership, and work status. The resulting file enabled further investigation into the trip generation process and travel behaviour.

Household income is divided into twelve (12) different categories, defined as follows:

Table 4.1 Household Income Categories in the GLTS 1981 survey (1981 prices)

Category	Range of Incomes
1	less than £3000
2	£3000 - £3999
3	£4000 - £4999
4	£5000 - £5999
5	£6000 - £6999
6	£7000 - £7999
7	£8000 - £8999
8	£9000 - £9999
9	£10000 - £11999
10	£12000 - £14999
11	£15000 - £19999
12	£20000 or more

Almost 20% of otherwise successful interviews gave no information concerning income. Records which did not contain information on household income were subjected to a process of income patching. Essentially this process estimates income from two other variables - the socioeconomic group of the head of household and the number of employed residents. The method is described in Stroud (1974).

4.2 The London Transportation Studies Model

The Strategic Transportation Evaluation Model, STEM, (GLC, 1977 to 1986) was first assembled after the 1971 Greater London Transportation Survey. Later, with the 1981 survey, the model was recalibrated and restructured in order to take into account changes in travel behaviour and the relative importance of the different travel segments, and to take advantage of new developments in modelling (MVA, 1987b).

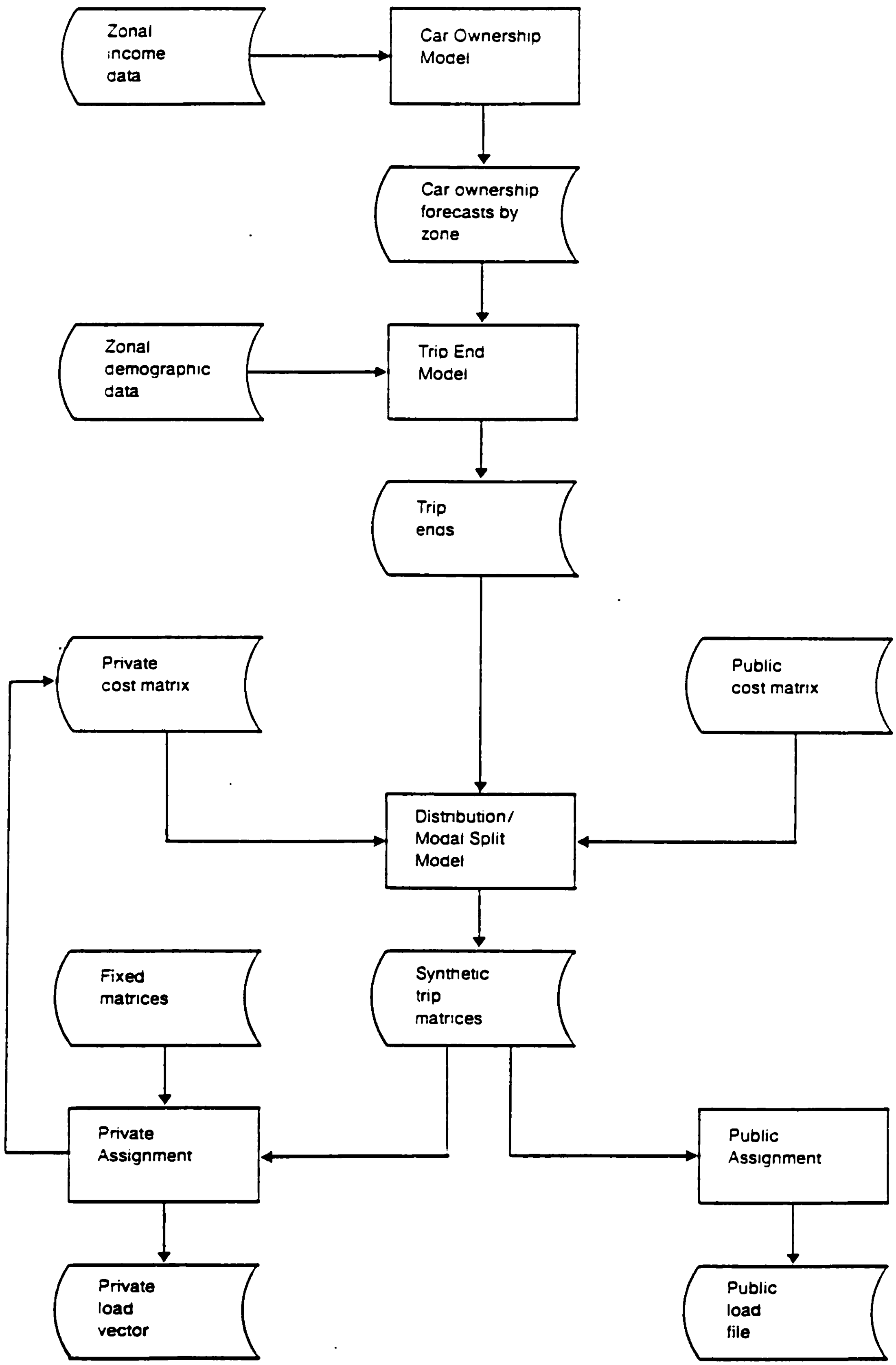
In 1987 the recalibration of the model with the 1981 data was completed and this was subject of a technical audit (MVA, 1987a). Some of the recommendations of the audit have since been implemented to provide the basis of the Interim London Transportation Studies (LTS) Model. The term 'interim' is appropriate in the sense that the model has been constantly revised in order to incorporate enhancements to the specification.

The LTS is a conventional aggregate model of the kind that evolved from land-use and transport planning studies undertaken in the 1960s. It represents the movement of people and goods by public and private transport along their respective networks between pairs of zones. The same zoning system as the one used for the GLTS is employed within the model. Locations outside the survey area are further represented by 118 cordon crossing points, of which 91 are for roads and 27 for railways.

The Model is divided into the traditional four stage process, which comprise trip generation (or production), trip distribution, modal split and assignment. The models are calibrated against travel patterns in the base year and then attempt to forecast future travel patterns on the basis of demographic, socioeconomic and transport level-of-service change. The general structure of the Model is presented in **Figure 4.2**.

Figure 4.2 General structure of the London Transportation Studies Model

(Source: MVA 1987a)



The following description generally follows the structure of the Model. It starts by describing the car ownership sub-model. The estimation of household income distribution required by the car ownership sub-model is also described together with underlying assumptions. Next the trip end model is described for work trips, home based and non home based trips. The doubly constrained gravity model used for distribution and modal split is described in the third part. The expression for generalised cost for private and public transport is presented separately. Finally, highway and public transport assignments are briefly described.

4.2.1 Car ownership model. Car ownership has been one of the most important factors affecting changes in travel behaviour and the demand for travel. It represent one of the major variables used to forecast trip production and the generation of travel, because it has such a large and direct influence on household travel behaviour and the level of household activities.

Car ownership has been traditionally associated with household income, although it is generally recognized that this relationship may not be stable over time. In fact, car ownership is affected by a number of elements including changes in fuel and car prices and in employment, as well as wider policies of car restraint, taxation and economic growth.

Nevertheless, most car ownership models have established some relation between household income and ownership levels.

The car ownership sub-model of LTS is a household based model to predict the number of households at each level of car ownership, given a distribution of household income. The basic assumption of earlier versions of the LTS car ownership sub-model was that the probability of a household owning a car (or two or more) was generally determined by the level of household income, and that, once price changes have been properly accounted for, these relationships remain constant through time. This may be expressed alternatively by saying that the relationships between income and car ownership change only as a result of the prices of new and used cars changing relative to each other, and to other commodities (Saunders and Smith, 1977).

For purposes of forecasting travel behaviour, the definition of ownership was taken to include all cars that are freely at the disposal of the household. However, since the relationships with income were initially defined only in terms of cars actually owned by the household, further correction was necessary to take into account other cars available to the household, in particular those provided by companies. This was done by applying a set of factors for the whole GLTS area, specific to income band, derived by Delgado-Contreras (1986).

Eldridge and Mogridge (1970) have argued that rates of depreciation have generally increased over time, implying that the price of used cars falls faster than that of new cars. Since lower income households tends to buy older cars, this gives them a differential price advantage. Thus, the probability of lower income households owning cars tends to increase over time, even without income rises. The variable income relative to car prices' has been termed 'car purchasing income'.

More recently, it has been recognized (MVA, 1987a) that car-ownership and income relationships are not stable over time, and the use of income growth alone will tend to underestimate the growth of car ownership. In addition, further observations (Bates, 1981) have indicate that income is not a sufficient determinant of car ownership and even correcting for 'car purchasing income' the growth in car ownership could not be properly explained. Comparisons have been made between 1971/1981 GLTS data (MVA, 1987a) and, although the upward shift in car ownership at given real income is clear, this cannot be accounted for by means of a car price effect, since car prices tended to rise over the period. According to MVA (1987a), however, unpublished work by Mogridge and Bates shows that in central areas, propensity to be car owning actually fell between 1962 and 1971, for given income, while it increased in the outer areas.

As a result of these inconsistencies and issues concerning the measurement and definition of car ownership, the forecasts from the LTS car ownership model have been controlled to the London-wide growth rates indicated by the Traffic Appraisal Manual

(TAM) (DTp, ongoing) forecasts, distinguishing the trends in single and multi car owning households. There are two parts to the process of controlling the LTS estimates. The first involves the application of the National Road Traffic Forecast income growth to the LTS income distributions. The second part requires the adjustment of the relationship between car ownership and income to ensure that the LTS forecasts are consistent with TAM.

The first step therefore is concerned with the estimation of the household income distribution. Household income is predicted by both TAM and LTS, but the method of modelling income distribution is somewhat different.

In TAM, a Gamma distribution is assumed for all households, whereas LTS considers households with and without employed members separately. Thus where the TAM future income distributions are determined by application of a single growth factor to the base year mean income, the LTS model requires both an estimate of how the incomes of household with employed members will rise, and assumptions of future distributions of income of households with no employed members.

In the LTS Model, for households without an employed person the distribution is held constant in real terms over time. This was believed to be in line with the prevailing government policies towards household benefits in general. For households with at least one employed person however, a log-normal distribution is assumed. Furthermore, the coefficient of variation of household income in each traffic district is assumed to remain constant over time while both the mean and standard deviation increase in line with income growth.

4.2.2 Trip end model. The trip end model forecasts for each zone separately the trip productions and attractions for work and non home based trips. The models are estimated through linear relationships either in a simplified form of category analysis (for trips based at home) or regression (the remainder).

In the context of the morning peak period, three types of trip defined. Work trips are defined as those starting from the person's home and ending at his work place. Other home based trips (OHB) are all non work trips starting from home. Finally, non home based (NHB) trips are all trips not contained in either of the previous categories and not ending at home. Trips ending at home are dealt with separately (see **Section 4.2.3**).

Car availability is the term used in the GLTS for whether or not a car is available to each person making a trip. In the 1981 household survey, each person was asked whether a car was normally available to them for making trip as a driver, passenger or both, and all the three categories were regarded as making 'car available' trips.

Home based trip production are estimated from a simplified form of category analysis separately for work and other home based trips. Household motorised[1] trip rates (for car available and non car available) are estimated in which households are classified by household car ownership, number of employed residents (in the case of working trips), family size (for other home based trips) and location (the trip rates vary between the 9 GLTS sectors).

Instead of a full categorisation of the household characteristics, a simpler 'main effects' model without interaction terms is used. The trip rate consists therefore of three parts: a constant term, a part dependent on the number of household cars, and a part dependent on the number of employed residents or family size. In forecasting the number of home based trip productions in a zone, these trip rates are summed over the households in the zone.

The trip attractions in each zone for journey from home to work are estimated from linear relationships with employment. Employment is disaggregated into three categories: office, manufacturing and others. Different relationships were obtained for zones in the central, inner and outer London sectors.

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[1] Motorised trips exclude walking and cycling as a main mode and also certain other types of trip which are represented in the fixed matrix (see section 4.2.3). The definition of motorised trip is common to both the trip end and the distribution/modal split model components.

The other purpose trip attractions (which includes both OHB and NHB trips) in each zone are estimated from linear relationships with employment (other than office and manufacturing) and the number of households. Again, different relationships were obtained in zones in the central, inner and outer London sectors. The proportion of NHB trips is then estimated from an aggregate regression model which depends on the total number of trips attracted to that zone.

Finally, NHB origins and destinations are assumed to be the same in each zone.

There are a number of inputs required for these models. The total number of households for each household size category and the number of employed members in the households, as required for each zone by the home-based production models, are estimated by linear relationship with the total population and the total number of employed residents in that zone respectively. Different relationships were obtained for zones in the central, inner and outer London sectors.

The outputs of the attraction models are balanced with productions by means of a single scaling factor for each type of trip. The scaling factors are calculated to balance the internal attractions with those productions not attracted to the cordon, separately for each type.

4.2.3 Distribution/Modal split model. The Distribution Modal Split model (DMS) is a doubly-constrained gravity model which operates simultaneously for a number of person types and modes. The model is calibrated to match both observed zonal trip ends (by person type) and the observed trip cost distributions (by mode and person type). In forecasting, the primary purpose of the model is to allocate the trip production of the trip end model to satisfy the trip attractions, taking account of the deterrent effect of trip cost (by mode). The model is calibrated and run separately for work trips and for the combination of Other and Non Home Base (OHB and NHB) trip. It is applied to the 3-hour morning peak period.

In order to represent internal trips, DMS use the data from the household survey only. Moreover, a limited number of calibration areas are considered (only 2 for internal trips) for which separate deterrence functions are defined.

It should be noted that not every trip is represented within the DMS, others being represented by the LTS 'fixed' matrix. There are eleven different trip types portrayed within the fixed matrix, with the largest contribution coming from light vehicles. Other components include trips to home (the reverse flow direction in the morning peak), cross-cordon trips, and taxi trips. The fixed matrix account to about 20% of the final private light vehicle matrix (MVA, 1987b). Although this matrix is excluded from the distribution modal split process, they are assigned with the rest of the car traffic.

For each type of trip the inputs to the DMS model calibration are: trip origin by person type (i.e. car availability), trip destination and observed trip cost distributions by person type and mode.

Trip origins (car available and non car available) and destinations are estimated by the trip end models described previously.

Observed trip matrices are used to form the observed cost distributions. These are the public (car available and non car available) and private matrices for each type of trip (work, OHB and NHB). Trip cost matrices (skims) are obtained from the assignment of the observed matrices to the calibration year networks. Public transport costs are independent of network loading, and private vehicle types are subject to incremental loading capacity restrained assignment. Intra-zonal trip costs are assumed to have half the cost of travel to the nearest neighbouring zone.

For the purpose of assignment of private vehicle trips, peak hour and occupancy factors are input to the model. These operate on the synthesised matrices to convert 3-hour private transport person trips to peak hour vehicle trips for use in assignment. Two distinct factors are used: one to represent the proportion of peak period trips which take place in the peak hour and a second one to represent the reciprocal of occupancy.

The output of a DMS calibration run is a set of trip cost distributions for every purpose, person type/mode combination and calibration area. These distributions are used to forecast a synthetic matrix for each such combination. Person trip matrices are then combined to derive a combined matrix for public and private transport passengers.

The model for work trip purpose may be specified as:

$$T_{ij}^{am} = A_i^a O_i^a B_j D_j K^{amr}(C_{ij}^m)$$

where:

a	is the person type (car availability)
m	is the mode
r	is the calibration area associated with the particular movement
O_i^a	is the number of work trips by person type **a** with origin in zone **i**
D_j	is the number of work trips with destination in zone **j**
C_{ij}^m	is the (generalised) cost of travel from **i** to **j**, by mode **m**, and
A_i^a, B_j	are balancing multipliers which ensure that the trip end constraints are satisfied, thus:

$$\sum_{m=1}^{2} \sum_{j} T_{ij}^{am} = O_i^a$$

$$\sum_{a=1}^{2} \sum_{m=1}^{2} \sum_{i} T_{ij}^{am} = D_j$$

The function $K^{amr}(C)$ represents the deterrent effect of cost **C** for a particular person type, mode and calibration area. This is determined as a balancing multiplier so that the trip cost distribution is matched for each cost band.

The model for OHB/NHB is similar, with **p** denoting whether it is OHB or NHB trip:

$$T_{ij}^{amp} = A_i^{ap} O_i^{ap} B_j^p D_j^p K^{amp}(C_{ij}^m)$$

Satisfying the following constraints:

$$\sum_{m=1}^{2} \sum_{j} T_{ij}^{am} = O_i^{ap}$$

$$\sum_{a=1}^{2} \sum_{m=1}^{2} \sum_{i} T_{ij}^{amp} = D_j^p$$

The models have to be calibrated in order to estimate deterrence functions which satisfy the trip end and trip cost distribution constraints. Calibration were undertaken at district level.

Districts within the cordon are split into two calibration areas to distinguish between trip to the central area and other trips. Cordon crossing trips are assumed to have a fixed mode, and hence are defined as separate calibration areas within the model.

The calibration data are derived from the GLTS surveys. The 1.5% sample household survey data is used to create the internal part of the trip matrices. Inwards cordon-crossing trips are derived from the GLTS cordon survey (10-25% sample varies by survey station) and the BR survey (25% sample).

4.2.4 Private Transport Generalised Cost. The generalised cost is used to refer to the various 'costs' which might affect the demand for travel. Private transport generalised cost is calculated according to:

$$c = t + \frac{TM}{AO}(DC.d + TC.t + e)$$

where:

d link distance

DC vehicle operating cost per unit distance (pence/km)

t link travel time

TC vehicle operating cost per unit time (pence/hour)

e toll charge

TM time equivalent of money (sec/penny)

AO average occupancy for apportioning cost across passengers.

The basis for the calculation of vehicle operating cost distance and time factors used in the LTS model was taken from the TRRL Report LR 661 (Dawson and Vass, 1974). Accordingly, a fuel and non-fuel element of vehicle operating cost is defined. Following the Highway Economic Note 2, HEN2 (DTp, 1989a) the non-fuel element of vehicle operating cost is assumed to remain constant in real terms (i.e. 1981 values were used throughout), while the fuel-related element is inflated in line with expected real fuel price changes.

According to MVA (1987b), the published fuel price indices from 1981 to 1986 were used to estimate the real change in the price of fuel for that period used in the LTS model. Beyond that date, HEN2 assumptions have been adopted.

The non-work values of time recommended in HEN2, adjusted for the London Area, have been used in the Interim Model networks. Accordingly, this is 100.6

pence/hour (1981 prices). This value has also been used for future years, in agreement with the general approach of holding model coefficients constants over the forecasting year. Whereas the value of time was thus held constant over the years, different assumptions have, however, been made regarding growth in incomes and car ownership.

The usual assumption is that the value of time will increase in real terms in proportion to real incomes (see **Section 2.2.3**). The fact that the value of time was held constant is likely to have reduced the effects of changes in travel time in the distribution/modal split modelling process, and in the estimation of user benefits derived from different investment alternatives.

According to MVA (1987a) the average occupancy for apportioning cost across passengers (AO) is 1.48.

The historical values of the Dartford Tunnel tolls have been used for 1981 and for 1986. For subsequent years the tolls have been held at the 1986 values. No other toll exists.

4.2.5 Public Transport Generalised Cost. This is calculated in terms of generalised cost for legs, where a leg comprise a walk link and a section common to the routes taken by one or more services of a given mode, where service frequencies are combined for calculation of waiting times. The generalised costs for each mode, **m** (bus, rail or walk), on leg **l** are calculated as:

$$C_l^m = f^m . T_l + g^m . W_l + F_l^m$$

where:

C_l^m is the generalised cost by mode m along a leg (or walk link) l;

T_l is the travel time along leg l;

W_l is the waiting time necessary to use leg l;

F_l^m is the fare for using mode m on leg l at 1981 prices converted from money into generalised time;

f^m is the link travel time cost factor;

g^m is the waiting time cost factor.

All costs are expressed in (generalised) seconds.

Link travel times (based on operator schedules) are coded directly as data when building the network; the link travel time cost factor provide different weighting to time spent on each mode, representing traveller's perceptions. Values of 1.0, 1.2 and 2.0 are considered respectively for rail, bus and walking;

Waiting times are input in the form of tables, which can cater for route frequencies, ranging from 1 to 60 services per hour. According to MVA (1987a) it was not possible to determine the precise derivation of buses waiting times used in the LTS model. Rail waiting times are based on random passengers arrivals for headway of 12 minutes or less, and otherwise based on planned arrivals. For simplicity, this is expressed (in minutes) in the approximate form as:

$$W^{rail} = \frac{h}{6} + 4$$

where **h** is the service headway in minutes.

Similarly to the previous cost factors, the waiting time represents the relative disutility of waiting time with respect to in-vehicle time, and the commonly accepted value of 2.0 is assumed.

Boarding penalties are often included to represent passenger resistance to boarding or changing routes. However, according to MVA (1987a), no boarding penalties were applied in the base network.

For a given journey, the public transport fare can vary between both routes and modes. The present interim network model does not make this distinction, allocating a single fare to each O/D movement. According to MVA (1987a), a fares table is defined for each mode relating fare to distance travelled. The values in the tables take account of the duration of each fare scheme, and a weighted average fare is calculated. The TS Note 146 (GLC, 1985b) contains the detailed derivation of the fares tables. The final fares table is factored to take account of reduced fares and converted to generalised time units by the use of the value of time. It has been assumed that fares remain unchanged in real terms. Fares are used in calculating the minimum public transport generalised cost for each OD movement as a input to the DMS component, but are not used when loading trips onto the network.

4.2.6 Highway Assignment Model. The form of the GLTS highway assignment model is that of deterministic, capacity-restrained assignment. It uses equilibrium methods based on Wardrop's (first) principle for gaining convergence between iterations of calculating paths and delays. The model has a distinctive approach towards calculating junction delays, which are calculated separately from the speed of travelling along links. The capacity calculations are based on a simplifying assumption which treats all junctions as a form of signalised intersection.

The purpose of the equilibrium method, based on Wardrop's first principle, is to load trips onto each path within a set in proportions that equalise the costs of taking different routes between each OD pair. This stable situation is normally achieved after several iterations when travel times converge to fixed values. In this way, although individual paths are calculated on the basis of minimum cost, trips between OD pairs may potentially spread over as many routes as iterations are used to achieve convergence (MVA, 1987b).

Link speeds are not flow dependent but are fixed according the input data. This is on account of the relatively small part that link capacity restraint is taken to have in the urban context compared with junction capacity restraint.

Paths through the network are calculated on the basis of minimising generalised cost between origin and destination zones. After paths are calculated, trips from the origin-destination demand matrix are loaded onto links in the network according to the path routeings to provide the starting point for the first capacity restraint iteration. The resulting link flows are used to calculate a new set of link costs and minimum cost paths, and the matrix is reloaded onto these paths. An appropriate linear combination of the two loading is then calculated; this constitutes the starting point for the next iteration. In this way a set of paths connecting each OD pair is generated, together with the allocation of the OD flow among these paths.

The total time to travel along a link is assumed to be made up of three parts:

(i) A time during which the traffic is travelling at a speed dependent upon the physical characteristics of the link (running time or speed). Note that this is not dependent on the link flows.

(ii) A delay at the destination junction which is minimum in light traffic conditions and maximum when the arm is running at capacity (delay time).

(iii) A time during which the traffic is crawling in a queue. This is the 'crawl time'.

Paths are always calculated as minimum cost routes (trees), and trips are loaded onto the network accordingly. However, the definition of 'cost' is varied. For loading cars, light vehicles, and taxis, cost is simply time plus any tolls that apply, where time is calculated from the flow/delay functions. For loading medium and heavy goods vehicles, cost is also given by time plus tolls, but time is calculated under free flow conditions. Finally, for deriving skim matrices, cost is a combination of time and distance as given in the generalised cost function described previously.

When assessing the highway assignment model it should be noted that it is used for two distinct, though related, tasks. First, to provide skim cost matrices for distribution/modal split (DMS) modelling and economic evaluation. Second, to provide link loadings (flows) for scheme appraisal.

The skim cost matrices provide aggregated information, the total costs between origins and destinations; they are used to reflect the general cost patterns over the modelled area for DMS modelling, and to determine the magnitude and sign of the cost changes for economic evaluation.

The precision required of this link loading information is much greater in order for the model to reflect the characteristics of a particular schemes, specially when the scheme affects only a few links in the network.

4.2.7 Public Transport Assignment Model. The main features of the GLTS public transport assignment model are the network and service route building path calculations, and trip loading. Network and route building take information on the road and rail networks over which the public transport system operates, and combines it with information on the routings of individual public transport services to identify the legs available for use by public transport trips. This provides a basis upon which to calculate the path taken by trips between individual origin and destination zones, which minimise the generalised cost of travel without the fare element. The numbers of trips travelling between zones, as determined in the DMS model, are loaded onto the minimum cost paths connecting origin and destination zones.

Link costs are not flow dependent and no capacity restraint is applied to match assigned flows to capacities.

The base GLTS public transport network uses four transport modes: walk, bus, underground and rail. A maximum of eight modes is possible and definitions may be adjusted for use in scheme networks (e.g. busways, light rail or other new services).

Each bus or rail service in the network is defined by a set of information including: mode, route name, whether it is a one or two way route, the route frequency (or headway) and the sequence of nodes through which the route passes. The frequency data (and the times/speeds in the link data) may be defined for up to three different time periods. There is also a facility to inhibit boarding and alighting at nodes.

All flows assigned to the network are derived from an Origin Destination (OD) travel demand matrix at GLTS zonal level. The zonal proportions of district movements used in disaggregation of synthetic matrices are from the 1981 observed data.

Paths are built by determining the minimum cost route, based on the identification of legs. The minimum cost path from a zone to any node in the network is formed as a sequence of legs, and correspondent waiting time, and walk links. Paths in the scheme networks are based on generalised cost without the fares element. Skimmed costs for the scheme networks are 'corrected' by adding the fares element of the base network costs.

Trips are assigned to the set of services which comprise a leg rather than to individual services.

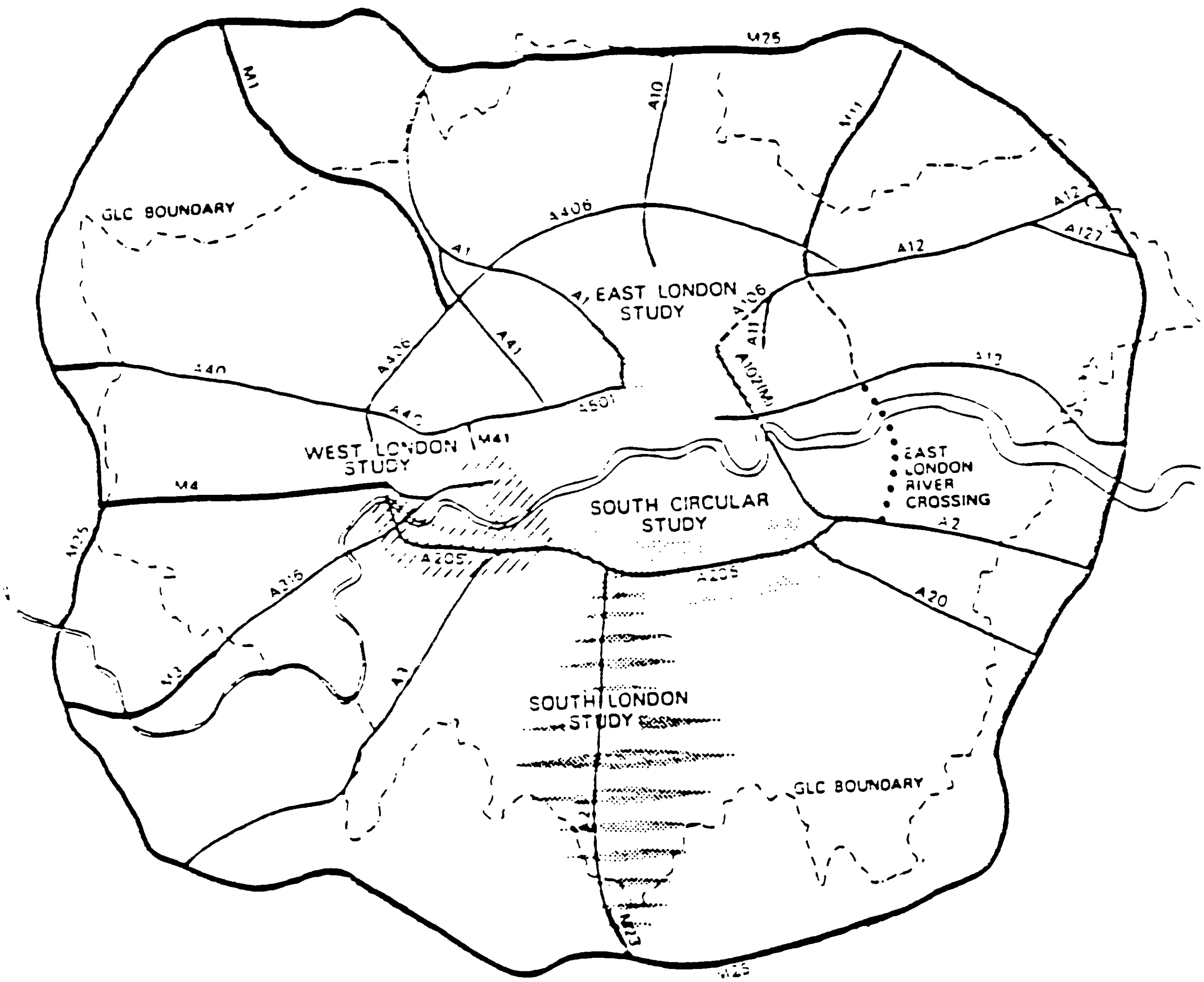
4.3 The London Assessment Studies

In November 1984 the Secretary of State for Transport commissioned four different studies to investigate transport related problems in some of the busiest part of London. The so called London Assessment Studies comprise the East, West, South Circular and South London Assessment Studies[2]. The areas chosen were respectively: east London, between the A1 in Islington and the A102 in Hackney and Tower Hamlets; West London, including the Western end of the South Circular Road and the Earl's Court one-way system; the main orbital section of the South Circular from just east of Wandsworth to Woolwich; and the corridor through South London to the M25 and Gatwick. These are illustrated in **Figure 4.3**.

[2] These have been comissioned respectively to the following consultants: Over Arup and Partners, Sir William Halcrow and Partners, Travers Morgan Planning and Mott Hay and Anderson.

Figure 4.3 The London Assessment Studies Area

(Source: DTp, 1986c)



The study area of the South London and South Circular studies overlap in the northern part of the former and there was some interface between the options arising from both studies. In some cases, mutually complementary proposals from the two studies were required for the full benefits of either to be gained; in other cases proposals from the two studies conflicted with each other in physical or operational terms. The same applied between the South Circular Study and the West London and East London studies, although to a lesser extent.

The area covered by the four studies is extremely varied in its character. At the east end, the region is still the location of many small industries and enterprises, but has been subject to some of the London's biggest recent office developments. It accommodates a range of housing styles and occupants, as well as including some of the most degraded urban landscape of London. At the other extreme the West has a more homogeneous residential area, with a good road and public transport network although under severe congestion. To the south, it ranges from dense inner city to green belt, and although much of the area is residential in character there are significant areas of industrial and commercial development.

The Assessment Studies were divided into two distinct stages:

Stage 1, finished in December 1986, identified the precise nature of the problems in the Study Areas. These were reported by **Stage 1 Reports** produced separately for each of the four studies (DTp, 1986b, 1986c, 1986d, 1986e). In a common approach to all four studies, a wide range of problems within the Study Area, affecting road and public transport users, residents and businesses alike were distinguished. It was also noted that there was a marked imbalance between high road traffic volumes and limited road network capacity exacerbated by high levels of illegal parking. This imbalance leads to widespread congestion which severely affects the efficiency of longer distance traffic movements through the area and impinges on the daily environment of people who live, work, and shop in the area (see DTp, 1986b, 1986c, 1986d, 1986e).

The aim of **Stage 2**, as identified in the Working Arrangements was:

(i) to identify a range of transport options, including public transport options, for reducing the problems identified in the Stage 1 report;

(ii) to evaluate these options in the light of Government's objectives for Roads and Transport in Greater London, and any local objectives for the local area stated by the Local Authorities;

(iii) to reduce this initial range to a substantive group of feasible options, that secure value for money in economic, operational and environmental terms; and

(iv) to produce a report upon the derivation of options, in sufficient detail to enable Ministers to take decisions on progress.

Stage 2, of the study was further split into two stages: **Stage 2A** concerned with the identification of a wide range of strategic transport options at a very broad brush level of detail, and **Stage 2B** intended to develop the more promising options.

Moreover, there were a number of London-wide issues which was necessary to address in order to provide parameters for modelling traffic usage of the area, and the assessment of the options. These included policies relating to parking enforcement, company car taxation, public transport subsidies, bus deregulation, heavy goods vehicles and lorry bans, traffic restraint measures such as road pricing, capacity/land use effects and basic traffic growth/car ownership assumptions. Work on London-wide policy issues was carried out centrally by the Department of Transport, who subsequently provided the consultants with a detailed backcloth of policy parameters that were to form the basis for the evaluation of traffic in the area (DTp, 1986c).

The **Stage 2A** examined several options which would alleviate problems revealed at the previous stage. These options provided the necessary specification of general requirements for LTS model forecasts to support **Stage 2A**, and to construct the base (or 'do-minimum'), highway and rail investment alternatives.

An Assessment Method Working Group, consisting of members of each of the four London Assessment Studies consultants and the Department of Transport was set up as a forum for establishing the methods of assessment to be used.

The method developed used the SACTRA 1986 report on Urban Road Appraisal (DTp, 1986a) as its starting point. From this base an approach suited specifically to the London Assessment Studies was developed. This recommended that options be assessed against the following three principal headings:

(i) effects on problems (including environmental problems);

(ii) practicability and costs; and

(iii) achievement of objectives.

As required by the Term of Reference it was vital that any option should be geared to reducing the problems defined in **Stage 1** of the Study. It follows that the degree to which that can be achieved should provide the main focus in the assessment of any option. In preparing the framework, the effects on problems are considered in term of existing problems which are ameliorated and/or exacerbated, and, where relevant, new problems which are created. Problems are then examined in turn for environmental, movement and safety considerations.

The difficulties of building or implementing an option are assessed under practicability. Consideration has been given to the dependency of the option on individual schemes, the legislative implications and agencies involved, the physical constraints on new construction, and the constructional complexity and disturbance caused by options. Costs have been assessed in terms of land, construction and operating cost, together with a broad indication of possible economic benefits.

Achievement of objectives is assessed on the basis of accessibility; employment, economic growth and regeneration; efficiency (of the transport system); environment; and safety.

The options examined by the consultants all have their strengths and weaknesses. The distribution of benefits was of course never uniform; some areas and some parts of the community inevitably benefit more than others. The costs, benefits and their distribution vary from option to option. No single option was superior to the others on all counts. Only when the options had been further developed and assessed and then subject to public comments, could judgements be made on their relative merits.

The recommendations from the consultants of the four London area assessment studies were finally submitted to the Secretary of State for Transport at the end of 1989. They have considerably narrowed down the number of options in each area and a number of schemes were then ruled out. There has since been no commitment to provide the resources for any of the schemes suggested and none had been implemented by the time of submission of this thesis.

4.3.1 LTS Model Forecasts. Discussion between the Department of Transport, the four London Assessment Study consultants and MVA/LTS, led to a specification of general requirements for LTS model forecasts to support **Stage 2A**.

Among a range of forecasts that were supplied, the following three were used in the work described in this thesis. A detailed description of each forecast is given by MVA (1988).

(i) 2001 Interim Model

(ii) 2001 Interim Model with additional rail schemes, and adjusted highway costs incorporating feedback from the improved rail system to conditions in the highway network.

(iii) 2001 Interim Model with enhanced highway network.

With the exception of the specific network changes which are the subject of the test, all planning and economic assumptions for the 2001 Forecast are held constant. Although there was two separate assumptions representing high and low economic growth situation, the forecasts described have been estimated by LTS model under the low economic growth assumption.

Forecast (i) is regarded as the 2001 'Do-Minimum' or base estimated for all the other forecasts. Forecasts (ii) and (iii) above were used to represent the final rail and highway investment policies. These are briefly described below.

The rail enhancements added to the Interim Model 2001 public transport network for Forecast (ii) were extensive. They included new railway lines, such as East-West crossrail, Chelsea Hackney Line and Heathrow-Paddington link, extensions to the Victoria, Bakerloo, Metropolitan lines and the Dockland Light Rail, as well as reorganization and improvements of British Rail services. According to MVA (1988), they are intended to provide a general indication of the overall scale of possible modal transfer, redistribution and re-routing effects in the morning peak, rather than precise estimates of the changes in demand for any particular line or corridor.

Enhancements to the Interim model highway network (Forecast (iii)) illustrate the general scale of the effects of highway investment. According to MVA (1987b), the forecasts themselves should be interpreted generally, and not necessarily as locally accurate of estimates of future highway traffic flows.

It was agreed by the DTp and the four consultants to include, in addition to the committed highway schemes described in the Interim model Report (MVA, 1987b) as being included in the Interim Model 2001 highway network, the following network enhancements for the highway investment option:

(a) the proposed East London River Crossing (ELRC);

(b) a number of highway schemes currently being progressed within the Docklands area, including the Docklands Highway and a new crossing of the River Lea;

(c) a set of schemes for all North Circular road junctions. In this option the North Circular Road is completely upgraded from Chiswick in the West to the Falconwood interchange on the A2 in the East (including ELRC).

Both rail and highway forecasts were carried out using the full model 3-cycle convergence of the highway and trip distribution and modal split models, as for the Interim Model. However, for the highway forecast, the interim model 2001 Public Transport network was used, with the associated matrix of costs. This implies that for comparing the highway investment option against a do-minimum alternative, changes in cost will occur only for private transport users.

The outcome matrices are therefore the result of trip redistribution and modal split effects, and consequential assignment effects, of a network change, including highway network cost effects. These effects are viewed as occurring over the medium and longer term as people adjust to the changing situation on both modes. These effects are discussed by MVA (1988).

The results of the LTS model forecast were provided for trip matrix, public transport and highway assignments. These included, for all three investment policies, the following district-to-district matrices:

(a) public and private trip matrices ($\mathbf{T}^m_{ij}$, $\mathbf{O}^m_i$, $\mathbf{D}^m_j$);

(b) private vehicle travel time;

(c) private vehicle total generalised cost.

In addition, for the public transport network, the following matrix was supplied, separately for the rail and base forecasts:

(d) public transport total generalised cost.

All the above matrices are at 345 district level (227 districts, 91 road cordon points and 27 rail cordon points).

As seen from (b) and (c), the individual matrices of private vehicle operating cost, for each investment option, were not given. These were estimated from the information contained in (b) and (c), namely private travel time and total generalised cost, and converted into money units by the use of value of time.

These private transport matrices however, did not have information on intradistrict operating costs and travel time. For operating costs, intradistrict values were calculated as one half of the minimum cost to or from that district. For travel times, instead, intradistrict values were calculated from the intradistrict operating costs using specific parameters relating travel time and cost. These parameters have been estimated by a simple (zero-intercept) regression model in order to examine a constant of proportionality between travel time and operating cost, separately for each investment option.

The model is defined as:

$$Time = \alpha \, Operating \;\; Cost + \varepsilon$$

From the above specification, α is the parameter that estimates the constant of proportionality between these two variables. The results are summarized below:

Table 4.2 Estimated constant of proportionality between private transport operating cost and travel time

INVESTMENT OPTION	α	s.e.
Do-Minimum	32.324	0.016
Railway	32.486	0.015
Highway	32.114	0.015

As expected, private transport travel times and operating costs were indeed found to be highly correlated. It is interesting to note that the parameter α shows that the ratio of travel time and operating cost would be slightly higher in the case of a rail improvement. This is consistent with the increase in congestion compared with the case of highway investment. However, the difference though highly significant statistically, amounts to only about 1 per cent.

The weighted public transport travel time and fare matrices were also separated into two matrices, one of fares and the other of travel time, where travel time includes all the different components (i.e. walking, waiting and in-vehicle).

Following suggestions from MVA, the proportion of time and money components for each pair of districts was taken from the public transport fares and total generalised cost matrices of 1986, provided specifically for this purpose. The 1986 matrices are however at the zone level, and in this respect the proportions (of time and money components) were calculated as the average for all zones in that district. These proportions were applied pro-rata to the public transport generalised cost matrix of 2001, estimated for the rail and do-minimum forecasts. Finally, fares are converted into money units by the use of value of time.

No data were provided with respect to walking and cycle modes.

The set of model forecasts represent the starting point for the construction of scenarios described in the next chapter.

CHAPTER 5
CONSTRUCTION OF THE SCENARIOS

5.1 Introduction

Previous chapters have examined theoretically some of the issues associated with income distribution and the evaluation of user benefits from changes in transport systems. The usually accepted assumptions on the role of income in transport demand modelling have been reviewed and new frameworks for the measurement of user benefits are proposed to be tested.

The data which are used throughout this research have also been described and discussed. In particular, investment options proposed by the London Assessment Studies were used for testing different policies using the LTS model. Output matrices from model runs have furnished information on the forecast travel patterns under three investment alternatives.

Much of the information on travel behaviour is however lost in the aggregate four stage process within the LTS model. In this chapter the data set is explored further, and household income distribution is estimated for the trips in each cell of the various output matrices. The objective of the work described here was to construct hypothetical but realistic alternatives scenarios for comparisons.

The process of estimating income distribution starts at the household level. The first step is to estimate the number of households in each income and household size category in the forecast year. This has provided much of the core of the scenario-building work.

The estimation of household income distribution for the trip ends is described separately for trip production and attraction. These estimates have provided the basis on which household income distributions for trip interchanges have been estimated subsequently.

In order however to implement the proposed frameworks for investigation, it was also necessary to make some suitable further assumptions. In particular, these were needed to estimate the number of travellers in each income category who would change their behaviour as a result of improvements in the transport system, by changing either origin/destination pair, or mode or both. These issues are also explored and discussed in this chapter.

Albeit that the aim of the work has been to forge a suitable data set for investigation, the opportunity to examine new approaches for modelling the distribution of income have provided further insights for public policy analysis, and transport in particular. Some of these issues are also explored below.

This chapter is divided as follows. Since the lognormal distribution has been used to estimate household income distribution and the income distribution for the trip attractions, the concept underlying the lognormal distribution is presented briefly in the next section. The estimation for the forecast year of the number of households in each income and household size category is presented respectively in **Section 5.3** and **5.4**. In **Section 5.5** household income distributions for the trip ends have been estimated separately for trip production and attraction. Moreover, the estimates for the trip production models are balanced with those for the attraction, and the final results are later aggregated into five income categories. These results are used to estimated income distributions for the trip interchanges as described in **Section 5.6**. Finally, in the last section a transition matrix is defined in order to estimate the number of travellers of each income category who would change their behaviour.

Throughout the chapter many of the arguments have been supported by the analysis of 1981 GLTS, and therefore the survey data is constantly referred to. The allocation of households to income categories follows basically the same structure as the survey, and hence yearly income is divided into twelve household categories as presented in **Table 4.1**. These categories are later aggregated into five distinct categories. Most of the results are presented disaggregated by sector or alternatively by area (central, inner and outer). Nevertheless, most of the work is carried at the district level. Money values are expressed in 1981 prices throughout.

5.2 The lognormal distribution: concept and theory

The lognormal distribution in its simplest form may be defined as the distribution of variate whose logarithm obeys the normal law of probability (Aitchison and Brown, 1969).

Consider a strictly positive variate $X(0<x<\infty)$ such that **Y=ln X** is normally distributed with mean μ and variance σ^2. The distribution of **Y** is therefore given by:

$$N(\mu,\sigma^2)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{(y-\mu)^2}{2\sigma^2}} \quad \textit{where} \quad y=\ln X$$

It follows that **X** is lognormally distributed. **X** is then said to be a Λ-variate and these statements can be written:

X is $\Lambda(\mu,\sigma^2)$ and correspondingly **Y** is $N(\mu,\sigma^2)$.

The distribution of **X** is completely specified by the two parameters μ and σ^2, and this seems to be the simplest natural specification. In some cases, the definition and scope of the distribution can be extended by the introduction of a third and fourth parameter. These further parameters define upper and lower bounds to the range of values of the variate **X** (the thresholds of the distribution). For the definition and discussion on three and four-parameter lognormal distribution see Aitchison and Brown (1969).

It may be emphasised that **X** cannot assume zero values, since the transformation **Y=ln X** is not defined for **X**=0.

It is clear from the definition, that many of the properties of the lognormal may be derived from those of the normal distribution although there are certain features of the former which differ from anything arising in normal theory. In particular, since the latter has additive reproductive properties it is expected, from the characteristic property of the logarithm function, that the lognormal distribution will have multiplicative reproductive properties.

Moreover, since X and Y are related, the distribution functions of the two variables are also related. The mean ξ and the standard deviation ρ^2 of the distribution of the X variate is given by:

$$\xi = e^{\mu + \frac{1}{2}\sigma^2}$$

$$\rho^2 = e^{2\mu + \sigma^2}(e^{\sigma^2} - 1)$$

From the previous two equations, the coefficient of variation η of the X distribution is given by:

$$\eta = \frac{\rho}{\xi} = \frac{\left[e^{2\mu+\sigma^2}(e^{\sigma^2}-1)\right]^{\frac{1}{2}}}{e^{\mu+\frac{1}{2}\sigma^2}} = \left(e^{\sigma^2} - 1\right)^{\frac{1}{2}}$$

which implies that the coefficient of variation depends solely on the σ^2.

In a number of situations it is more reasonable to suggest that the process of underlying change or growth is multiplicative rather than additive. In fact, the lognormal distribution has been applied in a variety of different fields. Some of its most common uses, however, have been in economic analysis, and in particular income size distributions.

There are many methods for point estimation of the parameters of the lognormal distribution, including maximum likelihood, the method of moments, quantiles, graphical methods or any hybrid form. Whatever method is adopted, the resulting estimator should have the properties desirable for the application in hand. However, when observations are given only as grouped frequencies, there are many difficulties in the various methods of estimation.

There are a number of important reasons for grouping data. One of the primary reasons is descriptive, as in graphical and tabular presentation of data; grouped data may also arises from studies involving variables where data sets are obtained from confidential sources, and thus must be presented and analyzed so as to maintain the privacy of the individual record. Furthermore, it is often difficult or, in some cases, even impossible to obtain accurate measurements (either because of limitations of measurement instruments or because of difficulties in obtaining and handling data), and as when data sets are very large, grouping may substantially reduce computation costs.

In practice, most transport studies deal with gross household income in relatively coarse bands. This is a common characteristic of many of household surveys. Moreover, the difficulties in obtaining reliable household income data were demonstrated in the GLTS of 1971 and 1981. In both surveys, almost 20% of otherwise successful interviews gave no information concerning income. Records which did not contain information on household income were subjected to a process of income patching. Essentially the method estimates income from two other variables - the socio-economic group of the head of household and the number of employed residents. The method is described by Stroud (1974).

According to the Encyclopedia of Statistical Sciences (ed. Kotz and Johnson, 1982) data grouping is "the process by which any variable **X** with a given distribution function F(X) (continuous or discrete) is condensed into a discrete distribution function, i.e.

$\mathbf{p_i = dF\ (X),\ i=1,2,...k}$" **(p. 528)**

where the range $[C_o, C_k]$ of X is portioned by $C_o < C < ... < C_k$ into **k** disjoint and exhaustive groups.

The C_i's are termed the interval limits or boundaries and (C_{i-1}, C_i) the **ith** interval or group. The number of cases falling into the ith group is denoted by $\mathbf{n_i}$, where $\Sigma_i\ \mathbf{n_i}$ = N, is called the ith group frequency.

The condensation is usually into the interval mid-points. Although it may be into the interval means or centroids as well as any other point in the ith interval. The intervals may be of different widths or, in the special case of equal width termed equispaced or equidistanced or simply equal.

Thus grouping essentially transforms one distribution function, continuous or discrete, into a multinominal distribution function.

There exist numerical methods for maximum-likelihood estimates (MLE) of location and scale parameters from grouped samples, where the parent distribution is assumed known.

Swan (1969) set out a practical technique for obtaining (computing) the MLE of the mean and the variance of a normal distribution and their asymptotic covariance matrix when each observation is specified only by an upper and lower bound.

Later, Benn and Sidebottom (1976) also wrote an algorithm to estimate the parameters for any distribution function, using MLE by iterative approximation with a facility for using weighted least squares to provide starting values. Since, however, the algorithm written by Swan uses a more general way of specifying the data (i.e. each observation being defined by upper and lower bounds) it may be used to fit normal distributions to data for which the latter is not appropriate (e.g. mixtures of grouped and exactly specified observations).

A more recent procedure for providing MLE from grouped data is the EM (expectation maximization) algorithm presented by Dempster, Laird and Rubin (1977). This is an iterative method for obtaining the MLE when the observations can be viewed as incomplete data. The term (EM) come from because each iteration of the algorithm consists of an expectation step followed by a maximization step. More specifically, the procedure consists of alternately estimating the incomplete observations from the current parameter estimates and estimating the parameters from the actual and estimated observations.

An EM algorithm for grouped data has been programmed by Wolynetz (1979). The procedure is designed to calculate the MLE of the mean and standard deviation of the Normal distribution. The observations in the sample are independent and each may be confined between two finite values or censored. An estimate of the variance-covariance matrix, based on the observed information matrix evaluated at the MLE is also computed (Wolynetz, 1979).

An important consideration is that convergence to the MLE estimate always occurs with the EM algorithm (see Dempster et al, 1977), whereas convergence may not occur with Swan's algorithm.

A comparison of several performance characteristics of both algorithms is presented by Wolynetz (1979). In general, the EM algorithm required on average more iterations to convergence than did Swan's procedure. The difference in the mean number of iterations increased as the censoring became more severe. Both procedures appeared to require more iterations as the sample size increased.

The derivation of the MLE from confined and censored data via the EM algorithm developed for this study is presented in **appendix 1**.

5.3 Estimating household income distribution

The household is at the core of the trip generation process. Car ownership in particular have been generally associated with household income, although the latter is closely correlated with many of the other household characteristics, such as household size, location and employment.

In this section household income distributions have been estimated for the forecast year. It starts by briefly examining the household income distributions from the 1981 survey. In this context, some of the relationship between household income and other relevant variables are also illustrated.

According to the 1981 survey, almost 20% of households had an income of £3000 or less. More than a third of all households received less than £5000, and close to 6% where at the top of the income distribution with £20000 or more.

Household income however varies considerably with location. Central London contains a comparatively large proportion of households at both ends of the income distribution. Almost a quarter of all households living in central areas receive less than £3000 and more than 8% had an income of £20000 or more.

Within the inner sectors there are also some significant differences in the proportion of households at the top end of the distribution, particularly between eastern and western sectors.

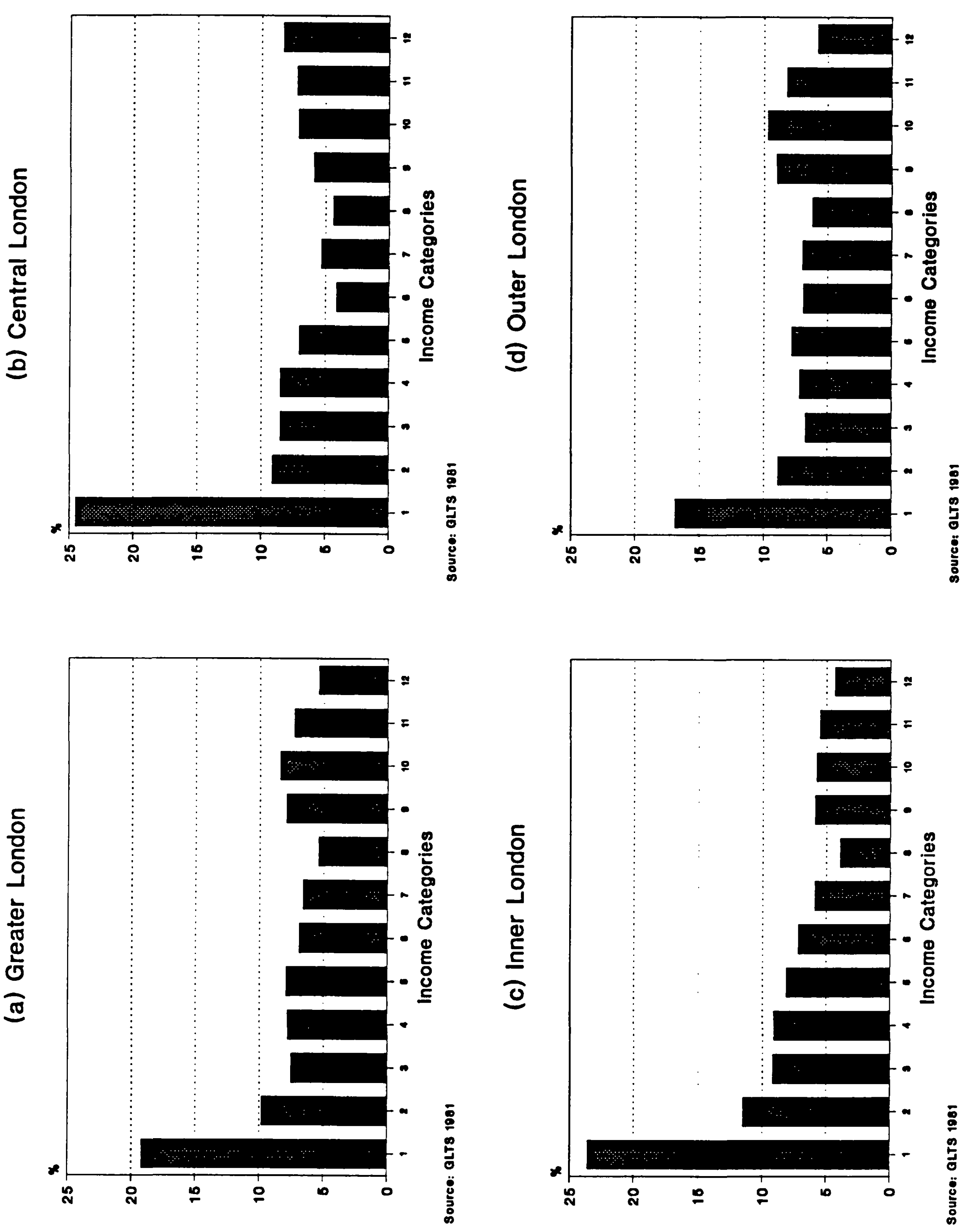
In the outer area, the distribution is more uniform, with some 20% of households within £10000 to £15000 income range.

Household income distribution in 1981 is illustrated in **Figure 5.1**.

As expected car ownership and household income also show a strong correlation. In 1981 the proportion of households with no car and one car only were equally divided, being 43.4% and 42.9% respectively (the rest having more than one car). In the case of non car owners, the great majority, almost 40%, had income less than £3000. This represented 85% of all households living on less than £3000 a year. As income rises the proportion of non car owners rapidly decreases. At the top of the income distribution, less than 15% of household were non car owners

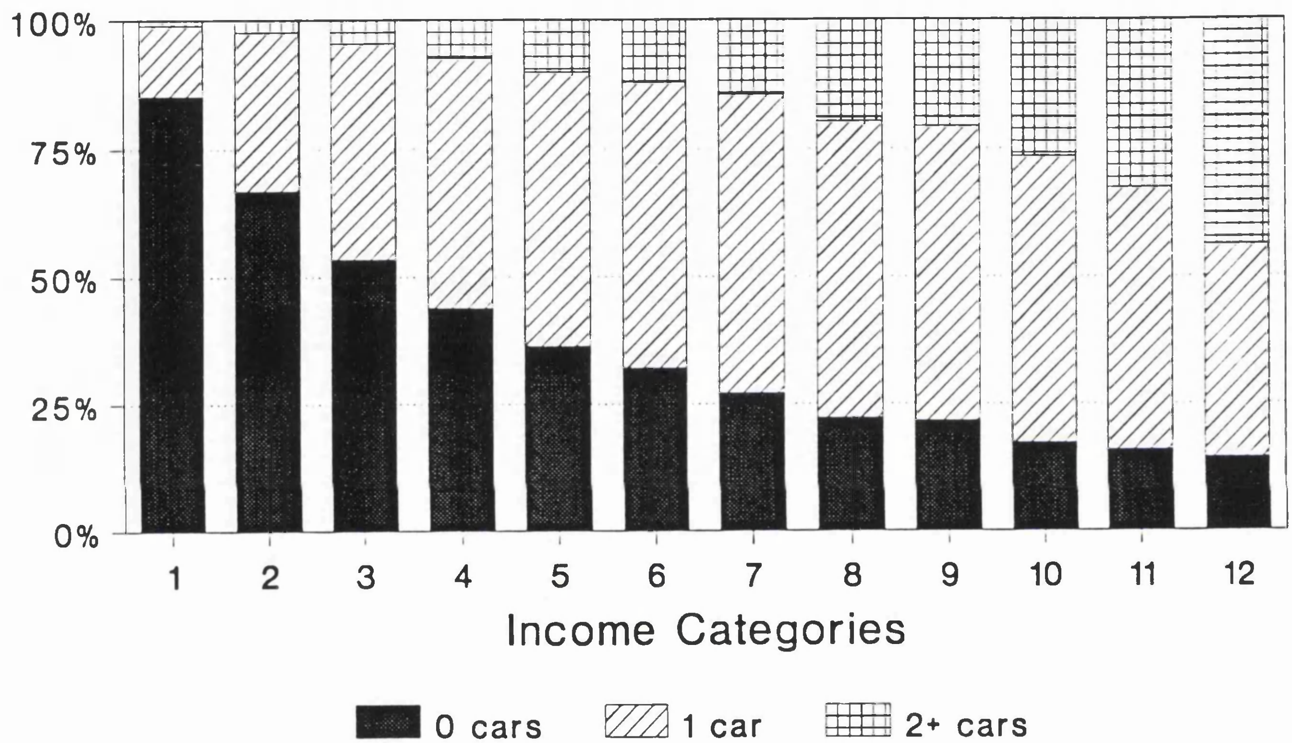
For car owners, the distribution of household with one car only is more uniform throughout the income spectrum. Households with income between £10000 to £15000, account together for 21% of households with one car. Of households with two or more cars, more than a third had yearly income exceeding £15000.

Figure 5.1 Household income distribution in 1981



A car is nevertheless an asset of more than 50% of households with an income of more than just £5000-£6000 a year. In income groups above this one, the great majority of all households have at least one car, with more than 85% of households at the top of the income distribution having one or more cars. The proportion of households with no cars, one or two or more cars across the income spectrum is illustrated in **Figure 5.2.**

Figure 5.2 Proportion of households with 0, 1 or 2+ cars in 1981



Source: GLTS 1981

Household income is, of course, largely determined by employment and in particular the number of employed residents. The socio-economic group of the head of household also contributes in determining gross household income.

Further analyses of household income distribution have shown that 89.4% of the households with annual income of less than £3000 had no employed member, living therefore on pensions or other forms of government benefits. A further 5.7% had only part time employed members. This represents more than 60% of all the households with no employed members and 56.4% of those with full time employed members.

According to the GLTS in 1981 there were almost 30% of households without employed members. Although some variability is expected with respect to household location, with a few exceptions, this average was broadly consistent across the whole of Greater London. Households without employed members were in the large majority confined to the bottom end of the income distribution. Irrespective of location, almost 90% of these households had a gross income of less than £5000.

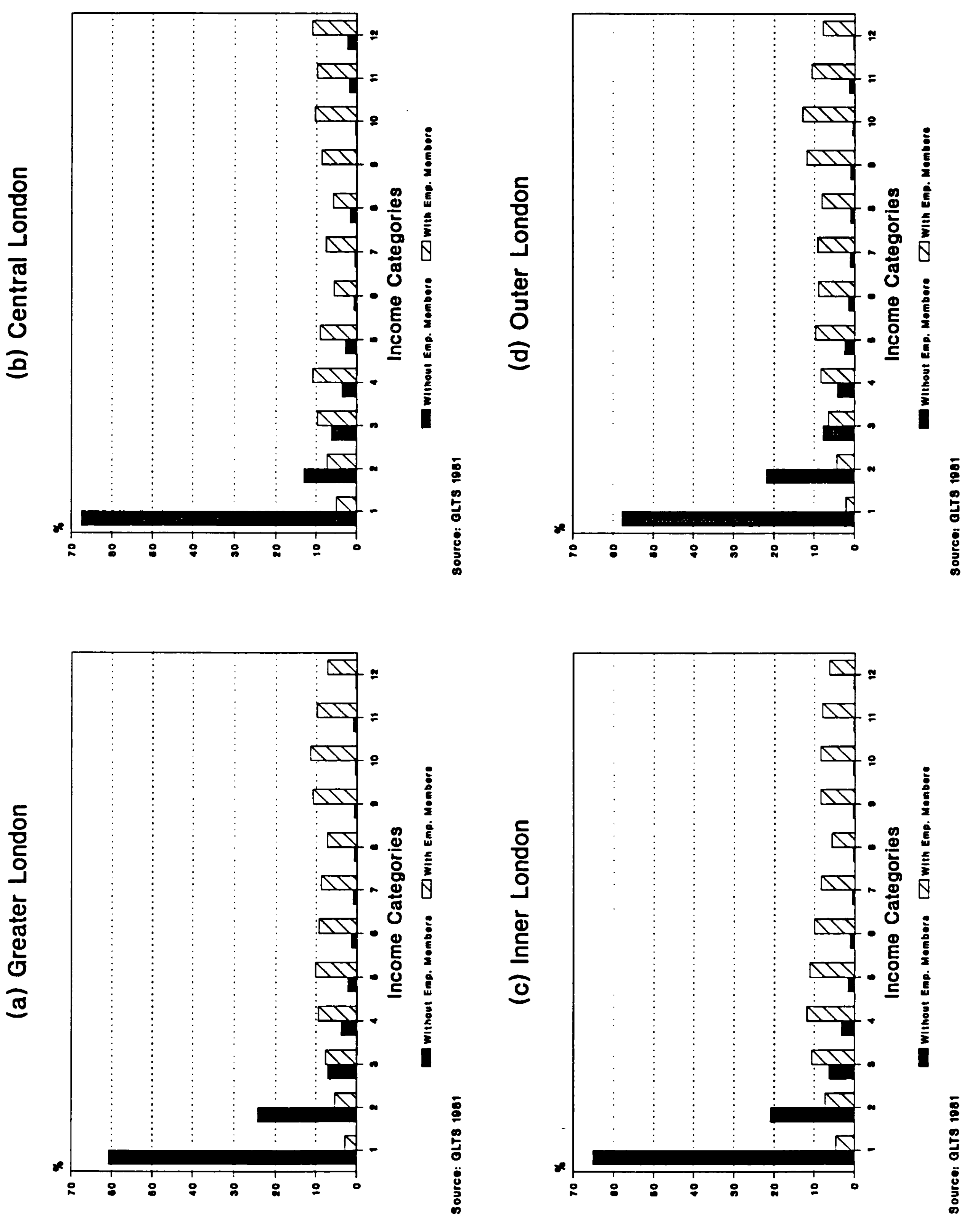
Households with employed members however have a much more dispersed income distribution. Income distribution for these households varies considerably with respect to location, household size, the socio-economic group of the head the household and the number of employed residents.

Income distribution for household with and without employed members is illustrated in **Figure 5.3**.

The London Assessment Studies have assumed household income to grow between 1981 and 2001 by 18% and 47.8% in real terms under respectively the low and high income growth assumptions. This gives average annual real growth rates of 0.83% and 1.97%, and these two assumptions have been used for the construction of the scenarios in this study.

Although further differences are to be expected between the high and low income growth assumption, particular with respect to car ownership, employment, fuel prices, and operating costs, in this study assumptions on income growth have been adopted solely for the purpose of estimating the proportions of households, and consequently trips, in each income category in the different scenarios under two levels of income growth.

Figure 5.3 Income distribution for households with and without employed members in 1981



It should be recognized that under the assumption of high income growth, one would expect high levels of car ownership with, consequently, a higher proportion of journeys to work by car, for instance. The objective here, however, was to establish two separate set of data under two levels of income growth, and to examine their implications in term of evaluation, despite the fact that the income differences will not be reflected in different modal split for the city as a whole.

The expected differences in the proportion of trips by public and private transport for each individual income category in the two levels of income growth reflect the distribution of households in the various income categories rather than changes in car ownership levels.

In fact, these assumptions do not represent situations that would be expected under two different levels of growth in the same hypothetical city. Rather, they do represent what one would expect:

(i) in a city with low income growth but patterns of car use at given incomes consistent with those found in London in 1981.

(ii) a city with higher income growth but generally lower levels of car use for given income then those found in London in 1981.

The rate of growth adopted, established by the studies and used in this research, were realistic figures to expect for the average rate of growth in income and earnings during the late 1980s. The recession that has arisen during the early 90s however might suggest that these were quite optimistic figures, but this would be a premature conclusion. The recession phase of the economy is anticipated to be short and the economic recovery expected from the creation of a single market in Europe may have a substantial impact on the economy of the region. Moreover, wage claims and settlements have been running higher than inflation, which appears to be falling.

The data for forecasts by the LTS model have also included estimates of the number and proportions of households with and without employed members. These are inputs to the home-based production models, and they have been estimated by linear relationships (see **Section 4.2.2**). It is also clear that these might differ according to the assumption about income growth, but they are considered to be the same for the construction of the scenarios given the availability of data.

In order to remain consistent with LTS estimates, in this study household income distributions have been estimated for the forecast year in two separate sections, using lognormal distributions.

For households with at least one employed person lognormal distributions have been assumed, thus assuming that the logarithm of income has a normal distribution. Following the notation presented in **Section 5.2,** the parameters mean ξ and standard deviation ρ of the income distribution are given by:

$$\xi = e^{\mu + \frac{1}{2}\sigma^2}$$

$$\rho = e^{\mu + \frac{1}{2}\sigma^2}\left[e^{\sigma^2} - 1\right]^{\frac{1}{2}}$$

where μ and σ are respectively the mean and standard deviation of the logarithm of income estimated from a normal population.

In addition, it has been assumed that for in the forecast year the coefficient of variation for household income for each traffic district was the same as in the survey year, while both the mean ξ and standard deviation ρ for the income distribution increase in line with income growth.

These assumptions imply that μ increases by the logarithm of the growth rate while the σ remains unchanged.

The distributions were fitted to data from the 1981 survey at the district level although in a number of cases some aggregation was necessary. In particular, given the comparatively small number of households living in central areas, for districts within Central London the distribution was fit at the sector level (i.e. a single pair of values was estimated for the parameters of the lognormal distribution for the whole of Central London).

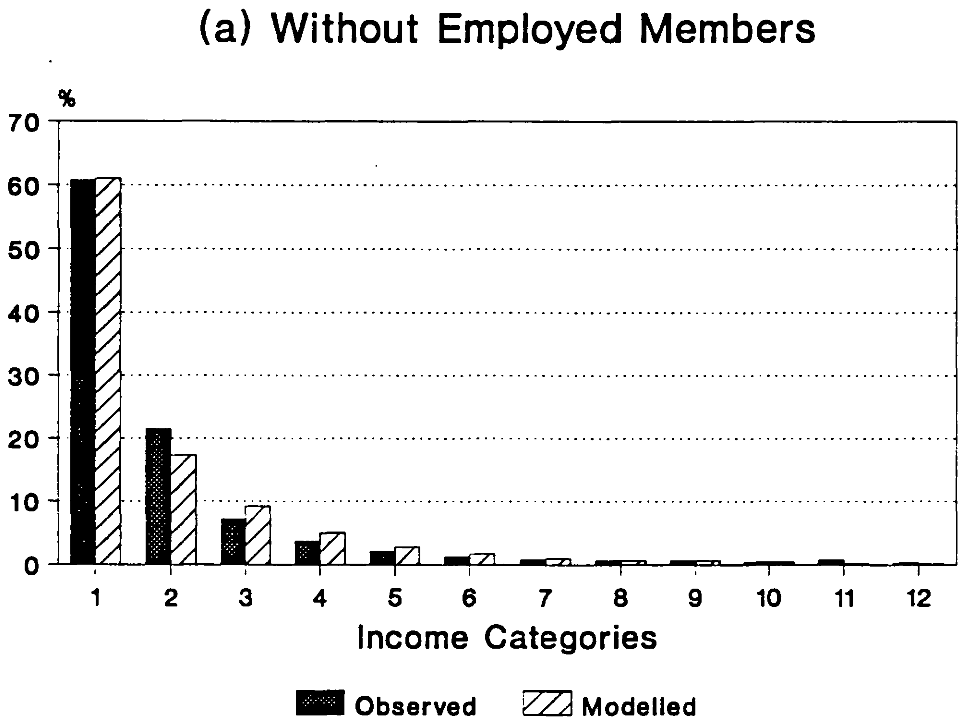
For households without an employed person however the distribution was held constant in real terms over time. The parameters of the lognormal distribution were estimated only in order to estimate the number of households in each of the income categories considered for the forecast year. These were calibrated at the sector, rather than the district level, based on data from the 1981 survey.

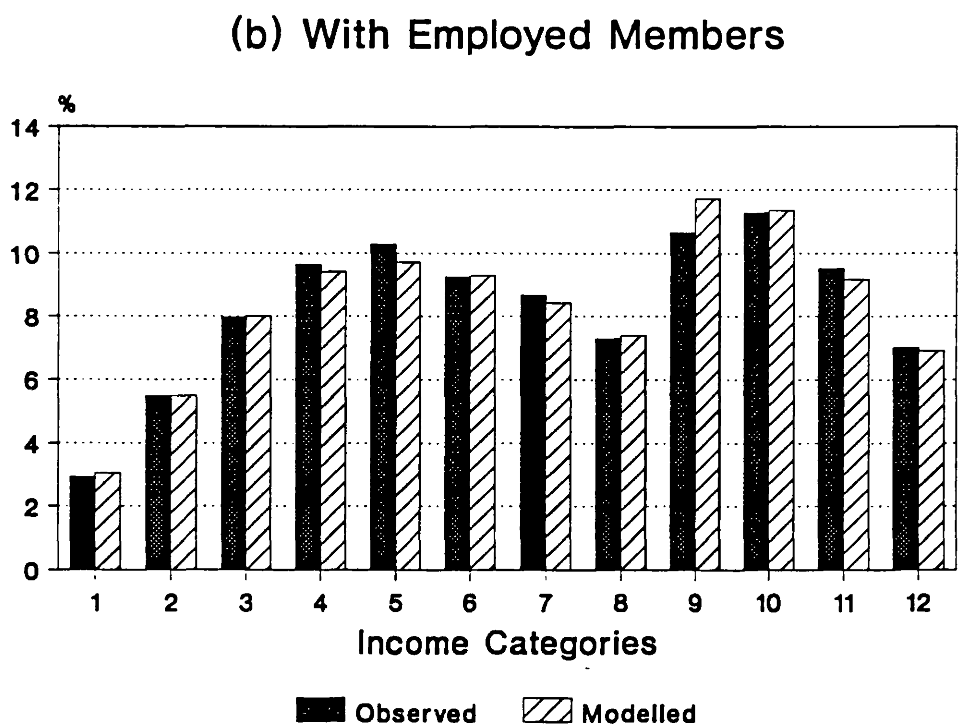
As these assumptions represent the basis of representation of economic growth within the LTS model, no formal statistical test was performed to compare observed and modeled values obtained with the parameters estimated for the lognormal distribution in the survey year.

Nevertheless, analysis of the aggregate distribution for the whole of Greater London shown in **Figure 5.4** indicates that the total of the differences in expected and observed percentages of households in the 12 income groups was around 20 and 10, respectively for households with and without employed members.

Because of the pattern of these differences, the estimated cumulative distribution function fits the data even better. In the case of household with employed members, for all districts and income categories, absolute differences in observed and expected cumulative distribution exceeded 5% in less than a third of the total categories. For households without employed members, these differences exceed 1% in less than 40% of total categories. It should be recognized however, that there are some appreciable differences between the observed and modelled distributions for individual districts, (especially for households without employed members where the sample sizes are small and the parameters for the distributions were estimated at sector rather than district level).

Figure 5.4 **Observed and modelled household income distribution from the 1981 survey**





Household income distribution for the forecast year is summarized in **Tables 5.1, 5.2** and **5.3**.

Table 5.1 Number of households in each income category with and without employed members estimated for the forecast year under low and high income growth assumptions

Inc. Cat.	Without Emp.	With Employed Members		Total			
	Low/High	Low	High	Low	%	High	%
1	507996	30140	10809	538136	18.7	518805	18.0
2	143653	65454	28531	209107	7.2	172184	6.0
3	76596	109176	55540	185771	6.4	132136	4.6
4	41234	143545	83697	184779	6.4	124931	4.3
5	23190	163398	107427	186588	6.5	130617	4.5
6	13641	169599	123997	183241	6.4	137638	4.8
7	8347	165536	133038	173883	6.0	141384	4.9
8	5283	154901	135524	160185	5.6	140807	4.9
9	5748	265968	259783	271716	9.4	265531	9.2
10	3463	287113	326502	290577	10.1	329965	11.4
11	1706	262542	358192	264249	9.2	359899	12.5
12	697	235484	429819	236181	8.2	430516	14.9
Total	831556	2052858	2052858	2884414	100.0	2884414	100.0

Table 5.2 Number of households in each income category and sector estimated for the forecast year with low income growth

IC	Sectors									Total
	Central	Inner			Outer					
	0	1	2	3	4	5	6	7	8	
1	13440	81142	49291	88095	52070	65654	60741	72219	55494	538136
2	4027	32322	17901	38771	20717	23682	22131	29441	20114	209107
3	3948	27451	16030	28332	18708	23001	20242	27262	20799	185771
4	3848	25701	14699	25902	19005	23872	21196	27837	22719	184779
5	3663	24446	13472	24867	19827	24672	22766	28742	24133	186588
6	3409	22738	12216	23083	20176	24738	23725	28812	24345	183241
7	3114	20555	10942	20550	19775	24003	23713	27843	23389	173883
8	2807	18134	9696	17710	18713	22649	28820	26058	21598	160185
9	4726	29133	15965	27299	32657	39885	40716	45055	36280	271716
10	5192	28978	16970	25262	35781	45448	46184	49367	37395	290577
11	5176	24269	16214	19102	32493	45400	44310	46059	31226	264249
12	6209	18685	18692	12501	26389	48209	41846	41875	21775	236181
T	59560	353553	212079	351474	316310	411212	390390	450570	339266	2884414

Table 5.3 Number of households in each income category and sector estimated for the forecast year with high income growth

IC	Sectors									Total
	Central	Inner			Outer					
	0	1	2	3	4	5	6	7	8	
1	12603	77699	46708	84323	50773	63632	59397	69720	53950	518804
2	3103	26346	14801	31930	17544	19339	18655	24173	16293	172184
3	2947	19687	12513	19573	13397	16331	14201	19120	14368	132136
4	2934	18052	11416	17632	12382	16048	13405	18276	14786	124931
5	2920	18232	10797	18637	13015	16940	14491	19388	16197	130617
6	2861	18494	10280	19379	14104	17985	16096	20842	17597	137638
7	2754	18258	9723	18169	15001	18693	17468	21853	18466	141384
8	2608	17484	9098	18143	15449	18908	18291	22174	18650	140807
9	4697	31227	16147	31458	30364	36658	36701	42790	35487	265531
10	5692	35914	19125	34092	39524	47930	49189	54718	43781	329965
11	6429	35736	20856	30887	44441	56724	57723	61507	45594	359899
12	10012	36424	30612	26252	50314	82023	74772	76008	44098	430516
T	59560	353553	212078	351474	316310	411212	390390	450570	339266	2884414

These results are illustrated in **Figure 5.5** and **5.6** below.

Figure 5.5 Household income distribution estimated for the forecast year with low income growth

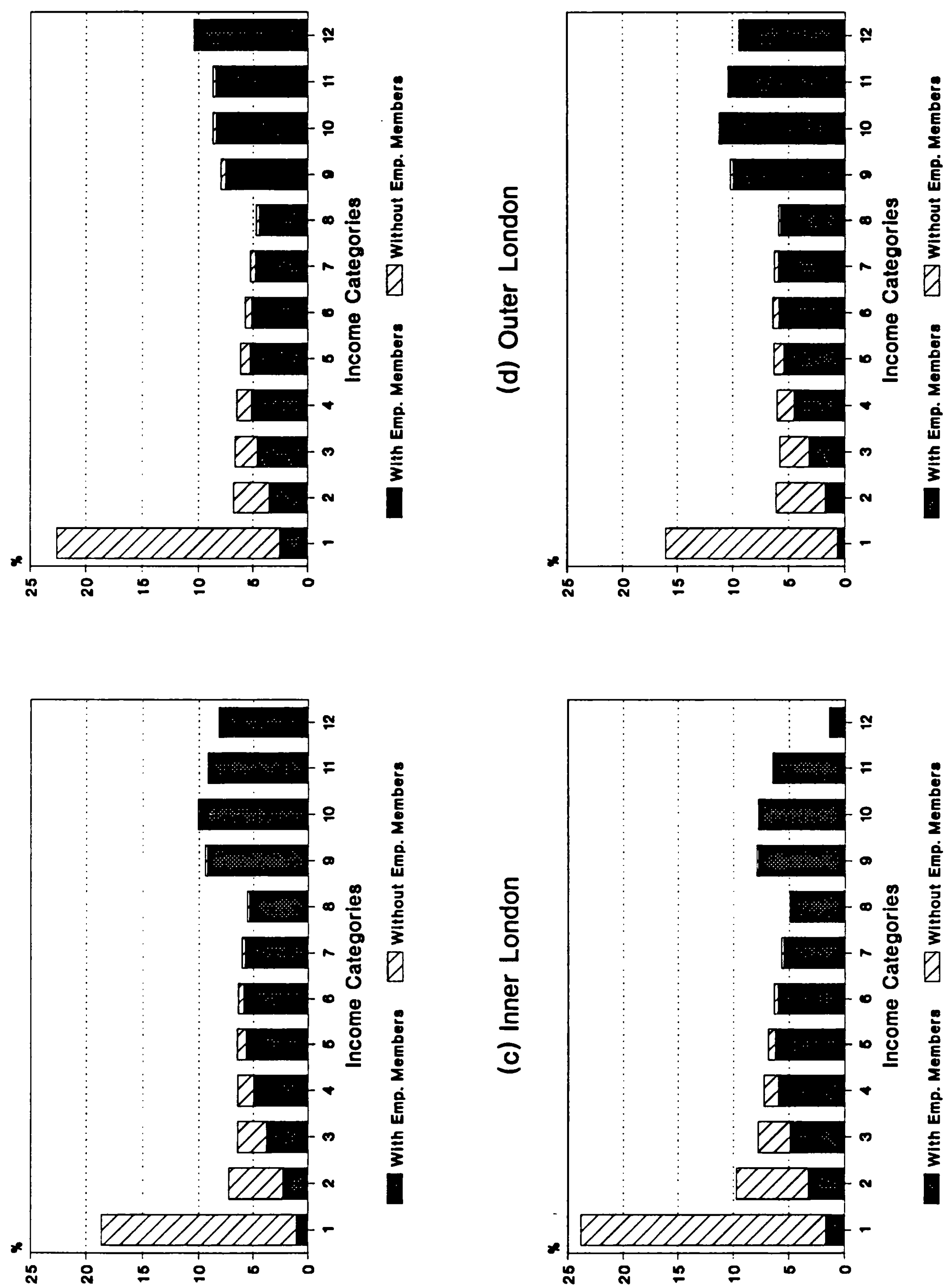
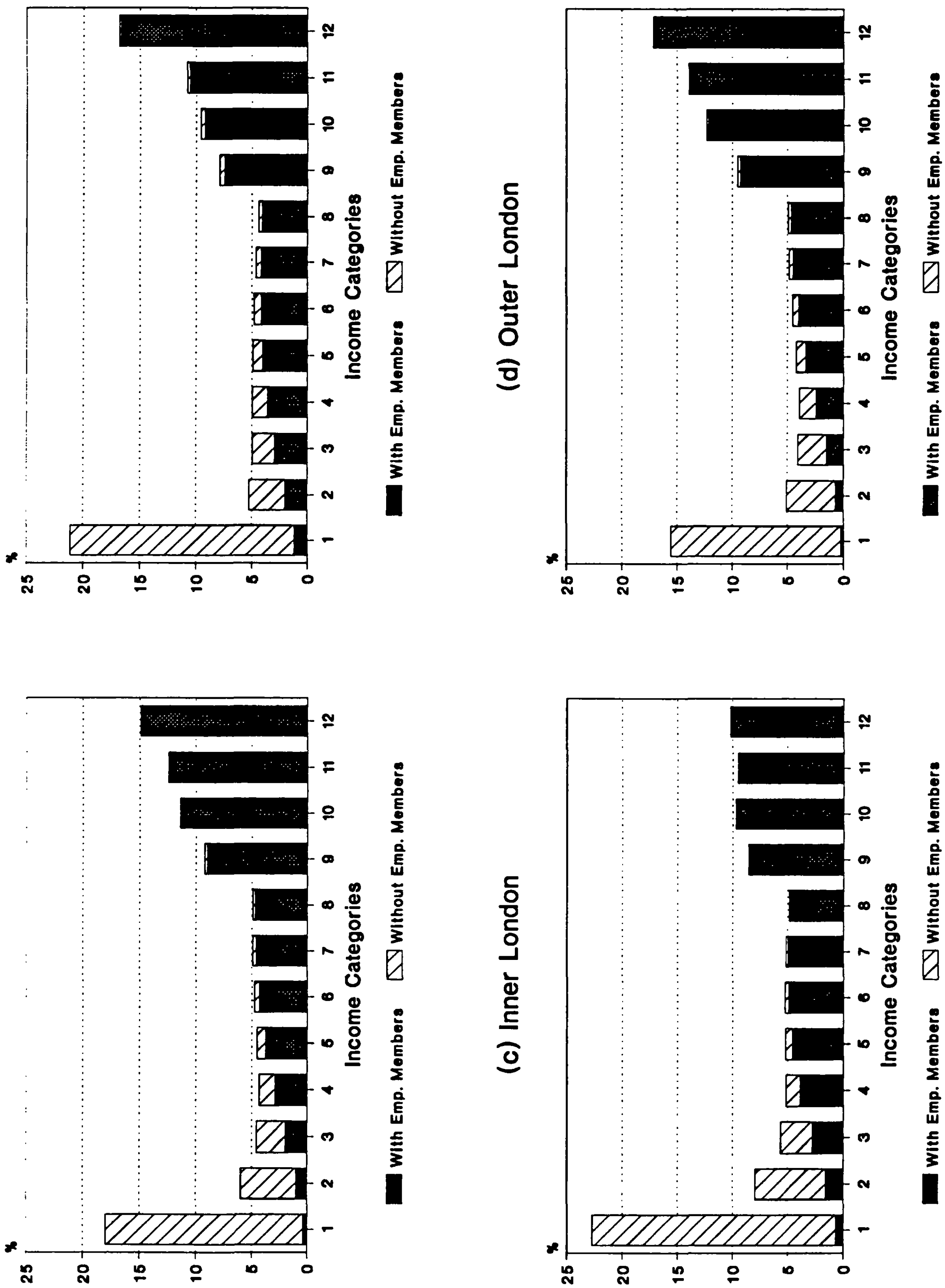


Figure 5.6 **Household income distribution estimated for the forecast year with high income growth**



Forecasting the future household income distribution was thus simplified by assuming that the coefficient of variation remains constant. Changes in income distribution however, depend on a number of government policies and it has been argued that, even though empirical evidence may indicate that this spread parameter is not constant, it is doubtful whether any reliable method could be applied to forecast its future course. This is nevertheless a definite assumption that has been made for the construction of the scenarios.

Assumptions of future growth rate for real income were confined to households income with at least one employed member. Real incomes of other households, those with no employed members, are assumed not to grow. Given these assumptions, and the relative proportions of the two households types, the resulting estimates should be reasonably consistent with forecast estimates of growth in earnings per head.

5.4 Estimating household size distribution

The main reason for considering household size is that the expressions for CV and EV (presented in **Section 3.5**) that are going to be applied in the evaluation require a personal income for the individual tripmakers. Instead, both the GLTS and LTS model work with household income.

Ideally, when dealing with an individual decision, one should take into account the net disposable income available from the household fund for that individual. In practice though, most studies deal with gross household income in relatively coarse bands. Some broad distinction between households with and without children are sometimes also included.

It should be recognized, however, that the conversion from gross household income to disposable income per head is not only a simple matter of dividing by household size. It is true that the more consumers there are in the household, the more demands are placed on the household budget, but little is known, inasfar as would be useful for modelling, about the way in which total household income is allocated among members of the family. In fact, it is often questionable whether household income distribution would translate to a fair (in the sense of equal rights) personal income distribution. The allocation of household income among the different members of the family has been recently explored by the IFS (1991). Another reason for taking into account household structure is that the need to carry out certain household responsibilities - particularly the care of small children - may impose quite binding time constraints on members, which might be expected, other things being equal, to increase, for instance, the value of time. It is thus possible to expect that household structure variables could enter segmentation in relation to both cost and time variables (MVA et al, 1987).

As the effect of household structure on the net disposable income of each individual in a household with given total income is so difficult to quantify, the translation from household income into personal disposable income required for use in the evaluation has, for the purpose of this study, been based solely on household size. This assumption is, of course, a limitation in the construction of the scenarios, and should be acknowledge in the evaluation.

According to the 1981 survey, more than a third of households in Greater London had two persons and around a quarter had only one member. Larger households were less progressively numerous and in particular, fewer than 10% of households had more than 5 persons. The average household size for the whole of Greater London was around 2.4, although it varied considerably by location and income.

Household size and income are highly correlated. In general, bigger households have more employed members generating greater family income. Larger proportions of single or two person household consist of middle-aged or elderly people, mainly of them retired.

Almost 70% of the households at the bottom end of the income distribution have one person only. This represents almost half of all single person households. At the other end of the income distribution only 5% of households had one person, whereas more than 20% had 5 persons or more. With the exception of the highest and lowest income categories, around 40% of the households have two members (this figure being slightly higher at the lower end).

The two-way **Table 5.4** shows the number and proportion of households in each income category by different household sizes.

Location would also be expected to affect the sizes of households. The spatial distribution of households is largely determined by land use and the environment. Higher housing prices and less space available in central areas for instance, have driven many larger households outwards. Employment opportunities and transport facilities would also be expected to affect household location, (as they also bear direct relation with land use, environment and the housing market).

In Central London, almost 45% of households have one person only and over three quarters of the households have less than 3 persons. In contrast, 32% and 22% respectively have one person only in inner and outer sectors.

Almost a quarter of households living in outer sectors have at least 4 members as opposed to 10% living in Central London. Independently of location, between 33% and 40% of households have two members only. In fact, two-persons household represented 38% of all households in London in 1981.

Table 5.5 shows the number and proportion of households for each sector for the different household sizes.

The interaction between location and income in influencing household size was examined in the two way analysis of variance. For all sectors or income categories taken together, the hypothesis that average household size is the same for each income category or sector respectively may be easily contested by inspection of the range of the income values in **Tables 5.4** and **5.5** even though they are based on a sample of only 1.4 per cent. Indeed, from the analysis of variance, F ratios are sufficient high, both for household income and location, to reject the hypothesis of equal means.

Table 5.4 Number and proportion of households in each income category by household size in 1981

IC	Household Size					Total	Average Size
	1	2	3	4	5+		
1	353025 (66.6)	143749 (27.1)	19911 (3.8)	9804 (1.8)	3734 (0.7)	530223 (100.0)	1.43
2	85789 (31.7)	130927 (48.3)	29463 (10.9)	15466 (5.7)	9205 (3.4)	270851 (100.0)	2.00
3	53986 (25.9)	91558 (43.9)	30784 (14.8)	18976 (9.1)	13109 (6.3)	208413 (100.0)	2.26
4	49824 (23.1)	87815 (40.7)	35373 (16.4)	26049 (12.1)	16851 (7.8)	215913 (100.0)	2.41
5	41584 (19.1)	88253 (40.6)	38495 (17.7)	29653 (13.6)	19370 (8.9)	217354 (100.0)	2.52
6	34629 (18.0)	75023 (39.1)	37435 (19.5)	28833 (15.0)	15996 (8.3)	191915 (100.0)	2.56
7	25442 (14.0)	69096 (38.0)	36319 (20.0)	33189 (18.3)	17564 (9.7)	181610 (100.0)	2.72
8	15318 (10.3)	57351 (38.4)	31820 (21.3)	29980 (20.1)	14902 (10.0)	149371 (100.0)	2.81
9	23319 (10.6)	85771 (39.1)	45834 (20.9)	39494 (18.0)	24779 (11.3)	219198 (100.0)	2.80
10	15803 (6.8)	91042 (39.4)	49078 (21.3)	48085 (20.8)	26947 (11.7)	230955 (100.0)	2.91
11	11699 (5.8)	75227 (37.5)	41495 (20.7)	41253 (20.5)	31174 (15.5)	200849 (100.0)	3.02
12	7658 (5.2)	41440 (28.0)	26666 (18.0)	38726 (26.2)	33484 (22.6)	147974 (100.0)	3.33
Total	718078 (26.0)	1037252 (37.5)	422674 (15.3)	359508 (13.0)	227114 (8.2)	2764626 (100.0)	2.40

Note: Numbers in brackets are percentages of the total for the income group.
Source: GLTS 1981

Table 5.5 Number and proportion of households in each sector by household size in 1981

Sector	Household Size					Total	Average Size
	1	2	3	4	5+		
0	26698 (44.4)	20066 (33.3)	7286 (12.1)	3348 (5.6)	2773 (4.6)	60171 (100.0)	1.93
1	107369 (29.9)	133215 (37.2)	49196 (13.7)	37900 (10.6)	30818 (8.6)	358497 (100.0)	2.31
2	85870 (39.7)	73413 (33.9)	27355 (12.6)	19241 (8.9)	10688 (4.9)	216568 (100.0)	2.05
3	96958 (29.4)	115574 (35.1)	49753 (15.1)	36335 (11.0)	31076 (9.4)	329696 (100.0)	2.36
4	61679 (21.3)	113503 (39.1)	47460 (16.4)	44158 (15.2)	23196 (8.0)	289996 (100.0)	2.50
5	88565 (22.7)	154412 (39.5)	62073 (15.9)	56092 (14.4)	29677 (7.6)	390818 (100.0)	2.45
6	84982 (23.3)	139425 (38.2)	58423 (16.0)	50210 (13.8)	31519 (8.6)	364560 (100.0)	2.46
7	95733 (22.5)	158482 (37.3)	68401 (16.1)	62532 (14.7)	40187 (9.4)	425335 (100.0)	2.51
8	70223 (21.3)	129163 (39.3)	52727 (16.0)	49690 (15.1)	27181 (8.3)	328985 (100.0)	2.50
Total	718078 (26.0)	1037252 (37.5)	422674 (15.3)	359508 (13.0)	227114 (8.2)	2764626 (100.0)	2.40

Note: Numbers in brackets are percentages of the total for the sectors.
Source: GLTS 1981

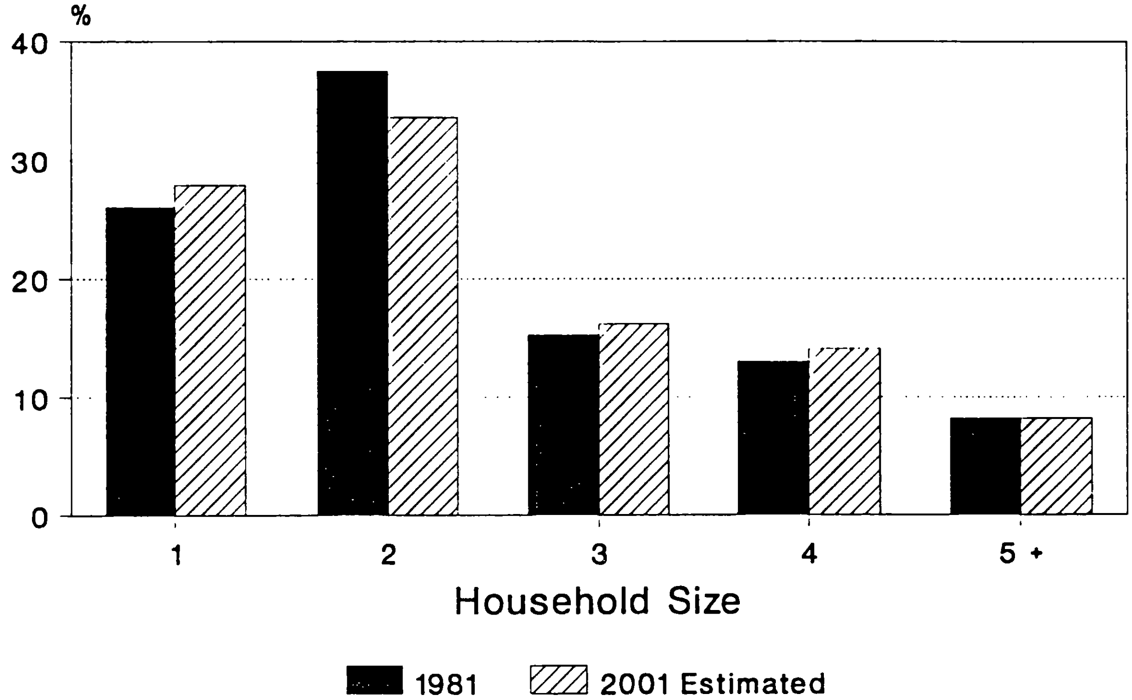
Nevertheless, location and household income are also correlated. In fact, most of the differences in the size of household with respect to location are explained by the household income distribution. Indeed, albeit the location parameter explains some of the differences in the household size, income appears to explain a greater part of the difference. For instance, the hypothesis that the average household size is the same across the study area for the lowest income category cannot be rejected at 5% the level. This also reinforces the notion about household composition for the lowest income category. The influence of location tends though to escalate with income, and the above hypothesis is rejected for all other income categories. The analysis also shows a significant interaction between these two effects.

Hence, the household size distribution for each household income category in the forecast year should be calculated considering both income and location effects.

The total number of households in each household size category (i.e 1, 2, 3, 4, and 5+) were estimated for the forecast year as input parameter for the LTS model for the London Assessment Studies. These were estimated by linear relationships, separately for zones in central, inner and outer London sectors (see **Section 4.2.2**). The results showed, that household size distribution in the forecast year is expected to remain rather similar to observed 1981 figures. Household size distribution for the 1981 survey and estimated figures for the forecast year are illustrated in **Figure 5.7**.

The proportion of households with one person is forecast to increase by about 7%, whereas a reduction of about 10% in the two persons category is expected. Otherwise, roughly similar proportions are forecast. These forecasts have provided the inputs from which household size has been estimated for each income category in the forecast year.

Figure 5.7 Proportion of households in each family size category in 1981 and estimated for forecast year



Source: GLTS 1981

In order to estimate the total number of households for each household size and income category, an iterative procedure has been adopted where estimates have been balanced with marginal totals (i.e. the total number of household in each income category and the total number of households of each household size category). As household location also influences household size, these numbers have been estimated separately for each district.

More rigorously, the problem can be stated as to estimate:

H_{ikz} the total number of households of size **z** (0,1,2,3,4,5+) of income category **k** in district **i**.

such that:

$$\sum_k H_{ikz} = H_{iz} \quad and \quad \sum_z H_{ikz} = H_{ik}$$

where:

H_{ik} is the total number of households of income category k in district i

and

H_{iz} is the total number of households of size z in district i.

Note that **H_{ik}** have been estimated as described in previous section and **H_{iz}** were inputs to the LTS model for the forecasts of the London Assessment Studies.

The final matrix (**H_{ikz}**) is to be estimated taking into account further information provided by another array, (**$h_{s(i)kz}$**) produced from the GLTS of 1981, where **s(i)** is the sector in which district **i** lies, and **$h_{s(i)kz}$** represents the proportion rather than the number of households of size **z** and income category **k** in sector **s(i)**.

A biproportional iterative procedure was adopted for each zone **i**, in which (**H_{ikz}**) is obtained in order that **H_{iz}** and **H_{ik}** constraints are satisfied and starting from the information contained in the array (**$h_{s(i)kz}$**) observed in the 1981 survey. For a more detail description of a similar methodology see **Section 5.5**.

A summary of the results is presented in **Tables 5.6** and **5.7** respectively, which show the totals for the whole GLTS area for the low and high income growth assumptions. The corresponding arrays were, however, calculated for every district for use in the evaluation procedures.

Table 5.6 Number and proportion of households of each household size in each income category estimated for the forecast year with low income growth

Inc. Cat.	Household Size					Total	Average Size
	1	2	3	4	5+		
1	387244 (72.0)	118714 (22.1)	18784 (3.5)	9794 (1.8)	3601 (0.7)	538138 (100.0)	1.37
2	77769 (37.2)	88908 (42.5)	23203 (11.1)	12394 (5.9)	6834 (3.3)	209108 (100.0)	1.96
3	56254 (30.4)	73165 (39.4)	27691 (14.9)	17158 (9.2)	11235 (6.1)	185773 (100.0)	2.21
4	50654 (27.4)	67884 (36.7)	30266 (16.4)	22449 (12.2)	13526 (7.3)	184780 (100.0)	2.35
5	43280 (23.2)	68796 (36.9)	33443 (17.9)	25539 (13.6)	15532 (8.3)	186589 (100.0)	2.47
6	39511 (21.6)	65216 (35.6)	36264 (19.8)	27963 (15.3)	14288 (7.8)	183242 (100.0)	2.52
7	30122 (17.3)	61137 (35.2)	35389 (20.3)	31933 (18.4)	15303 (8.8)	173884 (100.0)	2.66
8	20757 (13.0)	57341 (35.8)	35361 (22.1)	31766 (19.8)	14961 (9.3)	160186 (100.0)	2.77
9	37177 (13.7)	99257 (36.5)	58443 (21.5)	48694 (17.9)	28147 (10.4)	271717 (100.0)	2.75
10	25951 (8.9)	108715 (37.4)	564624 (22.2)	60405 (20.8)	30883 (10.6)	290578 (100.0)	2.87
11	20890 (7.9)	95177 (36.0)	57054 (21.6)	47303 (27.1)	36200 (13.7)	264250 (100.0)	2.96
12	15126 (6.4)	65827 (27.9)	46198 (19.6)	63151 (26.7)	45883 (19.4)	236185 (100.0)	3.25
Total	805006 (27.9)	970137 (33.6)	466720 (16.2)	406174 (14.1)	236393 (8.2)	2884430 (100.0)	2.41

Note: Numbers in brackets are in percentages of the totals for the income categories.

Table 5.7 Number and proportion of households of each household size in each income category estimated for the forecast year with high income growth

Inc. Cat.	Household Size					Total	Average Size
	1	2	3	4	5+		
1	388193 (74.8)	104846 (20.2)	15513 (3.0)	7602 (1.5)	2652 (0.5)	518806 (100.0)	1.33
2	70652 (41.0)	71052 (41.3)	17324 (10.1)	8666 (5.0)	4491 (2.6)	172185 (100.0)	1.87
3	45492 (34.4)	51511 (40.0)	18169 (13.8)	10434 (7.9)	6531 (4.9)	132137 (100.0)	2.10
4	39129 (31.3)	45920 (36.8)	19150 (15.3)	13125 (10.5)	7609 (6.1)	124932 (100.0)	2.23
5	34830 (26.7)	48710 (37.3)	22206 (17.0)	15672 (12.0)	9200 (7.0)	130618 (100.0)	2.36
6	34164 (24.8)	49674 (36.1)	25940 (18.9)	18649 (13.6)	9213 (6.7)	137640 (100.0)	2.41
7	28545 (20.2)	51184 (36.2)	27772 (19.6)	23258 (16.5)	10626 (7.5)	141385 (100.0)	2.55
8	21549 (15.3)	52230 (37.1)	30394 (21.6)	25096 (17.8)	11539 (8.2)	140808 (100.0)	2.67
9	42439 (16.0)	100734 (38.0)	55590 (20.9)	42712 (16.1)	24057 (9.1)	265532 (100.0)	2.64
10	34522 (10.5)	129289 (39.2)	72650 (22.0)	62390 (18.9)	31115 (9.4)	329966 (100.0)	2.78
11	33721 (9.4)	136905 (38.0)	76795 (21.3)	68863 (19.1)	43616 (12.1)	359900 (100.0)	2.87
12	31771 (7.4)	128081 (29.7)	85216 (19.8)	109708 (25.5)	75743 (17.6)	430519 (100.0)	3.16
Total	805005 (27.9)	970137 (33.6)	466720 (16.2)	406175 (14.1)	236393 (8.2)	2884430 (100.0)	2.41

Note: Numbers in brackets are in percentages of the totals for the income categories.

As expected, irrespective of the growth assumption, household size tends to increase with income. Also, as a result of the differences in the rate of growth of household income, the estimated household size distribution for each income category is slightly different for the high and low growth assumptions.

5.5 Estimating household income distribution for the trip ends

In this section household income distributions for the trip ends have been estimated separately for trip production and attraction. Trip production income distribution was estimated by category analysis, whereas for trip attraction it was estimated similarly to household income distribution. In addition, estimates from the trip production models are balanced with those from the attraction. The final results are later aggregated into five income categories. These steps are described separately in turn.

5.5.1 Trip production. The centre of the trip production mechanism is the household.

In several transport studies, household categories have been used to predict the total number of trips produced. In the LTS model in particular, household categories have been used to estimate both trip production and attraction (this is described in the previous chapter).

For the construction of the scenarios in this study, in order to estimate household income distribution for the trip origins, household trip rates have been defined and calculated for each transport mode. The objective is to estimate trip rates by each mode for households in different categories and location in 1981.

Three different modes have been considered. Private motor vehicle includes driver and passenger by car and motor cycle. Public transport includes buses, London Transport underground and British Rail trains. Last, although walking and cycling are at present not considered by LTS, household trip rates by these modes have been also estimated separately for analysis. Households are classified by the various income categories and by location.

The data from the GLTS 1981 comprise $\mathbf{H_{ik}}$ and $\mathbf{O_{ikm}}$ for each district **i** where:

$\mathbf{O_{ikm}}$ is the total number of trips by mode **m** made by people of household income **k** in district **i**

$\mathbf{H_{ik}}$ is the total number of households of income **k** in district **i** (as defined in **Section 5.4**).

Ideally, it would be desirable to estimate trip rates by each district, but data are too sparse for this. It was therefore decided to estimate a rate $\mathbf{R_{skm}}$ for each sector **s**. Note that each district **i** is in just one sector **s(i)**. The estimate should take account of the effects of income and location on the trip rate. Furthermore, these effects are known to differ among modes, so trips rates have been estimated separately for each transport mode.

Hence, for a given mode **m** the data consist of pairs of values $\mathbf{O_{ikm}}$ and H_{ik} and the R_{skm} to be estimated is a typical value of the ratio $\mathbf{O_{ikm}/H_{ik}}$ for districts **i** in sector **s**. It is therefore appropriate to fit a multiplicative model in which the $\mathbf{O_{ikm}}$ and $\mathbf{H_{ik}}$ are treated as two observations of the same variable **X** made at two different levels of a factor whose level is denoted by a subscript **t**, so that:

$$\mathbf{X_{1ikm} = O_{ikm}} \qquad \text{and} \qquad \mathbf{X_{2ikm} = H_{ik}}$$

The complete multiplicative model of this form in which effects are estimated at sector level rather than district is defined, in the conventional notation of generalised linear modelling as:

$$\ln X_{tikm} = a_{tm} + b_{sm} + c_{km} + (bc)_{skm} + (ac)_{tkm} + (ab)_{tsm} + (abc)_{tskm} + e_{tikm}$$

where $s = s\ (i)$

The third-order interaction term $\mathbf{(abc)_{tskm}}$ added little to the explanatory power of the model and was therefore omitted. The model for the ratio $\mathbf{X_{1ikm}/X_{2ikm} = O_{ikm}/H_{ik}}$ thus takes the form:

$$\ln\left(\frac{X_{1ikm}}{X_{2ikm}}\right) = a_{1m} - a_{2m} + (ac)_{1km} - (ac)_{2km} + (ab)_{1sm} - (ab)_{2sm} + \epsilon_{1ikm} - \epsilon_{2ikm}$$

It follows that the model yields as the required estimate $\mathbf{R_{skm}}$:

$$R_{skm} = \exp\{a_{1m} - a_{2m} + (ac)_{1km} - (ac)_{2km} + (ab)_{1sm} - (ab)_{2sm}\}$$

which is the product of an overall estimated rate $\mathbf{\exp(a_{1m}\text{-}a_{2m})}$ multiplied by an income factor $\mathbf{\exp\{(ac)_{1km}\text{-}(ac)_{2km}\}}$ common to all sectors and a sector factor $\mathbf{\exp\{(ab)_{1sm}\text{-}(ab)_{2sm}\}}$ common to all income categories.

The results given by the model are summarized in **Table 5.8.**

As expected, the result shows the higher mobility attained by higher income categories, both for private and public transport. The estimated coefficients indicates that on average, during peak times, higher income groups travel significantly more than their lower income counterparts, particularly by private transport. To a some extent, this is also true for walking and cycling, although there is a reduction in trip rates by these modes for the highest income categories.

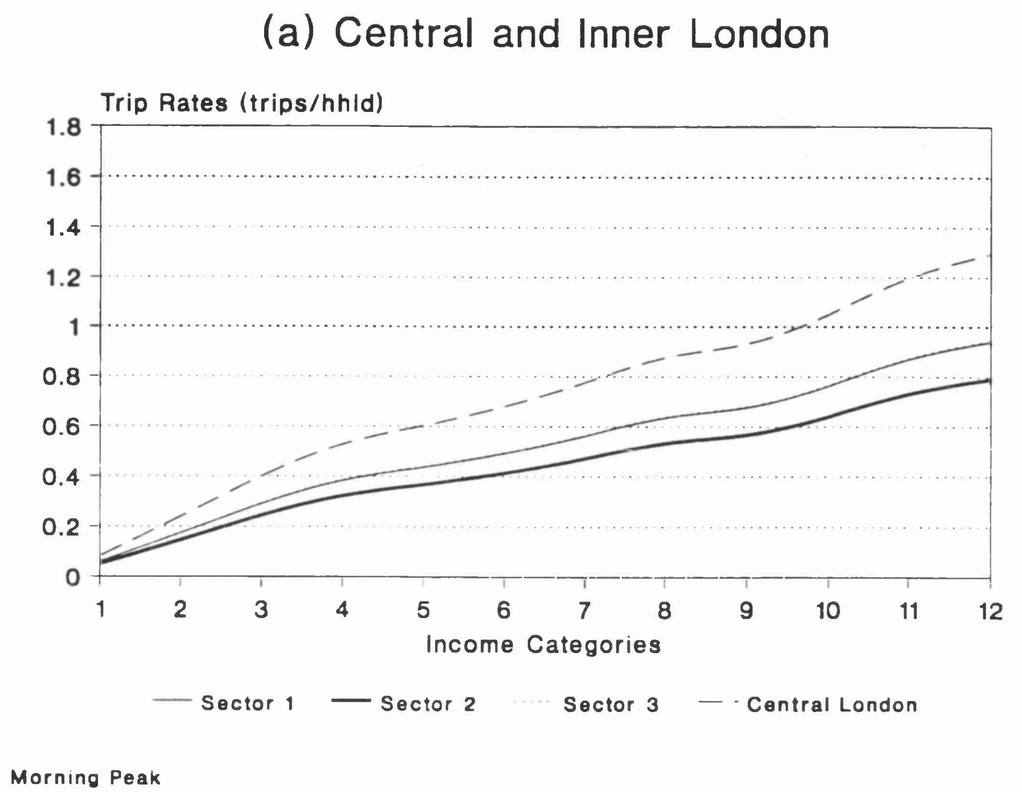
It is also interesting to note the location effect on the different transport modes. The outer sectors show a considerably higher trip rates for private transport than inner sectors. The opposite is true for public transport, with households in inner sectors more dependent on public transport for their trip to work. It also shows the substantially higher trip rates for walking and cycling within central London. A summary of the results, illustrating the estimated trip rates is presented in **Figures 5.8, 5.9** and **5.10** respectively for private transport, public transport, and walking and cycling.

Table 5.8 Estimated coefficients and standard errors from the log-linear model Private Transport, Public Transport, Walking and Cycling, 1981

	PRIVATE		PUBLIC		WALK & CYCLE	
	Coeff	St Err	Coeff	St Err	Coeff	St Err
Constant	-0.604	0.012	-0.762	0.012	-0.495	0.010
Sector 0	0.078	0.060	0.317	0.058	0.390	0.048
Sector 1	-0.242	0.026	0.213	0.024	-0.109	0.024
Sector 2	-0.416	0.032	0.082	0.030	-0.215	0.030
Sector 3	-0.238	0.028	0.211	0.026	0.121	0.024
Sector 4	0.154	0.024	-0.074	0.028	-0.046	0.026
Sector 5	0.262	0.022	-0.270	0.026	-0.078	0.022
Sector 6	0.177	0.022	-0.250	0.028	0.002	0.024
Sector 7	0.231	0.020	-0.123	0.024	-0.070	0.022
Sector 8	-0.006	*	-0.107	*	0.006	*
Income 1	-1.956	0.044	-1.098	0.030	-0.692	0.024
Income 2	-0.925	0.038	-0.554	0.034	-0.146	0.026
Income 3	-0.365	0.034	-0.217	0.034	0.102	0.028
Income 4	-0.091	0.030	-0.094	0.032	0.130	0.028
Income 5	0.018	0.030	-0.028	0.032	0.191	0.028
Income 6	0.134	0.030	0.030	0.034	0.194	0.030
Income 7	0.268	0.030	0.130	0.034	0.223	0.030
Income 8	0.410	0.032	0.237	0.036	0.174	0.034
Income 9	0.437	0.026	0.239	0.030	0.095	0.028
Income 10	0.562	0.026	0.340	0.028	0.015	0.028
Income 11	0.724	0.026	0.419	0.030	-0.127	0.032
Income 12	0.784	*	0.597	*	-0.160	*

*Coefficients for Sector 8 and Income 12 are determined by estimation from the other sectors and income levels because the sums of coefficients are required to be zero.
The standard errors can be assumed to be similar to those for other sectors and income groups.

Figure 5.8 Private Transport trip rates estimated from the 1981 survey



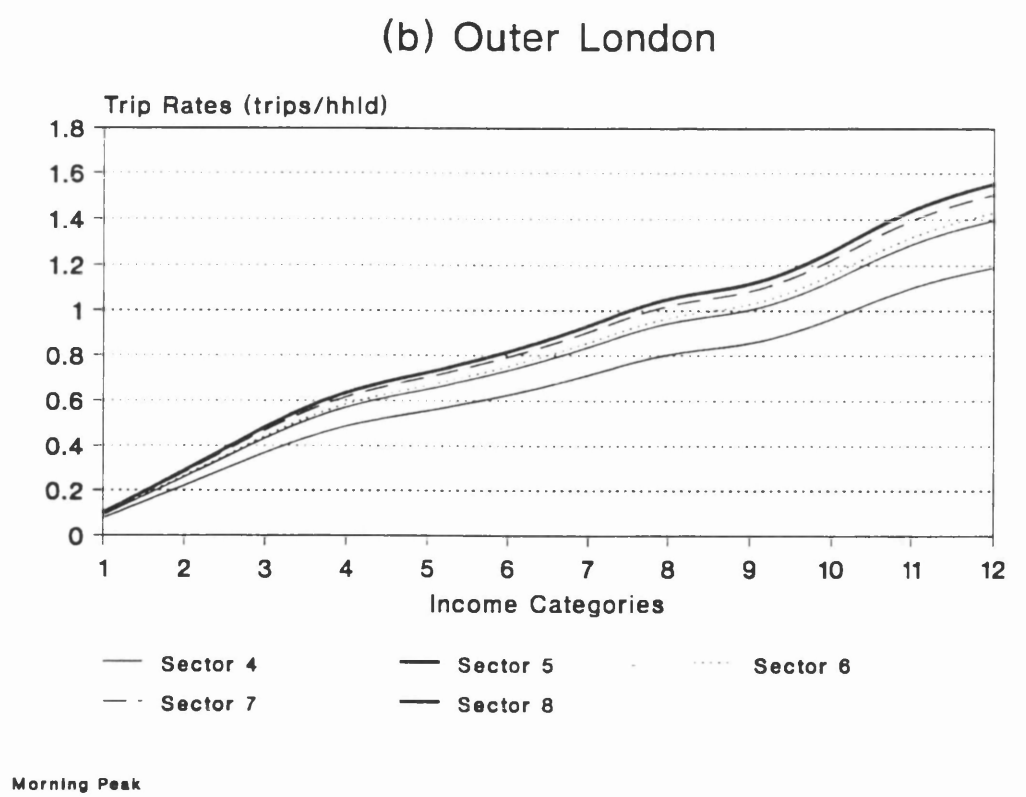
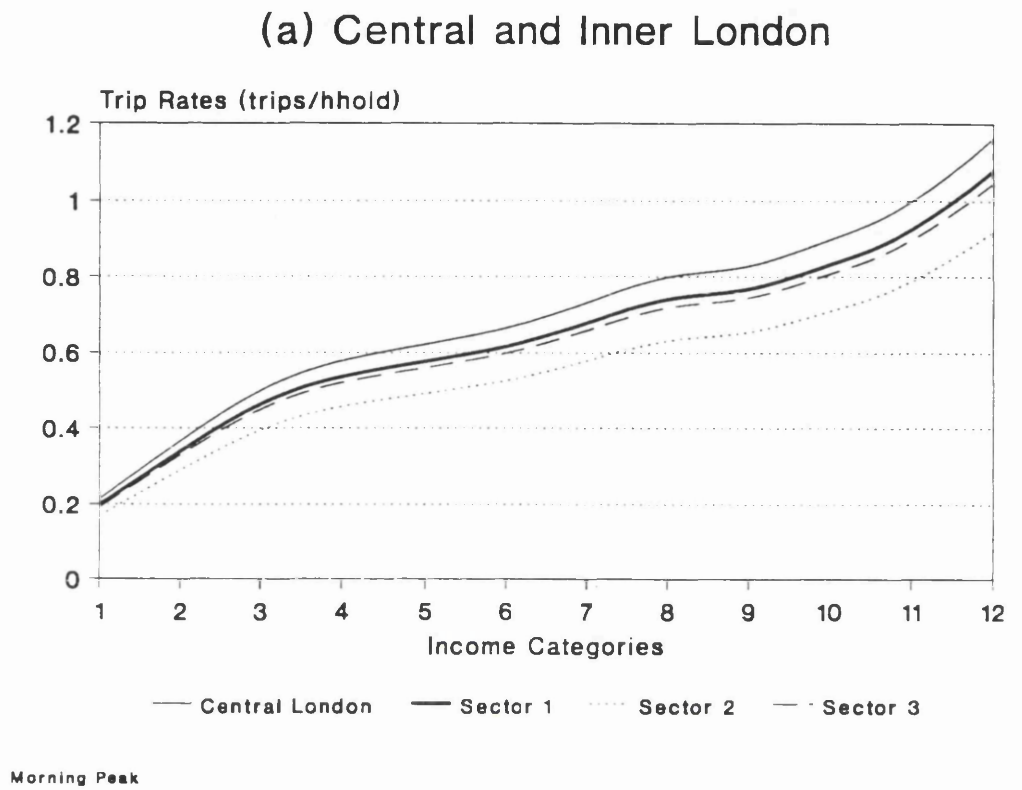


Figure 5.9 Public Transport trip rates estimated from the 1981 survey



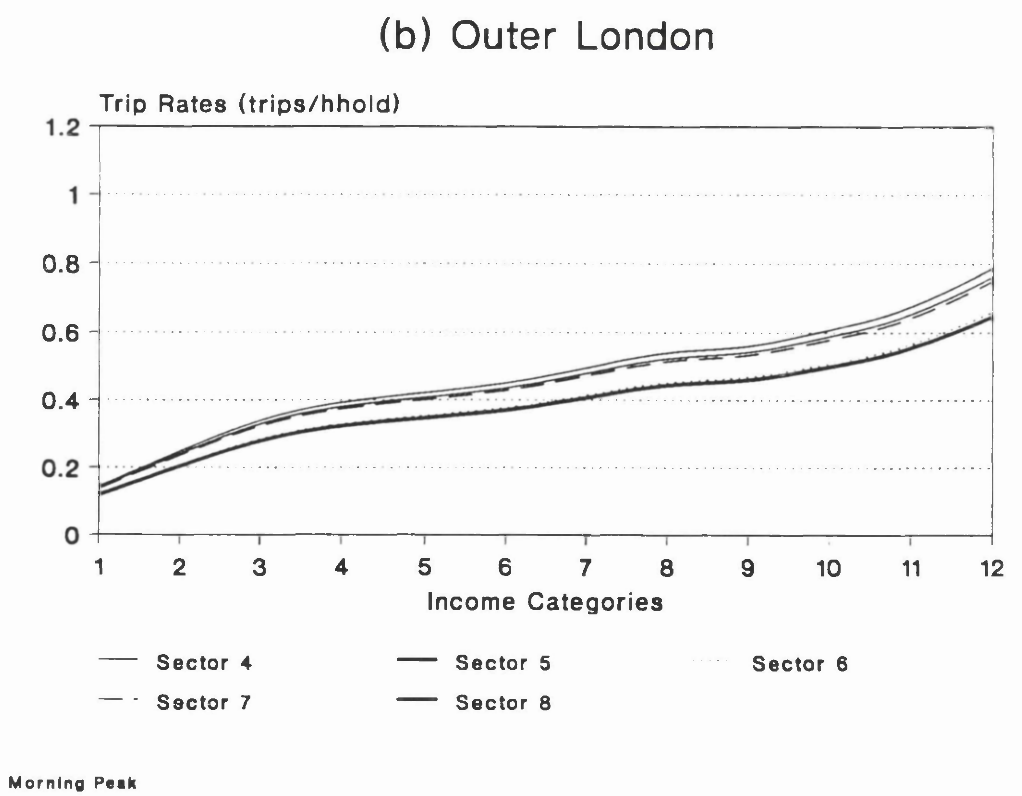
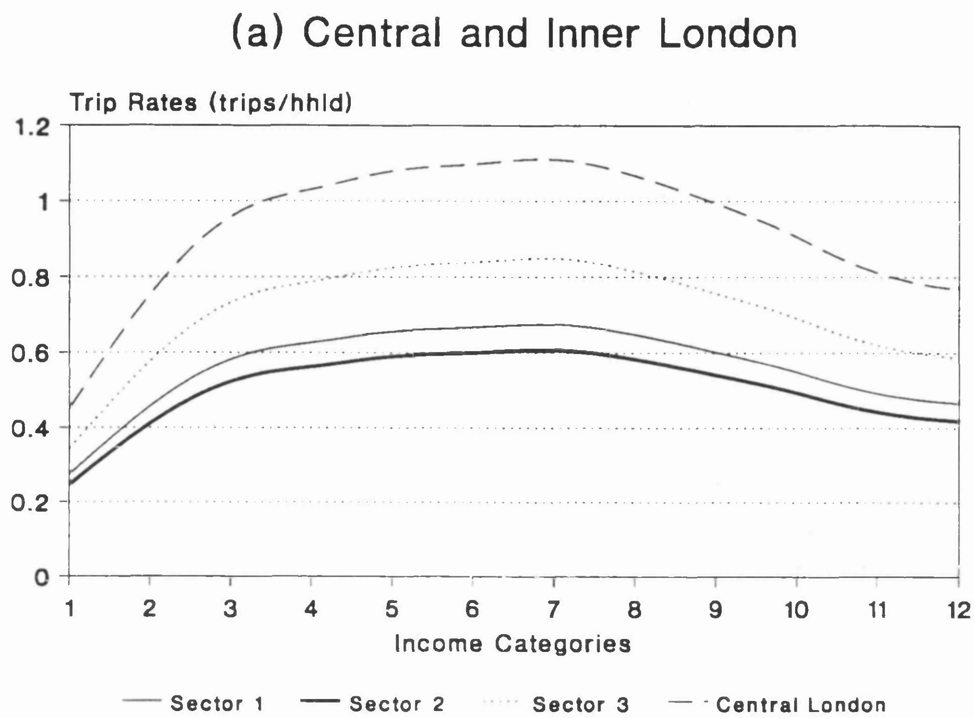
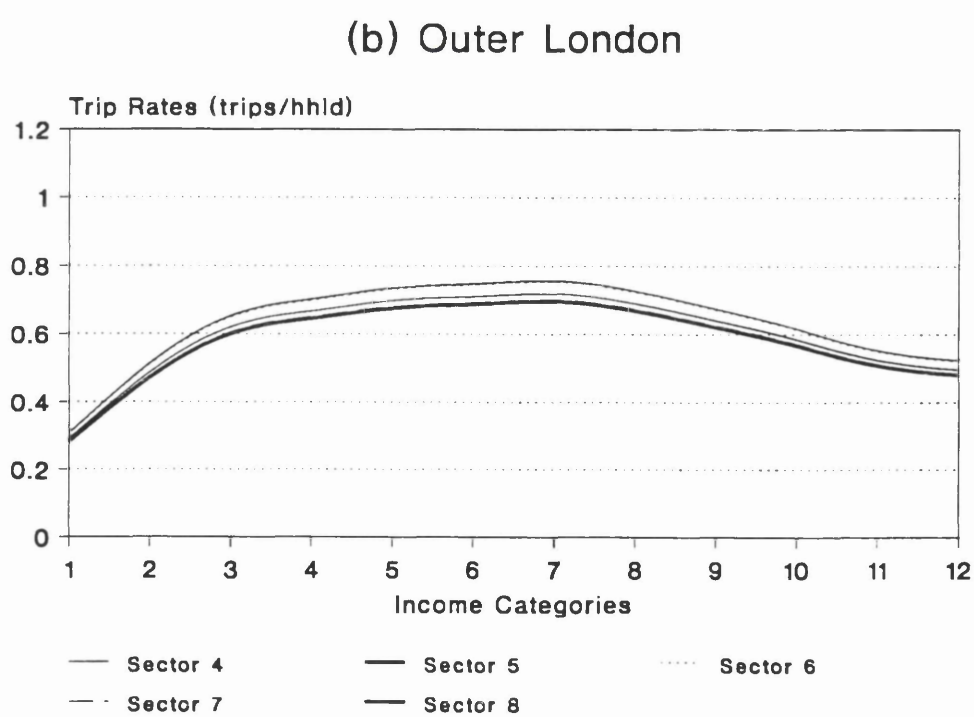


Figure 5.10 Walking and Cycling trip rates estimated from the 1981 survey



Morning Peak



Morning Peak

This modelling exercise yields a total of (12 x 9 = 108) different trip rates for each transport mode. For the purpose of estimating income distributions for the trip productions in the forecast year, these rates are assumed to remain constant over the years. Travellers are thus regarded as changing their travel behaviour indirectly as a result of an increase in their income, or changes in their household location.

These trip rates are used to estimate the proportion $\mathbf{P_{ikm}}$ of the trips by mode **m** produced in district **i** (in sector **s(i)**) that are made by people living in households in income category **k** to be:

$$P_{ikm} = \frac{H_{ik} \cdot R_{s(i)km}}{\sum_{k=1}^{K} H_{ik} \cdot R_{s(i)km}}$$

where **K** is the number of income categories.

For trips originating outside the cordon, the corresponding proportion $\mathbf{P_{ckm}}$ of trips by mode **m** produced was estimated from the proportions estimated for all the districts within the outer sectors. This is given by:

$$P_{ckm} = \frac{\sum_{i} P_{ikm}}{N}$$

where the summation is over all districts **i** within the outer sectors, where **N** is the number of districts within those sectors.

The distribution of trips across the income categories as estimated from the production models for the public and private modes are summarized in **Table 5.9.** and **Table 5.10** for the low income growth assumption and **Tables 5.11** and **5.12** for the high growth counterparts.

Table 5.9 Percentage of public transport trips produced by each income category estimated for the forecast year with low income growth

IC	Sector										
	Central	Inner			Outer					Cordon	Tot
	0	1	2	3	4	5	6	7	8		
1	7.29	8.15	7.95	9.34	5.21	4.89	4.74	4.99	5.21	5.00	6.18
2	3.81	5.62	5.03	7.13	3.61	3.07	3.01	3.56	3.27	3.30	4.20
3	5.26	6.72	6.34	7.34	4.60	4.23	3.91	4.64	4.78	4.30	5.21
4	5.82	7.11	6.57	7.62	5.29	4.98	4.63	5.35	5.91	5.10	5.85
5	5.91	7.22	6.47	7.81	5.86	5.50	5.29	5.85	6.69	5.59	6.26
6	5.84	7.09	6.21	7.66	6.29	5.83	5.79	6.17	7.13	5.99	6.47
7	5.91	7.07	6.11	7.54	6.76	6.22	6.35	6.57	7.55	6.49	6.75
8	5.94	6.92	6.02	7.19	7.09	6.50	6.77	6.82	7.73	6.79	6.87
9	10.04	11.11	9.92	11.08	12.34	11.37	12.00	11.80	13.01	11.79	11.59
10	12.19	12.14	11.57	11.25	14.85	14.12	14.91	14.24	14.73	14.39	13.55
11	13.15	10.92	11.87	9.10	14.44	14.99	15.33	14.39	13.22	14.69	13.19
12	18.85	9.92	15.93	6.94	13.67	18.29	17.29	15.60	10.78	16.58	13.89
T	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 5.10 Percentage of private transport trips produced by each income category estimated for the forecast year with low income growth

IC	Sector										
	Central	Inner			Outer					Cordon	Total
	0	1	2	3	4	5	6	7	8		
1	3.01	3.23	3.12	3.84	1.92	1.77	1.70	1.82	1.94	1.90	2.16
2	2.48	3.62	3.17	4.76	2.16	1.80	1.75	2.12	1.97	2.00	2.33
3	4.19	5.41	4.96	6.11	3.44	3.00	2.82	3.43	3.55	3.30	3.69
4	5.33	6.66	6.00	7.35	4.60	4.14	3.92	4.61	5.09	4.50	4.88
5	5.64	7.05	6.15	7.83	5.36	4.79	4.72	5.31	6.06	5.21	5.55
6	5.89	7.33	6.24	8.12	6.12	5.39	5.57	5.97	6.89	5.91	6.17
7	6.13	7.54	6.39	8.21	6.84	5.99	6.38	6.60	7.57	6.61	6.75
8	6.36	7.65	6.51	8.14	7.45	6.54	7.09	7.14	8.09	7.11	7.21
9	10.98	12.58	11.01	12.78	13.31	11.96	12.98	12.68	14.01	12.71	12.67
10	13.67	14.09	13.28	13.29	16.46	15.43	16.66	15.83	16.43	15.92	15.55
11	15.99	13.74	14.89	11.65	17.48	18.26	18.60	17.48	16.21	17.52	16.82
12	20.35	11.11	18.29	7.94	14.86	21.00	17.83	17.01	12.20	17.32	16.21
T	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 5.11 Percentage of public transport trips produced by each income category estimated for the forecast year with high income growth

IC	Sector										
	Central	Inner			Outer					Cordon	Total
	0	1	2	3	4	5	6	7	8		
1	6.31	7.15	6.96	8.14	4.66	4.35	4.26	4.41	4.66	4.40	5.45
2	2.69	4.19	3.81	5.32	2.79	2.30	2.33	2.68	2.43	2.50	3.16
3	3.62	4.41	4.54	4.62	3.02	2.74	2.52	2.99	3.02	2.80	3.40
4	4.09	4.58	4.73	4.73	3.17	3.09	2.71	3.26	3.54	3.10	3.65
5	4.34	4.94	4.79	5.35	3.56	3.49	3.12	3.67	4.13	3.50	4.06
6	4.50	5.31	4.83	5.90	4.08	3.92	3.64	4.15	4.75	4.00	4.52
7	4.81	5.78	5.05	6.43	4.76	4.50	4.36	4.78	5.52	4.60	5.10
8	5.09	6.15	5.24	6.77	5.42	5.06	5.05	5.37	6.17	5.20	5.62
9	9.19	10.97	9.31.	11.72	10.64	9.77	10.08	10.35	11.74	10.19	10.54
10	12.32	13.87	12.14	13.97	15.22	13.96	14.77	14.56	15.95	14.59	14.33
11	15.06	14.84	14.22	12.59	18.35	17.62	18.57	17.68	17.86	17.88	16.71
12	28.00	17.83	24.39	13.48	24.35	29.22	28.60	26.11	20.25	27.27	23.47
T	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 5.12 Percentage of private transport trips produced by each income category estimated for forecast year with high income growth

IC	Sector										
	Central	Inner			Outer					Cordon	Total
	0	1	2	3	4	5	6	7	8		
1	2.54	2.72	2.66	3.20	1.68	1.56	1.51	1.56	1.68	1.60	1.85
2	1.74	2.59	2.36	3.41	1.62	1.32	1.32	1.55	1.42	1.50	1.70
3	2.83	3.40	3.49	3.68	2.20	1.94	1.77	2.14	2.19	2.10	2.33
4	3.67	4.12	4.17	4.36	2.67	2.52	2.21	2.72	2.95	2.70	2.93
5	4.05	4.64	4.41	5.12	3.13	2.96	2.69	3.21	3.61	3.10	3.41
6	4.44	5.27	4.70	5.97	3.83	3.52	3.38	3.87	4.43	3.80	4.07
7	4.90	5.93	5.07	6.72	4.65	4.20	4.20	4.64	5.29	4.60	4.82
8	5.30	6.53	5.48	7.33	5.51	4.91	5.08	5.44	6.20	5.40	5.58
9	9.81	11.95	10.00	12.96	11.11	9.77	10.51	10.76	12.15	10.69	10.90
10	13.45	15.51	13.44	15.81	16.36	14.60	16.00	15.65	17.07	15.58	15.58
11	17.81	18.02	17.21	16.67	21.55	20.49	22.00	20.80	21.03	20.78	20.31
12	29.46	19.31	14.78	26.99	25.68	32.23	29.33	27.68	21.97	28.17	26.53
T	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Finally, these proportions are applied to estimated trip ends from the matrices generated for the London Assessment Studies, and therefore for the forecast year:

$$O_{ikm} = P_{ikm} . O_{im}$$

Note that from previous equation,

$$\sum_{k=1}^{K} P_{ikm} = 1$$

hence:

$$O_{im} = \sum_{k=1}^{K} O_{ikm}$$

which is a constraint required later.

5.5.2 Trip attraction The assumptions adopted to estimate household income distribution for the trips by each transport mode that are attracted to each district are similar to those used in the process of estimating household income distribution described in **Section 5.3**. Accordingly, two types of trips are defined: trips from households with at least one employed member and trips from households without employed members.

For trips from households with at least one employed member, a lognormal distribution of the household incomes was assumed. For each district and mode, the parameters for the distribution of incomes of households of origin of those trips arriving in that district by that mode were estimated from the 1981 survey. Moreover, over time the coefficient of variation of household income for each such distribution was held constant while both the mean and standard deviation were increased in line with income growth. Similarly, for trips from households without an employed member, the lognormal distribution of household income for trips arriving by each mode was supposed constant in real terms over time, but for these distributions, as in the case of the income distributions of the households themselves, the parameters were estimated at the sector level.

The observed distribution and the distribution modelled with the parameters estimated from the 1981 survey aggregated for the whole of Greater London are presented in **Figures 5.11** and **5.12** respectively for the public and private modes. Assuming that the proportion of trips from those two kinds of household do not change, the corresponding distribution was predicted for the forecast year.

The total number of employed residents in the households, as well as the number of households for each household size category, for the forecast year were estimated from linear relationships with employment and the number of households (see **Section 4.2.2** of previous chapter).

Although in reality the proportion of households with and without employment might well be different in the forecast year due to changes in society at large, in the absence of information for the construction of the scenarios, it was assumed that these proportions did not change.

Figure 5.11 Aggregated observed and modelled household income distribution for public transport trips arriving in Greater London

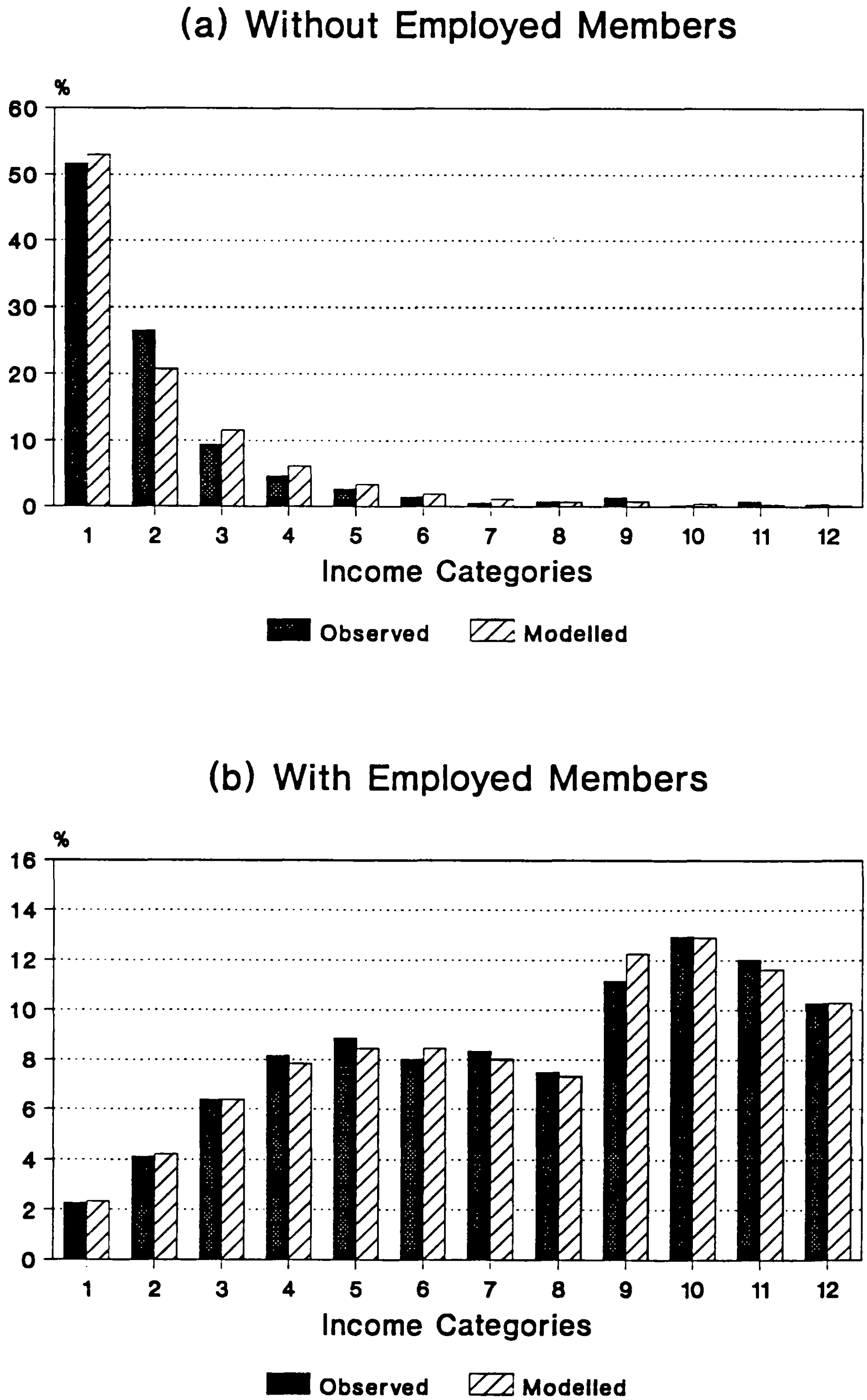
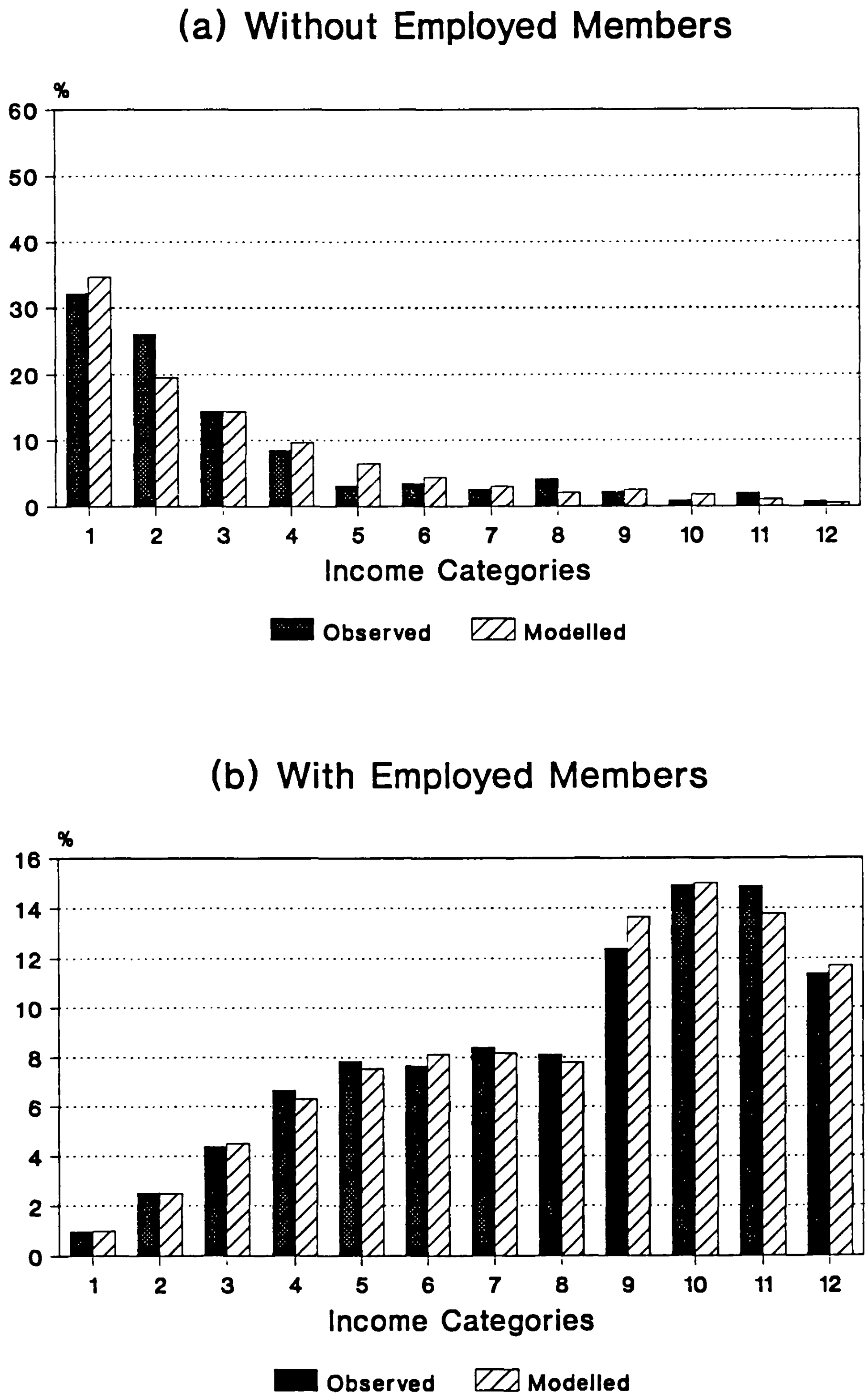


Figure 5.12 **Aggregated observed and modelled household income distribution for private transport trips arriving in Greater London**



5.5.3 Trip End Balancing and Aggregation. Because the income distributions for trip productions and attractions were estimated independently, it was necessary for the aggregate proportions given by the attraction models to be balanced with those given by the production models for each income category. Comparison of the proportions before balancing provided, however, a further check on the consistency of the two processes.

The household income distributions for the trips as estimated from the production and attraction models are generally similar, particularly for the low income growth assumption. However, the attraction models have underestimated the number of trips estimated for the lower income groups, both for public and private transport modes. Estimated distributions of household income for the trip productions and attractions are summarized in **Table 5.13**.

Table 5.13 Percentages of trips by private and public transport in each income category estimated from the production and attraction models for the forecast year

Inc. Cat.	Low Income				High Income			
	Public		Private		Public		Private	
	Prod	Att	Prod	Att	Prod	Att	Prod	Att
1	6.18	5.99	2.16	1.78	5.45	5.33	1.85	1.48
2	4.20	4.14	2.33	2.00	3.16	2.89	1.70	1.21
3	5.21	4.88	3.69	3.08	3.40	2.98	2.33	1.61
4	5.85	5.73	4.88	4.31	3.65	3.48	2.93	2.26
5	6.26	6.38	5.55	5.42	4.06	4.13	3.41	3.04
6	6.47	6.69	6.17	6.22	4.52	4.70	4.07	3.82
7	6.75	6.68	6.75	6.67	5.10	5.09	4.82	4.48
8	6.87	6.42	7.21	6.78	5.62	5.28	5.58	4.96
9	11.59	11.51	12.67	12.92	10.54	10.48	10.90	10.64
10	13.55	13.34	15.55	15.97	14.33	13.89	15.58	15.55
11	13.19	13.54	16.82	16.92	16.71	16.80	20.31	20.25
12	13.89	14.70	16.21	17.93	23.47	24.87	26.53	30.71
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

There was no reason however to expect exact balance between the attraction and production models, and, given that the differences are not very large, a single set of balancing factors have been applied correcting the estimates of the trip attraction to match those from the trip production for each income category. The factors required to balance the aggregate distributions were applied in each district.

Finally, trips were aggregated into five income categories. The number of five income categories were adopted in order to carry out the evaluation for different income subgroups, representing low and high income categories as well as further three intermediate categories. These categories were selected in order to distribute, as equally as possible, the total number of trips (both by public and private transport) among the five categories. The five new income categories considered were:

Table 5.14 Aggregated household income categories in the forecast year (1981 prices)

Aggregated Income Categories		Incorporating Original Categories
1	less than £6000	1 - 2 - 3 - 4
2	£6000 - £ 9999	5 - 6 - 7 - 8
3	£10000 - £14999	9 - 10
4	£15000 - £19999	11
5	£20000 or more	12

Note that these aggregated income categories have been used for estimating household income distribution for the trip interchanges described in the next section and throughout the evaluation.

The resulting estimates of income distribution for the trip ends is illustrated in **Figure 5.13**. **Figures 5.14** and **5.15** show the public transport trips origin and destination for the different regions of the study area respectively for the low and high income growth assumption. **Figures 5.16** and **5.17** show the private transport trips counterparts.

Figure 5.13 Final household income distribution for the trip ends estimated for the forecast year

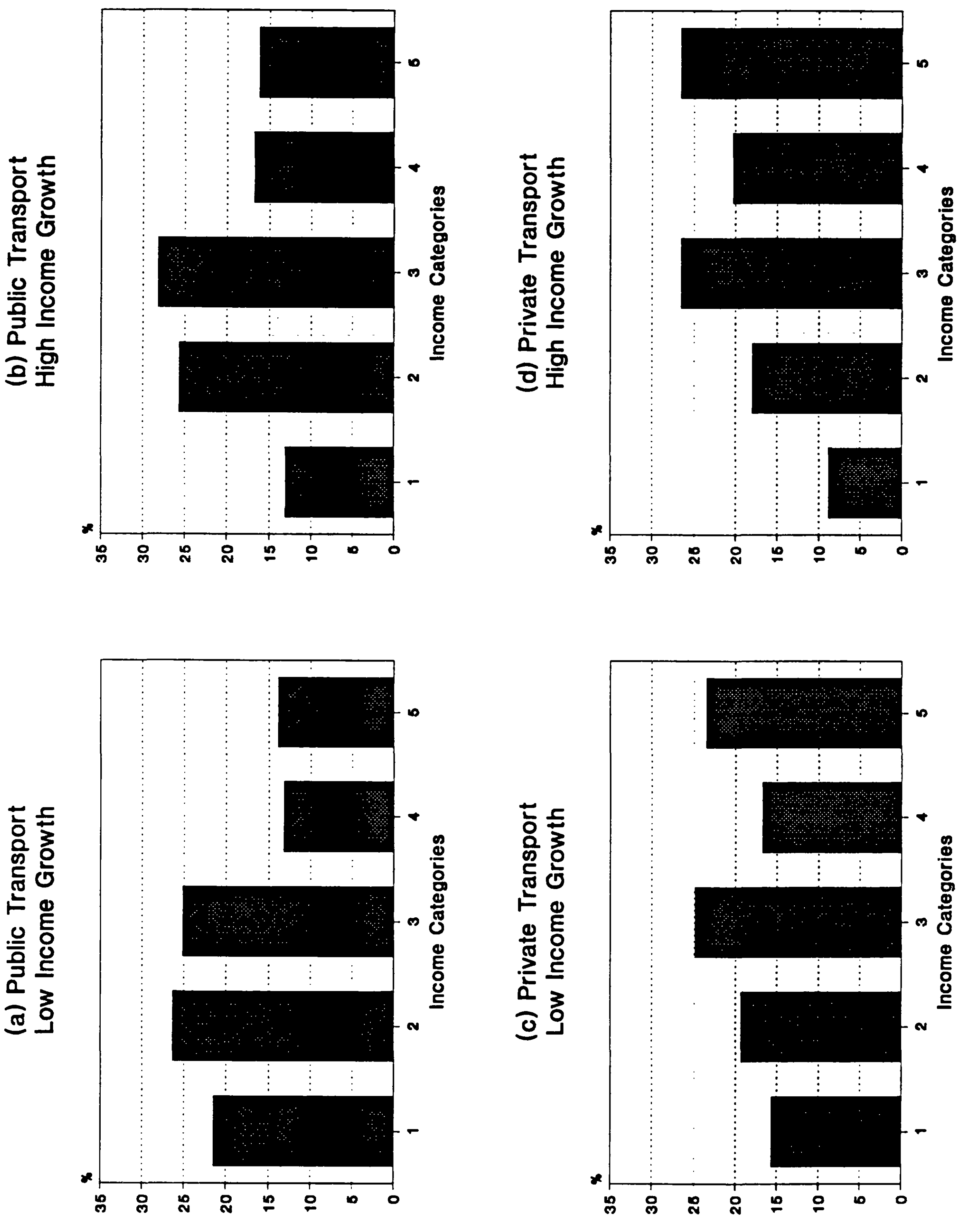


Figure 5.14 Final household income distribution for public transport trips origin and destination estimated for the forecast year with low income growth

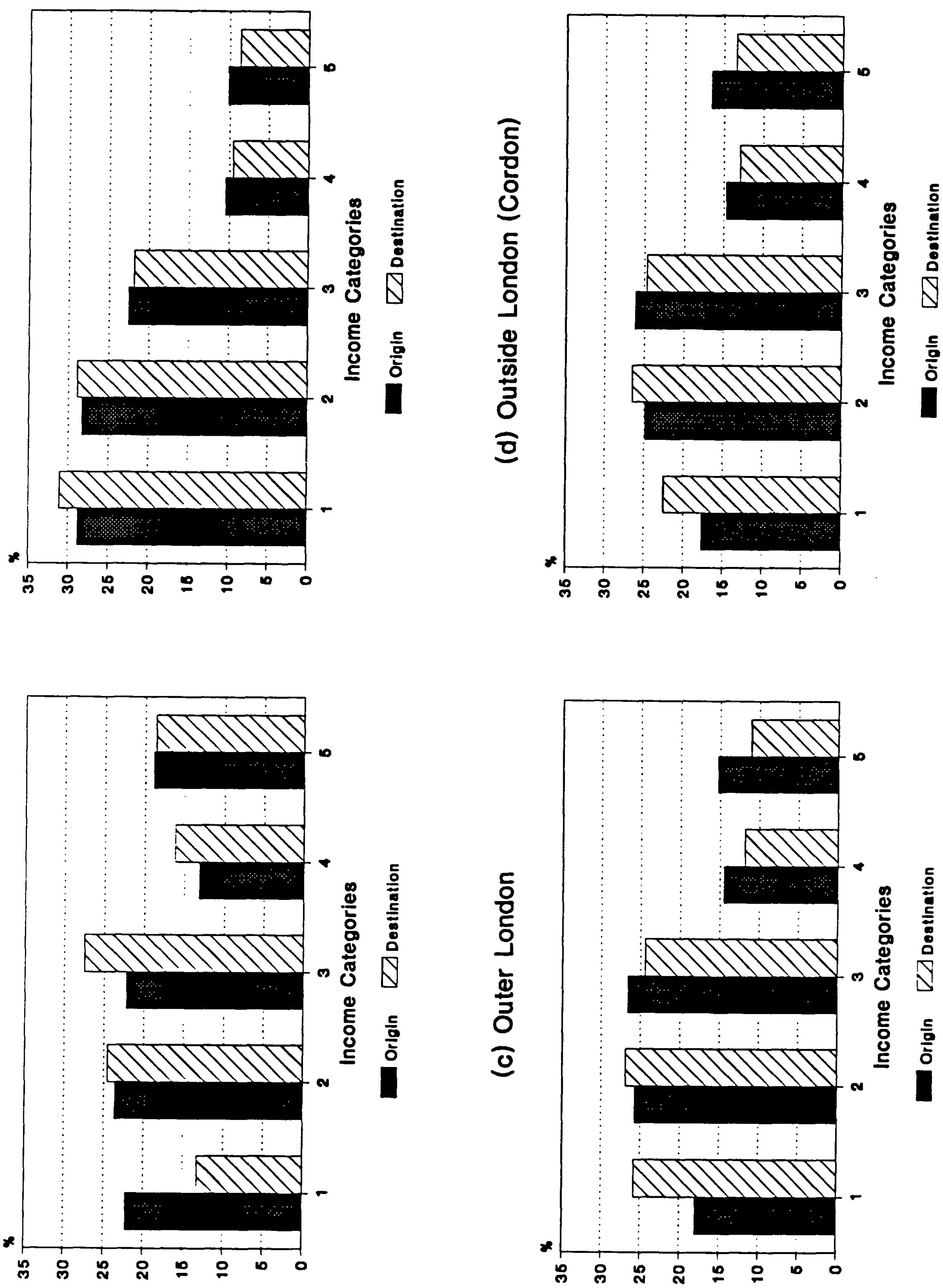


Figure 5.15 Final household income distribution for public transport trips origin and destination estimated for the forecast year with high income growth

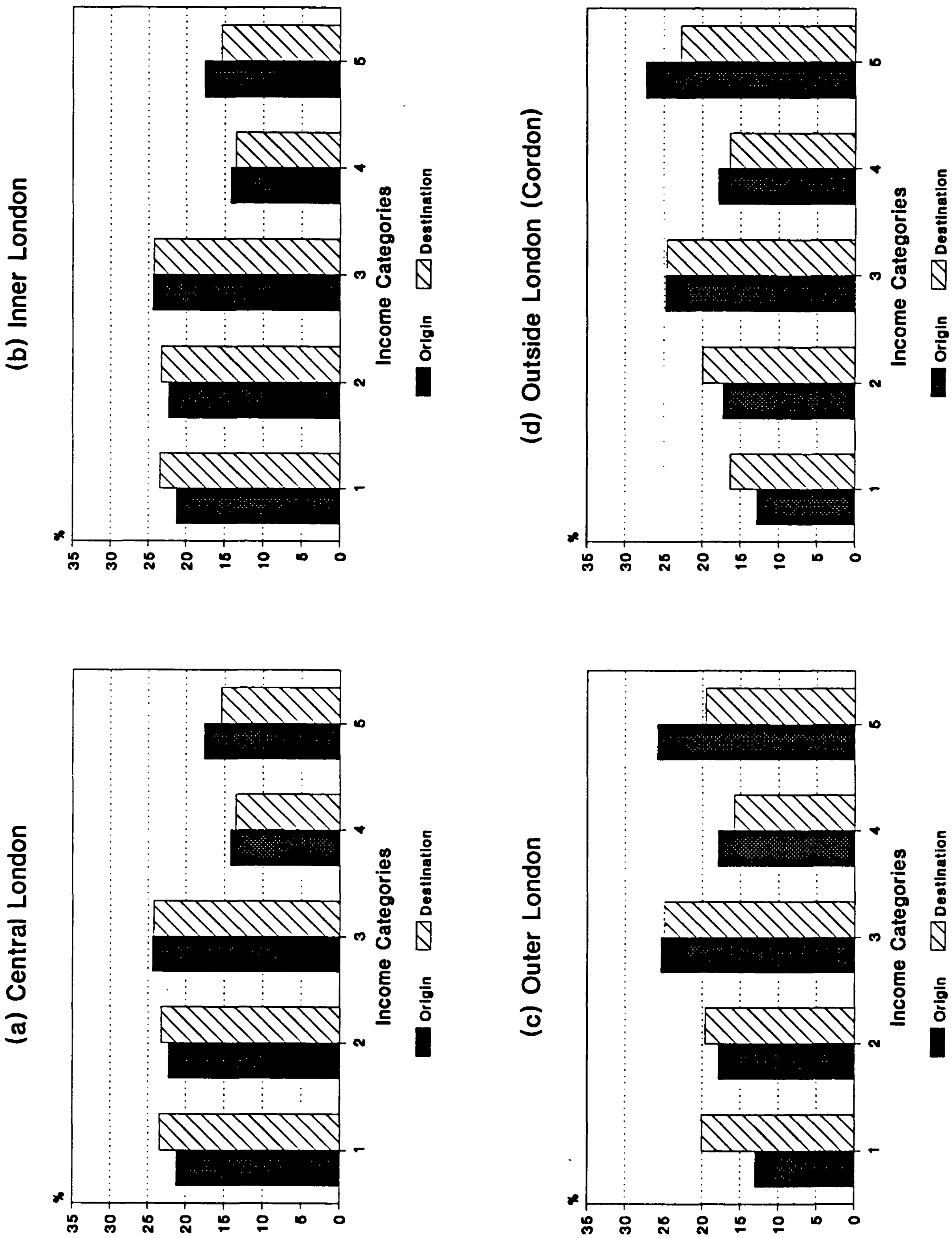


Figure 5.16 Final household income distribution for private transport trips origin and destination estimated for the forecast year with low income growth

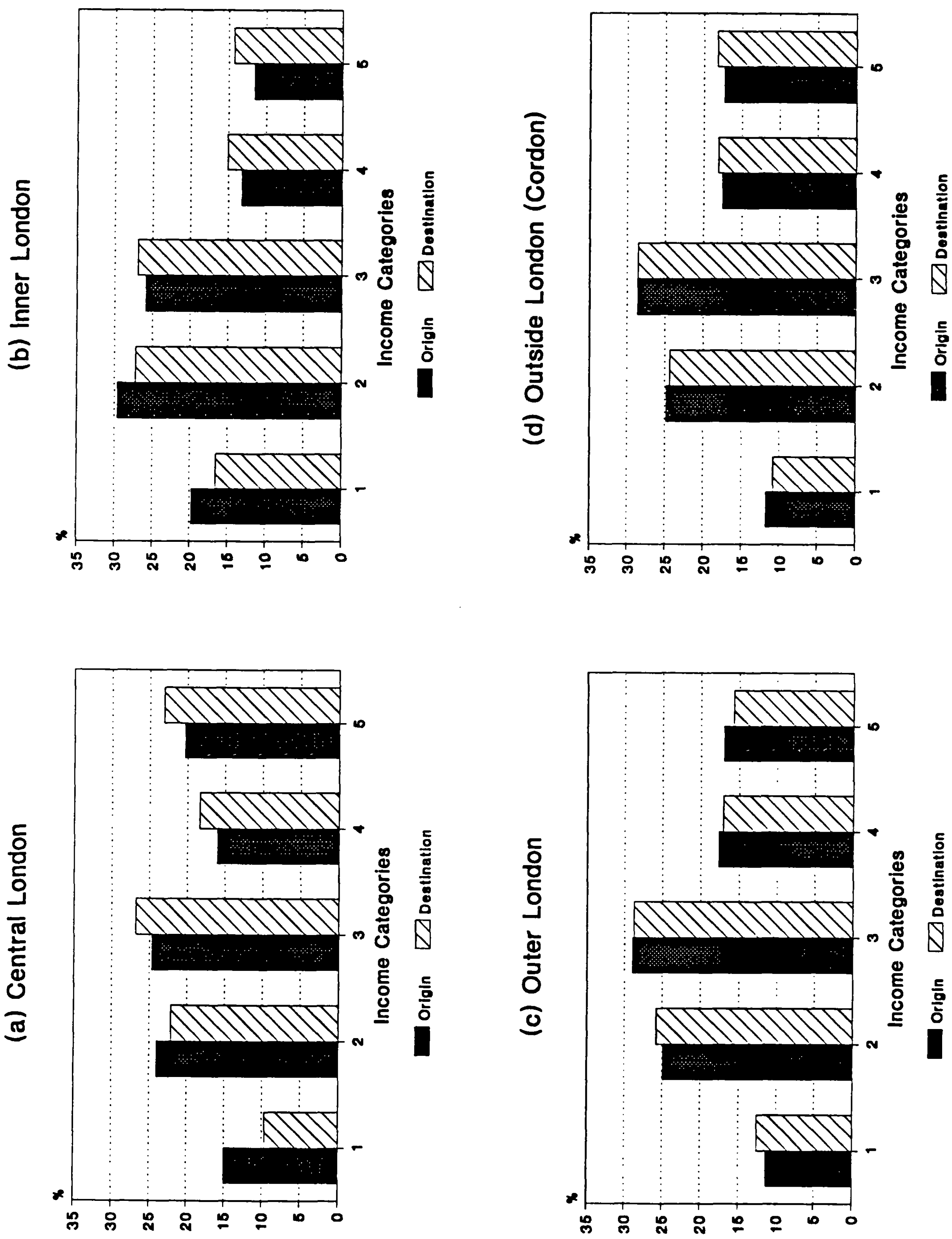
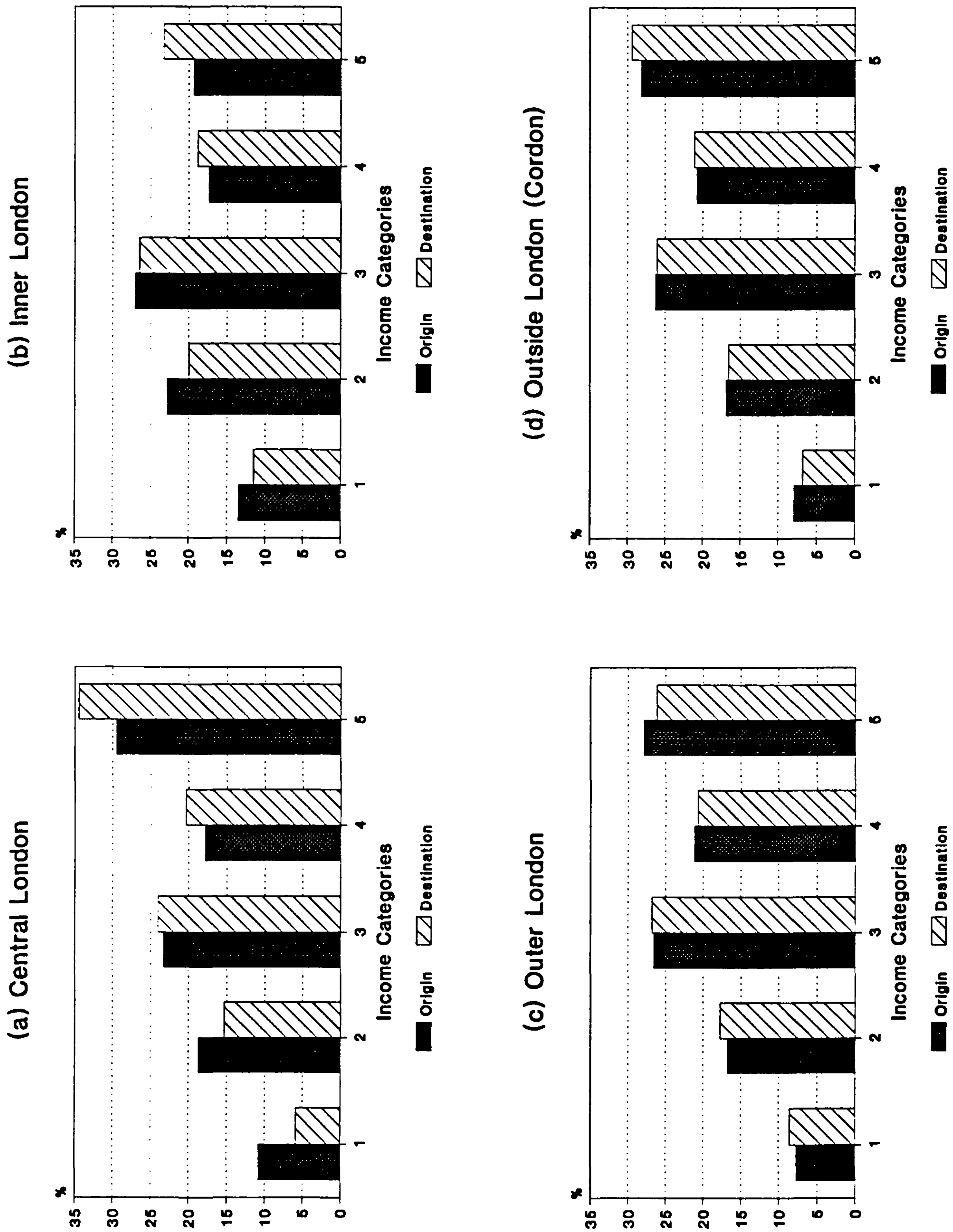


Figure 5.17 Final household income distribution for private transport trips origin and destination estimated for the forecast year with high income growth



5.5.4 Discussion. In order to estimate income distribution for the trip ends it would have been desirable to have included the number of employed residents and household size (in the case of trip production) and employment (in the case of trip attraction) for each income category. However, this would require forecasts for all the inputs, probably similarly to the way household size was estimated in previous sections. Thus, simplicity and consistency could have been jeopardised. Moreover, although household income is correlated with both household size and employment, the additional information provided by those variables would have been offset by the reduction in sample sizes.

Perhaps the principal attribute of the category analysis approach is that it simplifies the concept of household trip making behaviour. It is intuitively appealing to categorise households according to certain characteristics, and to associate with each household type an average or expected trip-making behaviour. The result suggest that the categorization used of households by location and income categories, and of trips by mode, gives a reasonable representation of such behaviour for the purpose of scenario building.

The fact that no formal mathematical relation is postulated to explain travel generation and income distribution, represents both the strength and weakness of the technique. On the one hand this avoids the difficult problems of specifying variables which may affect trip-making characteristics and income distribution. At the same time there is no facility for testing the statistical significance of various explanatory variables which may affect such relations, other than those included in the chosen models.

Tables of estimated numbers of trips by each mode from and to each district by people from households in each income category for the do-minimum scenario are given in **Appendix 2**.

5.6 Estimating household income distribution for the trip interchanges

The estimation of the household income distribution for the trip interchanges by each transport mode for each scenario can be approached similarly to the conventional trip distribution problem of the transport planning process.

In the forecast year, let:

O_i the number of trips starting in origin district i,

D_j the number of trips ending in destination district j,

T_{ij} number of trips from origin district i to destination district j.

Note that for the sake of simplicity the subscript **m**, specific to each transport mode, has been omitted in this section.

The **O_i**, **D_j** and **T_{ij}** are estimated numbers from the London Assessment Study where:

$$\sum_j T_{ij} = O_i,\ \sum_i T_{ij} = D_j \ \text{and} \ \sum_i O_i = \sum_j D_j = \sum_i \sum_j T_{ij} = T$$

Let also,

O_{ik} be the total number of trips produced by households of income k at origin i,

D_{jk} be the total number of trips of income category k ending at destination j,

and

T_{ijk} be the number of trips of income group k from origin i to destination j.

Both $\mathbf{O}_{ik}$ and $\mathbf{D}_{jk}$ are estimated from the household income and trip end models described previously, and the $\mathbf{T}_{ijk}$ are to be estimated taking into account the information provided by the corresponding three dimensional trip matrix, $(\mathbf{t}_{ijk})$ produced from the GLTS 1981 survey, the trip ends $\mathbf{O}_{ik}$ and $\mathbf{D}_{jk}$, and the trip interchanges $\mathbf{T}_{ij}$.

It is often appropriate to seek a matrix **T** which is obtained from another matrix **t** by applying a set of different multipliers to each pair of the three dimensions. In this form the trip distribution problem for trips disaggregated by income category, can be stated mathematically as follows:

Given $\mathbf{O}_{ik} \geq 0$, $\mathbf{D}_{jk} \geq 0$ such that:

$$\sum_k O_{ik} = O_i \quad and \quad \sum_k D_{jk} = D_j$$

and hence:

$$\sum_i \sum_k O_{ik} = \sum_j \sum_k D_{jk} = T$$

and any matrix $(\mathbf{t}_{ijk})$ of strictly positive elements, to find a matrix **T** of the form

$$T_{ijk} = r_i s_j p_k t_{ijk}$$

such that

$$\sum_j T_{ijk} = O_{ik}, \ \sum_i T_{ijk} = D_{jk} \ and \ \sum_k T_{ijk} = T_{ij} .$$

Let

$$\sum_i \sum_j T_{ijk} = T_k$$

These equations together imply that:

$$p_k r_i \sum_j s_j t_{ijk} = O_{ik}$$ for each i and k;

$$p_k s_j \sum_i r_i t_{ijk} = D_{jk}$$ for each j and k;

$$r_i s_j \sum_k p_k t_{ijk} = T_{ij}$$ for each i and j;

$$p_k \sum_i \sum_j r_i s_j t_{ijk} = T_k$$ for each k;

The problem then becomes that of finding the balancing factors, the r_i, s_j and p_k. It has not been possible to solve these equations for the r_i, s_j and p_k explicitly. Murchland (1966) has proved the existence and uniqueness of solutions, for the two-dimensional matrix, provided that all $t_{ij} \geq 0$. Existence and uniqueness was proved once again by Evans (1970) using a different method. The extension to the three dimensional case is immediate.

The **T** matrix can however be calculated to any required degree of accuracy using the Furness Iterative Procedure. These can be formally expressed:

Let $\{\mathbf{t}^{(n)};n=1,2,...\}$ be the sequence obtained by setting $\mathbf{t}^{(1)}=\mathbf{t}$ and calculating $\mathbf{t}^{(n+1)}$ from $\mathbf{t}^{(n)}$ at the n^{th} interaction as follows:

Iteration 3m - 1 (m=1,2,...)

Multiply each row i of each layer k of $t^{(3m-1)}$ by:

$$x_{ik}^{(m)} = \frac{O_{ik}}{\sum_{j} t_{ijk}^{(3m-1)}}$$

and thus making the ith row-sum for each layer k equal to O_{ik} as required.

Iteration 3m (m=1,2,...)

Multiply each column j of each layer k of $t^{(3m)}$ by:

$$y_{jk}^{(m)} = \frac{D_{jk}}{\sum_{i} t_{ijk}^{(3m)}}$$

and thus making the jth column-sum for each layer k equal to D_{jk} as required.

Iteration 3m + 1 (m=0,1,2,...)

Multiply each row i of each column j of $t^{(3m+1)}$ by:

$$z_{ij}^{(m)} = \frac{T_{ij}}{\sum_{k} t_{ijk}^{(3m+1)}}$$

and thus making the ith row-sum for each column j equal to T_{ij} as required.

A different sequence of matrices would be obtained if we have operated on the pairs of dimensions in a different order, but Evans (1970) has proved that the limiting matrices of all such sequences are in fact the same.

The methodology above has been used to estimate household income distribution for each cell on the origin destination matrix. The iterative procedure has been applied to each of the scenarios under investigation and for the low and high income growth assumptions. The 1981 GLTS was used to constructed the initial array.

5.7 Transition matrix

The breakdown by income groups of estimated numbers of trips by each mode will be used to derive aggregate measures of CV, EV and changes in consumer surplus, for two different pairs of alternatives in the notional scenarios. These are: highway and public transport investment policies each compared with the base (or do-minimum) situation.

The benefits associated with each of the two investment alternatives, are to be assessed for people in each income category and for the different measures proposed. The corresponding values of the marginal utility of income will also be investigated together with their use as weighting factors for obtaining an aggregate measure of welfare benefit. However, before the evaluation some further estimates and consideration are required.

The expressions for CV and EV presented in **Chapter 3** provide measures of the welfare effect of travel time and cost changes at the individual level. Thus, for comparison of two scenarios it is necessary to have knowledge of the changes in both costs and travel times (c_{do}, c_{d1} and t_{do}, t_{d1} in the equation in **Section 3.5**) for each mode and origin/destination pair concerned. Moreover, the discussion in **Section 3.5** is in terms of the individual. In practice, changes experienced by individuals must be aggregated to provide an overall measure of the welfare effect.

Before aggregation is considered, it is important to notice that:

(a) the total number of trips for each alternative scenario is the same:

$$\sum_i \sum_j \sum_m \sum_k T_{ijmk}^{(rail)} = \sum_i \sum_j \sum_m \sum_k T_{ijmk}^{(highway)} = \sum_i \sum_j \sum_m \sum_k T_{ijmk}^{(base)}$$

i.e. generation is assumed not to take place under either of the two investment alternatives; but

(b) redistribution by mode and/or destination may take place.

From the beginnings of the theory of travel behaviour, it has been clear that as the modal demand curves are inter-related, so the demand curve for any individual origin and destination will be closely related to all the other demand curves, since to varying degrees many journey destinations are substitutes for each other. This would mean that for scenarios being compared, differences may occur in numerous interzonal costs, and in one or more modes. The problem is to derive a measure of benefit which applies for all of them simultaneously.

In this sense, for each mode and zone pair, users can be divided into two classes: the first consist of users who travel between the same origin and destination by the same mode in both scenarios, and the second consists of those whose behaviour differs as a result of the differences in generalised cost resulting from the investment alternative that is being evaluated.

Suppose that for two scenarios being compared, there are $\mathbf{T_{ijkm}^{(0)}}$ and $\mathbf{T_{ijkm}^{(1)}}$ trips between origin **i** and destination **j**, for income category **k** by mode **m** (where superscripts **0** and **1** denote the two scenarios). Suppose also that $\mathbf{T_{ijkm}^{(1)}>T_{ijkm}^{(0)}}$. Let us now assume that:

(i) $\mathbf{T_{ijkm}^{(0)}}$ is the number of users in income category **k**, who travel between origin **i** and destination **j** by mode **m** in both scenarios. These users of the transport system who make the same trip will experience a benefit or cost equal to the difference in the welfare (however evaluated) associated with their travel by that mode between the zone pair concerned.

(ii) $\mathbf{(T_{ijkm}^{(1)} - T_{ijkm}^{(0)})}$ is the number of users in income category **k** in scenario **1** whose behaviour differs as compared with scenario **0** in such a way as to travel from **i** to **j** by mode **m** either by different choice of origin/destination pair, mode or both. Without further information on their travel patterns, we can not calculate the changes in welfare associated to this group of travellers. Suitable further assumptions have to be made about the behaviour of these travellers in scenario **0**.

Similarly, if $T_{ijkm}^{(1)}<T_{ijkm}^{(0)}$ the counterpart can be assumed. $T_{ijkm}^{(1)}$ represents the number of relevant users whose choice is the same with and without improvements in the transport system. In addition, further assumptions would have to be made about the behaviour of $(T_{ijkm}^{(0)} - T_{ijkm}^{(1)})$ travellers in scenario 1.

Assumption (i) in fact minimizes the number of people whose travel differs as between scenarios. For assumptions (ii), an entropy formulation can be used to derive the most likely matrix which satisfies underlying hypotheses about the patterns of travel in the two scenarios. The entropy formulation is described in Section 5.7.1 that follows.

5.7.1 An entropy formulation. The concept of entropy has been used to generate plausible travel patterns when only aggregate data is available. The notion has its origin in physics but its use has been extended to several other fields. Together with related measure of information, the concept of entropy has found several applications in urban and regional system. It has also been successfully applied in connection with different aspects of transport planning.

Entropy maximization has been used to derive doubly-constrained gravity models, as well as serving as the basis for the development of several more elaborate transport demand models. It has also been used to derive measures of user benefits (Williams, 1976) as mentioned in **Chapter 3**, although as stated by Jara-Diaz and Farah (1988), 'the entropy formulation does not easily fit into the idea of choice and utility'.

Whatever the use however, entropy is related to the functional form x.lnx. In a two-dimensional Origin-Destination Matrix (T_{ij}), the number of possible micro-states associated to the system may be expressed:

$$W(T_{ij}) = \frac{T!}{\prod_i \prod_j T_{ij}!}$$

where:

$W(T_{ij})$ is the total number of micro-states that generates the same T_{ij} matrix.

It is often assumed that the most likely arrangements for the elements in the matrix will be the one that maximises the total number of micro-states. The maximization of $W(T_{ij})$ can be achieved by maximizing its logarithm as a monotonic transformation of it, which is approximated well by the quantity:

$$S = -\sum_{i}\sum_{j} T_{ij} \ln T_{ij}$$

The problem here however is to obtain the most likely distribution over origins, destinations and modes for trips in each income category which may have redistributed over the years as a result of difference in transport policies. Users' behaviour may differ in terms of origin/destination pair, mode or both.

A matrix T_{ijmIJM} representing all possible pairing of choices of origin, destination and mode pair for the two scenarios being compared may be defined, where the two scenarios are expressed by upper and lower cases.

T_{ijmIJM} represents the number of trips between origin i, destination j, by mode m in scenario **0** which are instead made between origin I, destination J, by mode M in scenario **1** as a result of the differences in generalised cost resulting from the investment alternative that is being evaluated. Note that subscript **k** for income has been omitted since people have the same income in both scenarios. This analysis, however, applies to each income group separately.

The problem can then be expressed in terms of maximizing the following expression:

$$Max \sum_{ijm}\sum_{IJM} -T_{ijmIJM} \ln T_{ijmIJM}$$

subject to the following constraints (the Lagrange multiplier to be associated with each constraint is indicated in square brackets):

$$\sum_I \sum_J \sum_M T_{ijmIJM} = T_{ijm}^{(0)} \quad \textit{for each ijm} \qquad [\mu_{ijm}]$$

$$\sum_i \sum_j \sum_m T_{ijmIJM} = T_{IJM}^{(1)} \quad \textit{for each IJM} \qquad [\nu_{IJM}]$$

$$T_{ijmijm} = minimum(T_{ijm}^{(0)}, T_{ijm}^{(1)}) \quad \textit{for each ijm} \qquad [\phi_{ijm}]$$

and the cost constraint:

$$\sum_{ijm} \sum_{IJM} C_{ijmIJM} T_{ijmIJM} = C \qquad [\alpha]$$

where:

$$C_{ijmIJM} = C_{ijm}^{(0)} - C_{IJM}^{(1)}$$

and $C_{ijm}^{(0)}$ and $C_{IJM}^{(1)}$ are the generalised costs of the relevant journeys in the respective scenarios. It is clear that C_{ijmIJM} can be either positive (i.e. the travellers have reduced their travel cost), negative (the travellers have increased their travel cost) or zero. This cost constraint states that C is the difference (which may be zero) between the generalised travel budgets in the two scenarios.

The Lagrangean can then be expressed:

$$\mathcal{L} = \sum_{ijm} \sum_{IJM} -T_{ijmIJM} \ln T_{ijmIJM} + \sum_{ijm} \mu_{ijm} (T_{ijm}^{(0)} - \sum_{IJM} T_{ijmIJM}) + \sum_{IJM} \nu_{IJM} (T_{IJM}^{(1)} - T_{ijmIJM}) +$$

$$\sum_{ijm} \phi_{ijm} (\min(T_{ijm}^{(0)}, T_{ijm}^{(1)}) - T_{ijmijm}) + \alpha \left(C - \sum_{ijm} \sum_{IJM} T_{ijmIJM} C_{ijmIJM}\right)$$

With the first order conditions:

$$\frac{\partial \mathcal{L}}{\partial T_{ijmIJM}} = -\ln T_{ijmIJM} - 1 - \mu_{ijm} - \nu_{IJM} - \phi_{ijm} \delta_{iI} \delta_{jJ} \delta_{mM} - \alpha C_{ijmIJM} = 0$$

where

$\delta_{pq} = 1$ if $p=q$, and $\delta_{pq}=0$ otherwise.

Therefore for all i,j,m,I,J,M where $(i,j,m) \neq (I,J,M)$ the solution for the equation in the case defined here is simply:

$$T_{ijmIJM} = e^{-1} e^{-\mu_{ijm}} e^{-\nu_{IJM}} e^{-\alpha C_{ijmIJM}}$$

and further that, when $i=I$, $j=J$ and $m=M$:

$$T_{ijmijm} = e^{-1} e^{-\mu_{ijm}} e^{-\nu_{ijm}} e^{-\phi_{ijm}} e^{-\alpha C_{ijmijm}}$$

Previous expressions are in fact an extension to the doubly-constraint gravity model with the exponential function and thus its derivation was obtained in a similar fashion.

Evans (1971) have shown that any matrix t(α) (derived from the doubly-constraint gravity model) is independent of α (the parameter of the exponential function) if and only if the costs C_{ij} are such that it is possible to find number U_i and V_j such that $C_{ij} = U_i + V_j$ for all i and j. In those cases C_{ij} is termed (called) a trivial cost matrix.

It is important to note that, the first three sets of constraints imply either that:
$T_{ijmIJM}=0$ for all $(i,j,m) \neq (I,J,M)$ if $T_{ijmijm}=T^{(1)}_{IJM}$, or similarly that
$T_{ijmIJM}=0$ for all $(I,J,M) \neq (i,j,m)$ if $T_{ijmijm}=T^{(0)}_{IJM}$.

In addition the constraints also imply that the "row" and "column" sums are satisfied. Thus we obtain a reduced matrix of non-zero off-diagonal elements, whose terms are all of the form given by:

$$T_{ijmIJM} = e^{-1} e^{-\mu_{ijm}} e^{-\nu_{IJM}} e^{-\alpha C_{ijmIJM}}$$

Now since each element of C_{ijmIJM} is expressed as a difference between relevant elements of the two cost matrices, ($C_{ijm}^{(0)}$) and ($C_{IJM}^{(1)}$), it represents a trivial cost matrix. Hence, T_{ijmIJM} is independent of α and the problem of estimating the most-likely transition matrix is reduced to the simple biproportional problem, and is therefore given by:

$$T_{ijmIJM} = \frac{T_{ijm}^{(0)} T_{IJM}^{(1)}}{\sum_{ijm} \sum_{IJM} T_{ijmIJM}}$$

5.7.2 Implications for evaluation and further assumptions. The calculation of this transition matrix from this biproportional procedure (derived from an entropy maximization approach), suggest that trips may redistributed over the entire T_{ijmIJM} matrix. That implies that travellers between origin i, destination j, by mode m in scenario **0** and whose behaviour differs as a result of the differences in generalised cost resulting from the investment alternative that is being evaluated, have been allocated biproportionately in scenario **1** over the entire I, J, M possible choices.

Despite the large arrays and the computational burden, the transition matrix was calculated individually for each income category.

These results however imply unrealistic changes in trip behaviour. Very small proportion of trips are allocated over the entire transition matrix. That in turn suggests that a large number of those small proportions have had considerable changes in their travel patterns, changing origin/destination pair, mode or both.

From the point of view of evaluation, it implies that in many cases there were considerable changes in generalised cost (both reductions and increases) as a result of the investment alternative that is being evaluated. As such, the results from the evaluation were also found to be unrealistic

In order to limit the effect of unrealistic changes in travel behaviour a further constraint was introduced. That requires that travellers between origin i, destination j, by mode m in scenario **0** would be redistributed only to those origin/destination/mode combination IJM in scenario **1** whose cost differed at least as favourably between the scenarios as do the costs for combination *iim*. This may be given by:

$$T_{ijmIJM}>0 \quad only \quad if \quad C^{(0)}_{ijm}-C^{(1)}_{ijm}\leq C^{(0)}_{ijm}-C^{(1)}_{IJM}\leq C^{(0)}_{IJM}-C^{(1)}_{IJM}$$

$$T_{ijmIJM}>0 \quad only \quad if \quad C^{(0)}_{ijm}-C^{(1)}_{ijm}\leq C^{(0)}_{ijm}-C^{(1)}_{IJM}\leq C^{(0)}_{IJM}-C^{(1)}_{IJM}$$

However, after imposing this new restriction, it would no longer be certain whether a transition matrix (T_{ijmIJM}) satisfying all the conditions would exist, given the number of zero elements associated with cells which would not satisfy these new constraints. Even when such a matrix existed, a very large scale iterative procedure would be needed to calculate it.

In order to simplify the work it was simply assumed that for trips which redistributed, each traveller would experience in the scenario in which their origin, distribution and mode are not known, a journey cost an travel time equal to the average between the two scenarios of the money costs and travel times of the journey they make in the scenario where their origin, destination and mode are known.

Suppose that $T_{ijkm}^{(1)}>T_{ijkm}^{(0)}$. Then, as described in **Section 5.7**, $(T_{ijkm}^{(1)} - T_{ijkm}^{(0)})$ is the number of users in income category **k** in scenario **1** whose behaviour differs as compared with scenario **0** in such a way as to travel from **i** to **j** by mode **m** either by different choice of origin/destination pair, mode or both. For these travellers it was thus assumed that they experience a change in both money costs (**c**) and travel time (**t**) equal to:

$$\Delta c_{ijmk}=\frac{c^{(0)}_{ijmk}-c^{(1)}_{ijmk}}{2}$$

$$\Delta t_{ijmk}=\frac{t^{(0)}_{ijmk}-t^{(1)}_{ijmk}}{2}$$

Similarly, if $T_{ijkm}^{(1)}<T_{ijkm}^{(0)}$ the counterpart can be assumed, and $(T_{ijkm}^{(0)} - T_{ijkm}^{(1)})$ would experience a change in money cost and travel time as calculated by previous expressions with **0** and **1** interchanged.

With these changes in cost and travel time, we could then evaluated the associated changes in utility in money terms with the measures of CV and EV.

5.7.3 Discussion. This section has therefore made explicit assumptions regarding the calculation of changes in money cost and travel time for use in the evaluation.

For each mode and zone pair, users were divided into two classes: the first consists of users who travel between the same origin and destination by the same mode in both scenarios, and the second consists of those whose behaviour differs as a result of the differences in generalised cost resulting from the investment alternative that is being evaluated.

For the first group of travellers an assumption was made which in fact minimizes the number of people whose travel differs as between scenarios.

For the second group of travellers however, which corresponds to a small number relatively to that of the other group, it was assumed that they would experience in the scenario in which their origin, distribution and mode are not known, a journey cost and travel time equal to the average between the two scenarios of the money costs and travel times of the journey they make in the scenario where their origin, destination and mode are known.

Despite considerable investigation on alternative approaches, this last assumption has been accepted, despite its being a great simplification, in order to be able to proceed to the evaluation tests. It would be preferable to have a theoretically firmer basis for estimating the welfare differences associate with redistributed trips. However, in view of the fact that these differences are expected to be relatively small in total compared with the welfare differences for users who make the same journeys in both scenarios, it was reasonable to proceed with the simplification.

5.8 Conclusion

In this chapter the data set used for investigation in this research is explored in detail, and the household income distribution is estimated for the trips in each cell of the various output matrices. The objective of the work described was to construct hypothetical but realistic alternatives scenarios for comparison.

Furthermore, in order to implement the proposed frameworks for investigation, it was also necessary to estimate the number of travellers in each income category who would change their behaviour as a result of improvements in transport system, by changing either origin/destination pair, mode or both.

It is well known that much of the information on travel behaviour is lost in the aggregate four stage transport process, within which the data set was actually generated. Thus, throughout the chapter a number of assumptions and simplifications were made. Whenever possible these were discussed at some length, together with their implications for transport planning and, in particular, for the results of the evaluation tests presented in next chapter.

CHAPTER 6
EVALUATION OF USER BENEFITS RESULTING FROM CHANGES IN TRANSPORT SYSTEM

6.1 Introduction

In this chapter different measures of user benefits of adopting the highway investment or rail investment policies rather than the do-minimum policy as reflected in the scenarios constructed in **Chapter 5** are estimated for each income category.

Initially, the rule of half is used to estimate differences in consumer surplus. The rule of half however, as explained in **Chapter 3**, represents an approximation to the actual changes in consumer surplus. It may be a good approximation for small variations of perceived user costs.

Differences in generalised user cost (as a result of public or private transport network improvements) for each of the scenarios under comparison are small in percentage terms. The effects of changes in generalised cost on patterns of travel in the scenarios are moreover, confined to redistribution and reallocation between modes of the fixed trip ends input to the doubly constrained gravity model. Within these limitations the rule-of-half is likely to be an acceptable approximation.

Implicit in the notion of generalised cost is the concept that the various elements of generalised cost could be converted to a common currency, as is required for the evaluation. For this purpose, time is converted into money units through the value of time. Given the number of inconsistencies in determining the value of time discussed in **Section 2.2.3**, and, most importantly, in order to explore distributional issues, different values of time have been examined in the evaluation that follows. The implications of the results for evaluating transport projects are also highlighted.

Nevertheless, the rule of half is derived directly from the least rigorous form of money valuation of utility: the Marshallian Consumer Surplus. It is therefore based on the assumptions that the marginal utility of income is constant across the population, and that the cross effects of price changes on the (market) demand for transport are equal.

Against this background the commonly-accepted assumptions concerning household and personal incomes in transport demand modelling have been reconsidered and alternative measures of user benefits have been examined. Following Jara-Diaz and Farah (1987), it is assumed that travellers maximize a utility function subject to time and budget constraints. The indirect utility function expresses the characteristics of the selected alternatives through the modal choice process, and it is used to obtain the measures of individual welfare changes as a result of changes in the transport system. A discussion on the underlying assumptions and the measures of user benefits is given in **Chapter 3.**

In the expressions for the Compensating Variation (CV) and Equivalent Variation (EV), the elasticity of utility with respect to available time (β) plays a key role in the evaluation of user benefits. In addition, time savings act now as a multiplier of disposable income where β plays an explicit part. Finally, the ratios providing estimates of marginal utility of income for each income category and their use as weighting factors for obtaining an aggregate measure of welfare benefit are also investigated.

This chapter is divided into three sections as follows. The next section explores how these issues of evaluation are to be addressed by looking at the different scenarios established in the previous chapter. It also presents what comparisons are to be made and why, as well as discussing how the results should be looked at. **Section 6.3** presents these results concisely and briefly discusses them in the ways envisaged previously.

6.2 Starting point for evaluation

The output matrices from the LTS model have provided matrices of journeys and travel cost that were used to construct three different scenarios for comparison. In this context, benefits derived from railway or highway improvements to a do-minimum situation are evaluated. In addition, different assumptions about the average growth rate of household income have furnished two separate sets of data for investigation.

The assumptions regarding income growth were taken for the purpose of producing different income distributions for the forecast year despite the fact that income differences will not be reflected in different car ownership, trip distribution and modal split for the city as a whole. The objective was to explore the implications for the evaluation of user benefits.

The differences in modal split for each individual income category between the high and low income growth assumptions reflect the distribution of households over the various income categories rather than changes in car ownership levels. In fact, the assumptions on income growth do not represent situations that would be expected under two different levels of growth in the same hypothetical city. Rather, they represent what one would expect:

(i) in a city with low income growth but patterns of car use at given incomes consistent with those found in London in 1981.

(ii) a city with higher income growth but generally lower levels of car use for given income then those found in London in 1981.

The numbers and proportions of trips made by people from the various income categories by each transport mode and in total in the three-hour morning peak period in the scenarios constructed for comparison are summarized in **Tables 6.1** and **6.2** respectively for the low and high income growth assumptions.

Changes in the transport system as a result of railway or highway investment translate, among their most important effects, into user benefits in terms of travel time and operating cost savings. These are estimated in the evaluation that follows.

In particular, railway enhancements provide benefits for public and, to a small extent, private transport users. Benefits to the latter group of travellers account for a small proportion of the total benefits and it is largely due to a reduction in congestion as a result of shifts to the public mode.

Table 6.1 Estimated number (and percentage) of morning peak trips in each income category for the 'do-minimum', railway and highway scenarios with low income growth

	Mode	Income Categories					Total
		1	2	3	4	5	
DO MINIMUM	Private	244015 (13.0)	480913 (25.6)	529247 (28.2)	315938 (16.8)	305178 (16.3)	1875291 (100.0)
	Public	326049 (21.4)	401349 (26.3)	383520 (25.2)	201480 (13.2)	212238 (13.9)	1524636 (100.0)
	Total	570064 (16.8)	882263 (25.9)	912766 (26.8)	517418 (15.2)	517416 (15.2)	3399927 (100.0)
	% Private	42.80	54.51	57.98	61.06	58.98	55.16
RAILWAY	Private	236722 (13.0)	467383 (25.6)	515212 (28.2)	307840 (16.9)	297546 (16.3)	1824703 (100.0)
	Public	337480 (21.4)	414841 (26.3)	395995 (25.2)	207961 (13.2)	219056 (13.9)	1575332 (100.0)
	Total	574202 (16.9)	882224 (25.9)	911207 (26.8)	515801 (15.2)	516601 (15.2)	3400035 (100.0)
	% Private	41.23	52.98	56.54	59.68	57.60	53.67
HIGHWAY	Private	245194 (13.0)	483419 (25.7)	532003 (28.2)	317495 (16.8)	306450 (16.3)	1884562 (100.0)
	Public	324307 (21.4)	398851 (26.3)	380998 (25.1)	200217 (13.2)	211146 (13.9)	1515520 (100.0)
	Total	569502 (16.7)	882270 (25.9)	913002 (26.8)	517712 (15.2)	517597 (15.2)	3400082 (100.0)
	% Private	43.05	54.79	58.27	61.33	59.21	55.43

Table 6.2 **Estimated number (and percentage) of morning peak trips in each income category for the 'do-minimum', railway and highway scenarios with high income growth**

	Mode	Income Categories					Total
		1	2	3	4	5	
DO MINIMUM	Private	164234 (8.8)	334664 (17.8)	496055 (26.5)	381124 (20.3)	499181 (26.6)	1875258 (100.0)
	Public	237377 (15.6)	293713 (19.3)	379233 (24.9)	255112 (16.7)	359202 (23.6)	1524638 (100.0)
	Total	401610 (11.8)	628377 (18.5)	875288 (25.7)	636236 (18.7)	858384 (25.2)	3399896 (100.0)
	% Private	40.89	53.26	56.67	59.90	58.15	55.16
RAILWAY	Private	159328 (8.7)	324986 (17.8)	482564 (26.4)	371181 (20.3)	486610 (26.7)	1824669 (100.0)
	Public	245775 (15.6)	303764 (19.3)	391711 (24.9)	263345 (16.7)	370736 (23.5)	1575331 (100.0)
	Total	405103 (11.9)	628750 (18.5)	874275 (25.7)	634526 (18.7)	857346 (25.2)	3400000 (100.0)
	% Private	39.33	51.69	55.20	58.50	56.76	53.67
HIGHWAY	Private	165014 (8.8)	336352 (17.8)	498661 (26.5)	383081 (20.3)	501422 (26.6)	1884531 (100.0)
	Public	236128 (15.6)	292000 (19.3)	376773 (24.9)	253444 (16.7)	357175 (23.6)	1515519 (100.0)
	Total	401141 (11.8)	628353 (18.5)	875434 (25.7)	636525 (18.7)	858597 (25.3)	3400050 (100.0)
	% Private	41.14	53.53	56.96	60.18	58.40	55.43

The generalised costs of public transport users were not regarded as being affected by improvements in the highway network in the modelling that led to the highway scenario. Therefore, the highway investment generates benefits solely to private transport users compared to the 'do-minimum' scenario.

Given the differences in the composition of the demand of the public and private modes, changes in the transport system as a result of either railway or highway improvement would have a significant impact in terms of the distribution of benefits across the income spectrum. This is the one of the issues addressed by the results.

User benefits are initially estimated using the rule of half, for each pair of alternative scenarios under comparison. The total difference in consumer surplus is approximated by:

$$\Delta MCS = \sum_k \sum_m \sum_i \sum_j \frac{1}{2}(T^0_{ijmk} + T^1_{ijmk})(C^0_{ijmk} - C^1_{ijmk})$$

As in **Section 3.4.1**, **T** refers to the number of trips and **C** to the generalised cost, superscripts **0** and **1** denote the scenarios being compared and subscripts **i,j,m,k** refer to origin, destination, mode, and income respectively. These differences in benefits are further calculated separately for the various income groups and transport modes.

In addition, an indicator of the average benefit per traveller by each transport mode has been calculated for each income category, and is given by:

$$ACS_{km} = \frac{\sum_i \sum_j (T^0_{ijmk} + T^1_{ijmk})(C^0_{ijmk} - C^1_{ijmk})}{\sum_i \sum_j (T^0_{ijmk} + T^1_{ijmk})}$$

where $\mathbf{ACS_{km}}$ is the indicator of average benefit per traveller by mode **m** in income group **k**.

The generalised cost is given by the usual money and travel time components, as discussed in **Sections 4.2.4** and **4.2.5**. The differences in benefit are thus estimated for a typical individual in each cell **ijmk** of the array ($\mathbf{T_{ijmk}}$) from changes in travel time and costs.

Travel time savings are converted to units of money by appropriate values of time. Changing the value of time adopted for evaluation would alter therefore not only the total benefit figure, but also the overall distribution of benefits across the population. In this respect, in the estimation of user benefits that follows an income-related and a common (equity) value of time have been examined.

The income-related values of time have been calculated on the basis of 40% of the average wage rate associated with each income category. Moreover, for determining the wage rate an average household size specific to each income category, two hundred working days per year and eight hours of work per day have been assumed. Note that no correction has been made to reflect household composition. These values are summarized in **Tables 6.3** and **6.4** for the low and high income growth assumptions.

Table 6.3 Income related values of time used in the evaluation for low income growth assumption

Income Categories	Assumed Mean (£)	Household Size	Value of Time (pence/hour)
less than £6000	4000	1.8	55.6
£6000 - £10000	8000	2.6	76.9
£10000 - £15000	12500	2.8	111.6
£15000 - £20000	17500	3.0	145.8
£20000 or more	26000	3.3	196.8

Table 6.4 Income related values of time used in the evaluation for high income growth assumption

Income Categories	Assumed Mean (£)	Household Size	Value of Time (pence/hour)
less than £6000	4000	1.7	58.8
£6000 - £10000	8000	2.5	80.0
£10000 - £15000	12500	2.7	115.7
£15000 - £20000	17500	2.9	150.9
£20000 or more	28000	3.2	218.8

The common value of time adopted is calculated on the basis of 40% of the average wage rate for the city as a whole, and it amounts to 115 pence/hour and 140 pence/hour, respectively for the low and high income growth assumptions. The objective was to explore the differences that would imply in the evaluation using a common value of time and a income related value of time adopted for two hypothetical (high and low) levels of income growth.

The estimated measures of total and average user benefits, as well as the distribution of estimated benefits across the income spectrum represent the first set of results presented in the next section. The implications of assuming different values of time are also illustrated and in particular a comparison is made between the results for the income-related and the common value of time. The results are summarised in **Figures 6.3 to 6.8** presented in the next section. The proportion of benefits estimated to accrue to each income group is represented by the vertical lines, separately for benefits estimated with the common value of time and with the income related value of time presented in **Tables 6.3** and **6.4**. These are also contrasted with the proportion of trips in each income category. The average benefit per traveller to each group is represented by the horizontal lines, distinguishing savings in travel cost and time (N.B. The horizontal scale differs among these diagrams)

The choice of the value of time is explored further. Measures of estimated benefits have been calculated with values of time varying as a proportion of the wage rate. The effect on the distribution of benefits across the various income groups is illustrated in **Figure 6.9** in the next section.

The second set of results presented in the next section are associated with the measures of Compensating and Equivalent Variation estimated for the two pairs of different scenarios under comparison.

These measures are derived from the neo-classical theory between goods and leisure. Assuming that the individual travellers have a general utility function (of the Cobb-Douglas form), and they maximize utility subject to constraint on their overall income and time availability the measures of CV and EV are given as in **Section 3.5** by:

$$CV = I - (I - B.c_{d0})\left[\frac{T-W-B.t_{d0}}{T-W-B.t_{d1}}\right]^{\frac{\beta}{1-\beta}} - B.c_{d1}$$

$$EV = (I - B.c_{d1})\left[\frac{T-W-B.t_{d1}}{T-W-B.t_{d0}}\right]^{\frac{\beta}{1-\beta}} + B.c_{d0} - I$$

As previously, in these equations **T** is the time period, **W** is the number of working hours (which is fixed) **B** is the number of trips to work in period **T**, and **c** and **t** are the money cost and travel time of the selected alternatives in scenario **0** (**d0**) and scenario 1 (**d1**). Household income is converted into personal income by dividing by the average household size presented in **Tables 6.3** and **6.4** previously. It is recognized, that the conversion from gross household income to disposable income per head should not simply a matter of dividing by household size, but time did not permit any attempt to reflect household composition or taxation in this study. Again, it has been assumed that there are two hundred working days in a year and eight hours of work per day.

The measure of CV gives the minimum amount by which traveller would have to be compensated in scenario 1 in order to be as well off as in scenario 0. The EV, on the other hand, is the amount of money which would have to be given to the travellers in scenario 0 to make them as well off as they would be in scenario 1 with the same income.

It will be seen that β, the elasticity of utility with respect to time, plays a key role on the valuation of user benefits. Except for extreme cases where β approaches to one, the post and pre-compensation measures of welfare changes (respectively CV and EV), give similar results, both in absolute terms and in terms of the distribution of these benefits across the income groups. Differences in the measurement of CV and EV for the railway scenario compared with do-minimum scenario with low income growth is illustrated in **Table 6.5**.

Table 6.5 Estimated values of CV as percentage of EV Railway scenario compared with do-minimum scenario with low income growth assumption

Beta	Income Categories					Total
	1	2	3	4	5	
0.1	99.96	99.98	99.98	99.98	99.97	99.98
0.2	99.83	99.86	99.88	99.90	99.90	99.87
0.3	99.66	99.70	99.72	99.75	99.75	99.72
0.4	99.45	99.49	99.54	99.57	99.58	99.53
0.5	99.13	99.19	99.25	99.32	99.34	99.26
0.6	98.65	98.72	98.83	98.92	98.96	98.84
0.7	97.86	97.97	98.14	98.29	98.35	98.15
0.8	96.28	96.46	96.74	97.00	97.13	96.79
0.9	91.67	92.03	92.67	93.25	93.55	92.79

The results presented in previous table are illustrative of the correspondence between CV and EV. Two important points however, arise from the results.

First, CV and EV give similar results both in absolute terms and in terms of the distribution of these benefits across the income groups, although, irrespective of the elasticity figure β, EV is always greater than CV. Second, as β tends to one, and consequently the implicit value of time also escalate, the differences between the two measures also increase.

The fact that EV is greater than CV, particularly for high values of β, suggests that the amount of money that would have to be given to the travellers when they face the initial (do-minimum) situation to make them as well off as they would be in the railway scenario is always just slightly greater than would be the case if the changes were actually introduced. The difference becomes appreciable when travellers value their potential time savings very highly.

In this respect, for the results discussed in **Section 6.3**, the values of CV have been presented, the main conclusions being equally valid for EV.

The implications of the elasticity parameter, β, for the total measure of benefit for each income group are summarised in **Tables 6.6** to **6.9**. These values are also contrasted with the Marshallian measures of consumer surplus estimated with the common and with the income related values of time, which are also presented in the tables.

Implicit in this valuation are the expressions for the value of time (VT) and the marginal utility of income (λ):

$$VT = \frac{\beta}{1-\beta} \cdot \frac{I - B.c_i}{(T - W - B.t_i)}$$

$$\lambda = K(1-\beta)\left[\frac{T - W - B.t_i}{I - B.c_i}\right]^{\beta}$$

where c_i and t_i are the money cost and travel time for the journey respectively.

The expression for the value of time represents the monetary value to the individual traveller of a small relaxation of the time constraint (e.g. a reduction in his/her travel time). Estimated in this way, the value of time is negatively correlated with travel cost for journeys of a given duration and positively with travel time for journeys of a given cost. As travel time increases, the money value of a reduction in travel time would be greater than in conditions of comparatively shorter journeys.

The implicit values of time associated for a range of values of β (between 0.1 and 0.7) for the different income categories (corresponding to the mean incomes presented in previous **Tables 6.3**) are illustrated in **Figure 6.1** for four separate pairs of travel time and money cost. For the sake of illustration, these are portrayed for the low income growth only.

It is often suggested that the marginal utility function is an appropriate way of to make an explicit attempt to derive distribution weights for use in economic analysis. The marginal utility of income represents in money terms the value of one extra unit of income available to the individual traveller. As expected therefore, it decreases with income, and an increase in available time has a positive effect on λ for a given cost of the journey to work. Yet, in the expression the effects of both travel time and travel cost are not particularly significant, except when the cost of a journey represent a large proportion of the person's income. Ultimately, the marginal utility of income is determined by income itself (decreasing with it), and available time.

The corresponding ratios for the marginal utility of income among the different income groups for different values of β are illustrated in **Figure 6.2** for a set of four different journeys.

Figure 6.1 **Associated values of time for different values of β for four distinctive journeys**

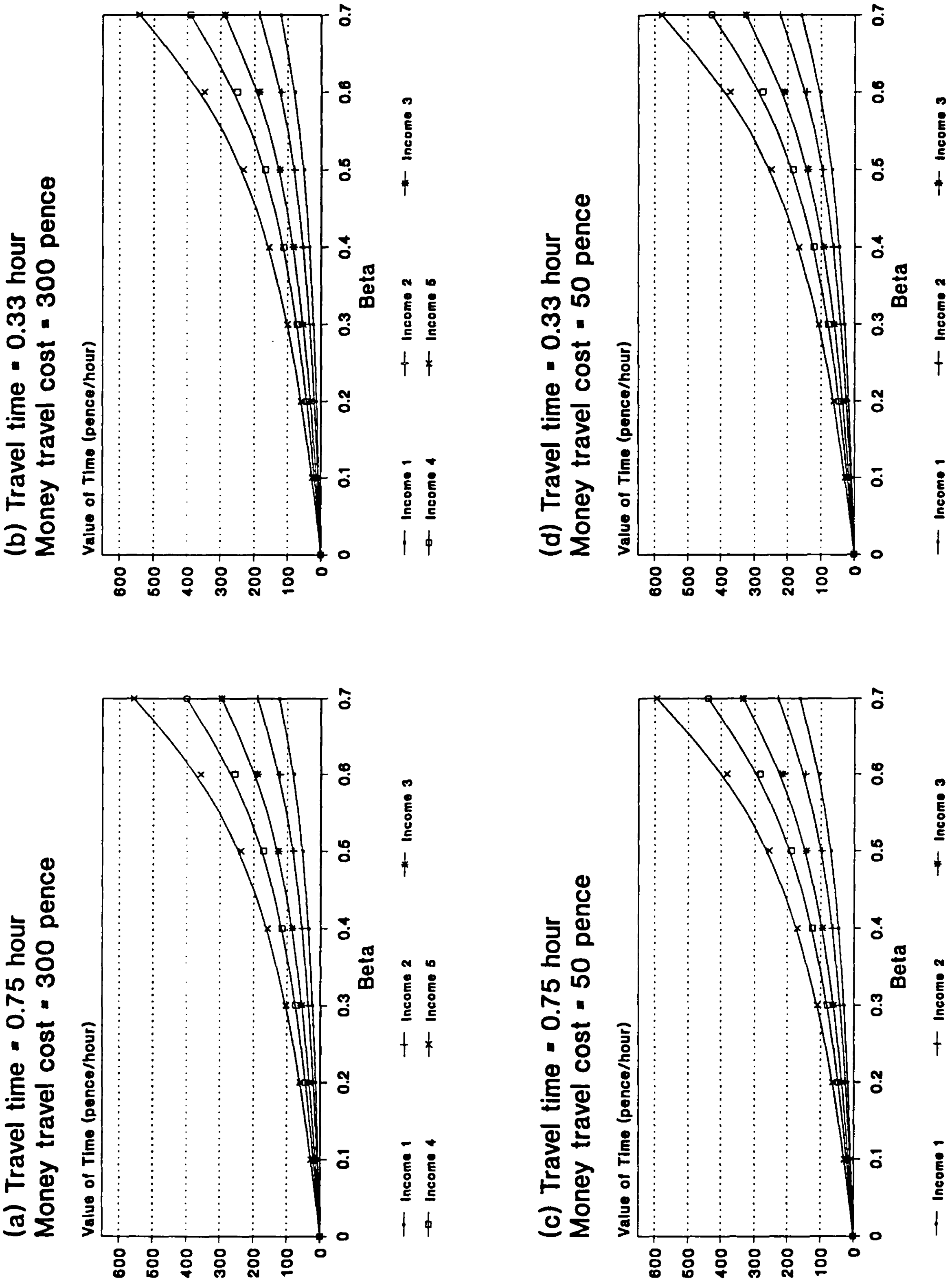
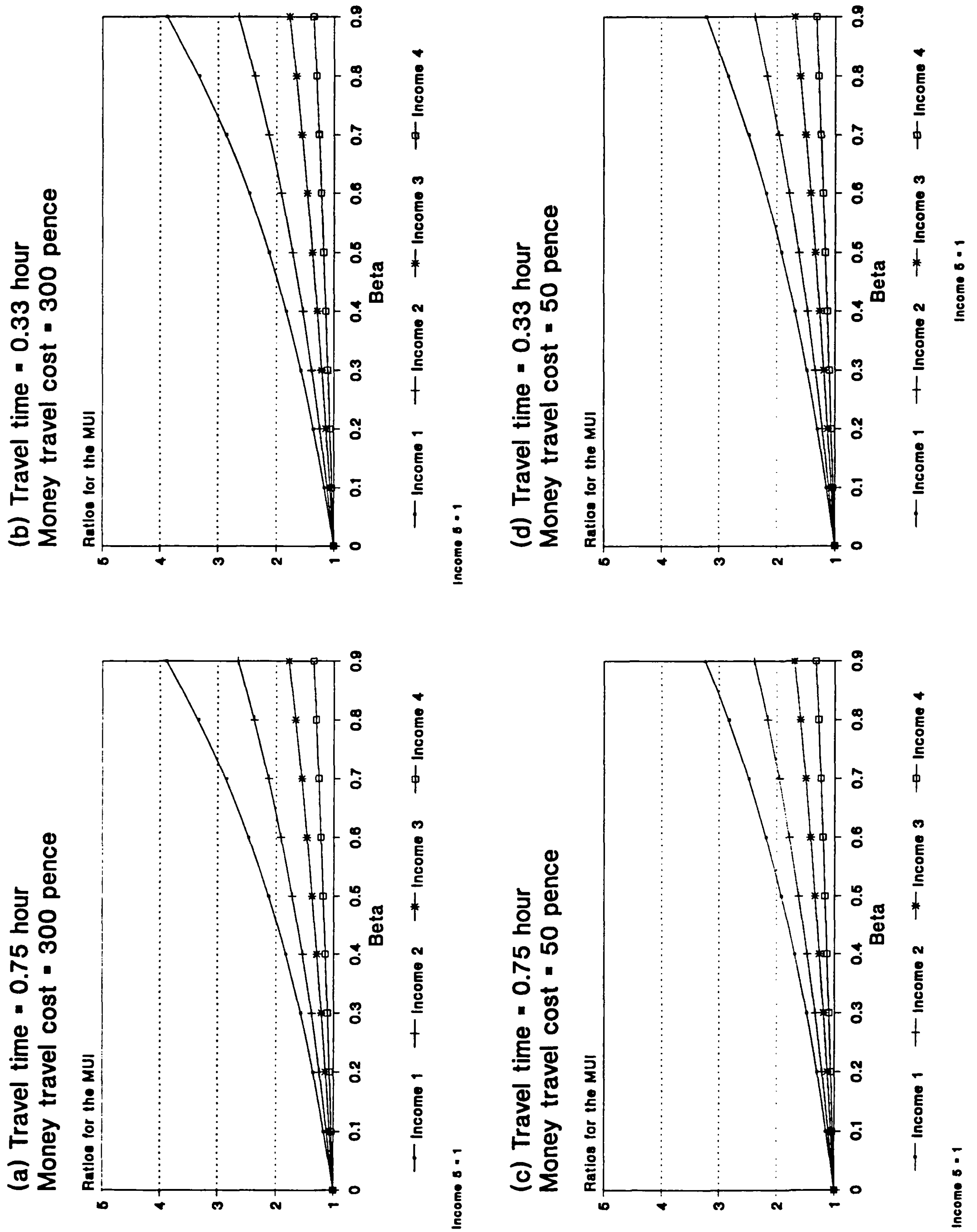


Figure 6.2 Ratios for the marginal utility of income for different values of β for four distinctive journeys



Finally, the last set of comparison attempt to examine the differences associated with the various measures of welfare changes. In this respect, changes in consumer surplus estimated from the rule-of-half are compared with CV, individually for the various income categories and as an aggregate measure of total benefit. In this comparison the role of the elasticity parameter, β, is also investigated.

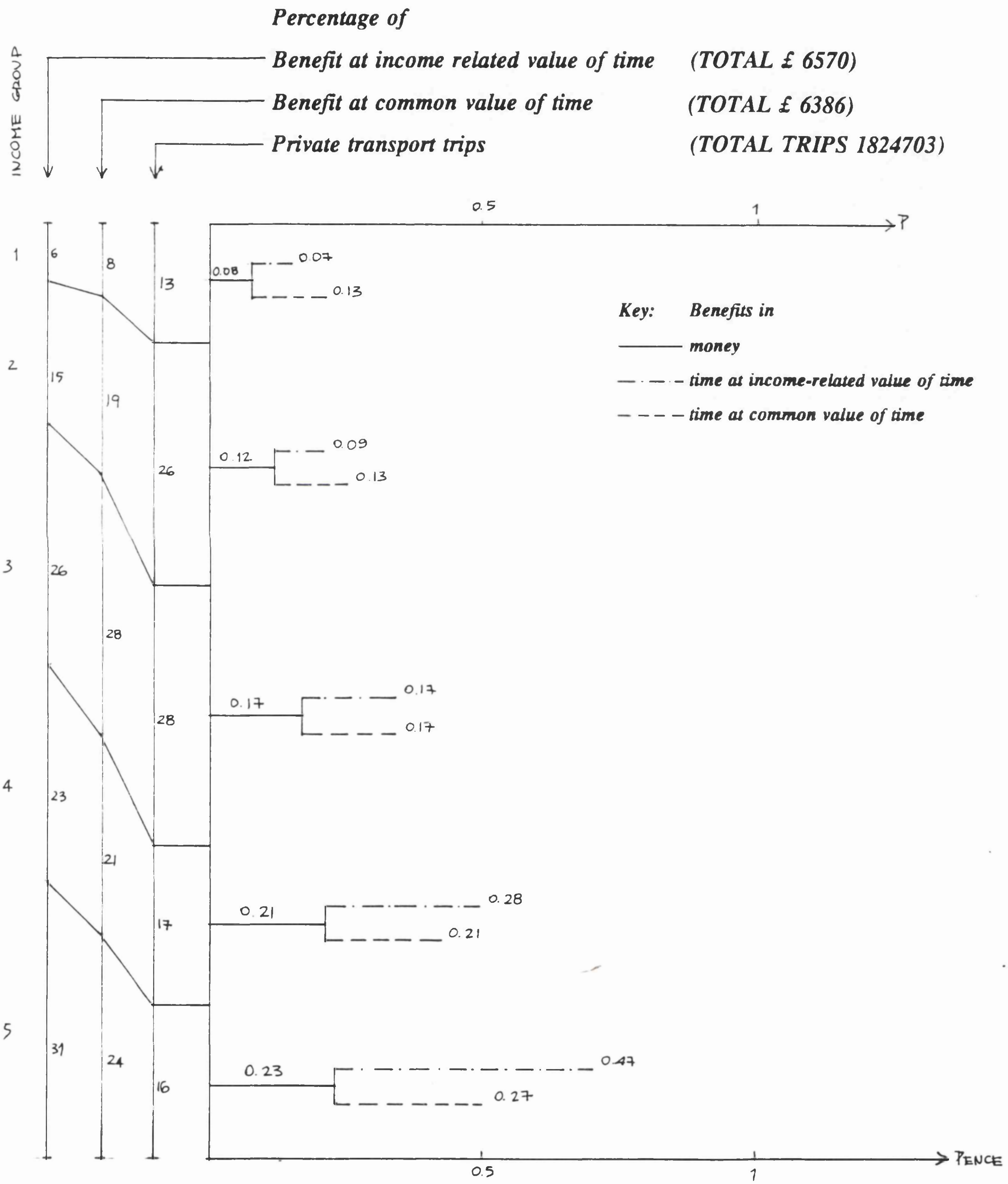
All evaluations are carried for the three hour morning peak period. Money values are expressed in 1981 prices throughout.

6.3 Results of the evaluation

In this section a summary of relevant results are presented.

6.3.1 Consumer surplus with common and income-related values of time. Private and public transport user benefits from the rail investment scenario compared with the do-minimum scenario with low income growth are presented respectively in **Figures 6.3** and **6.4**. Similar diagrams for the high income growth are displayed in **Figures 6.5** and **6.6**. The estimates presented in these diagrams are of increase in consumer surplus as estimated by the rule-of-half.

Figure 6.3 Private transport user benefits per weekday from rail investment scenario compared with do-minimum scenario with low income growth



AVERAGE BENEFIT PER TRAVELLER

Figure 6.4 Public transport user benefits per weekday from rail investment scenario compared with do-minimum scenario with low income growth

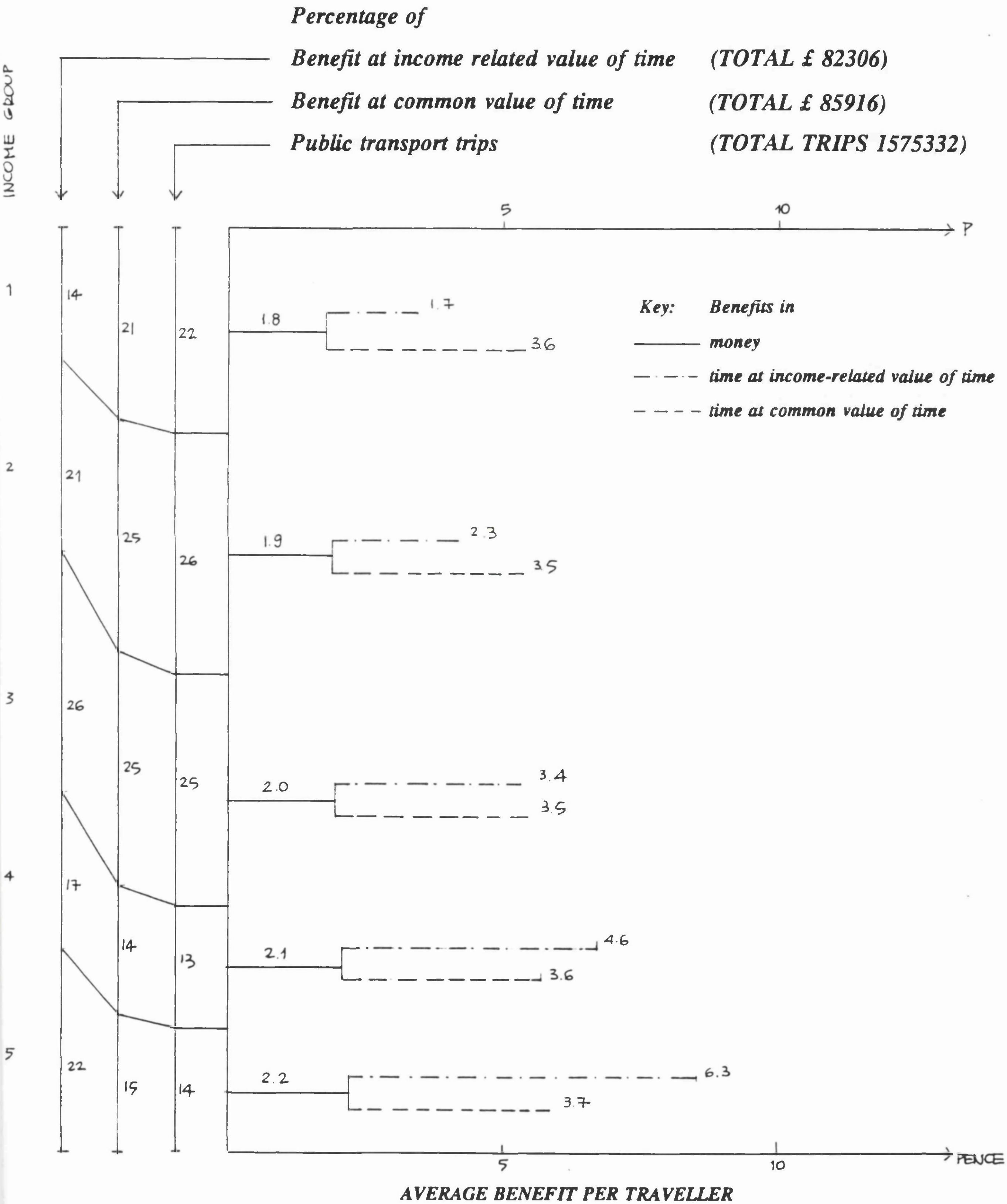


Figure 6.5 **Private transport user benefits per weekday from rail investment scenario compared with do-minimum scenario with high income growth**

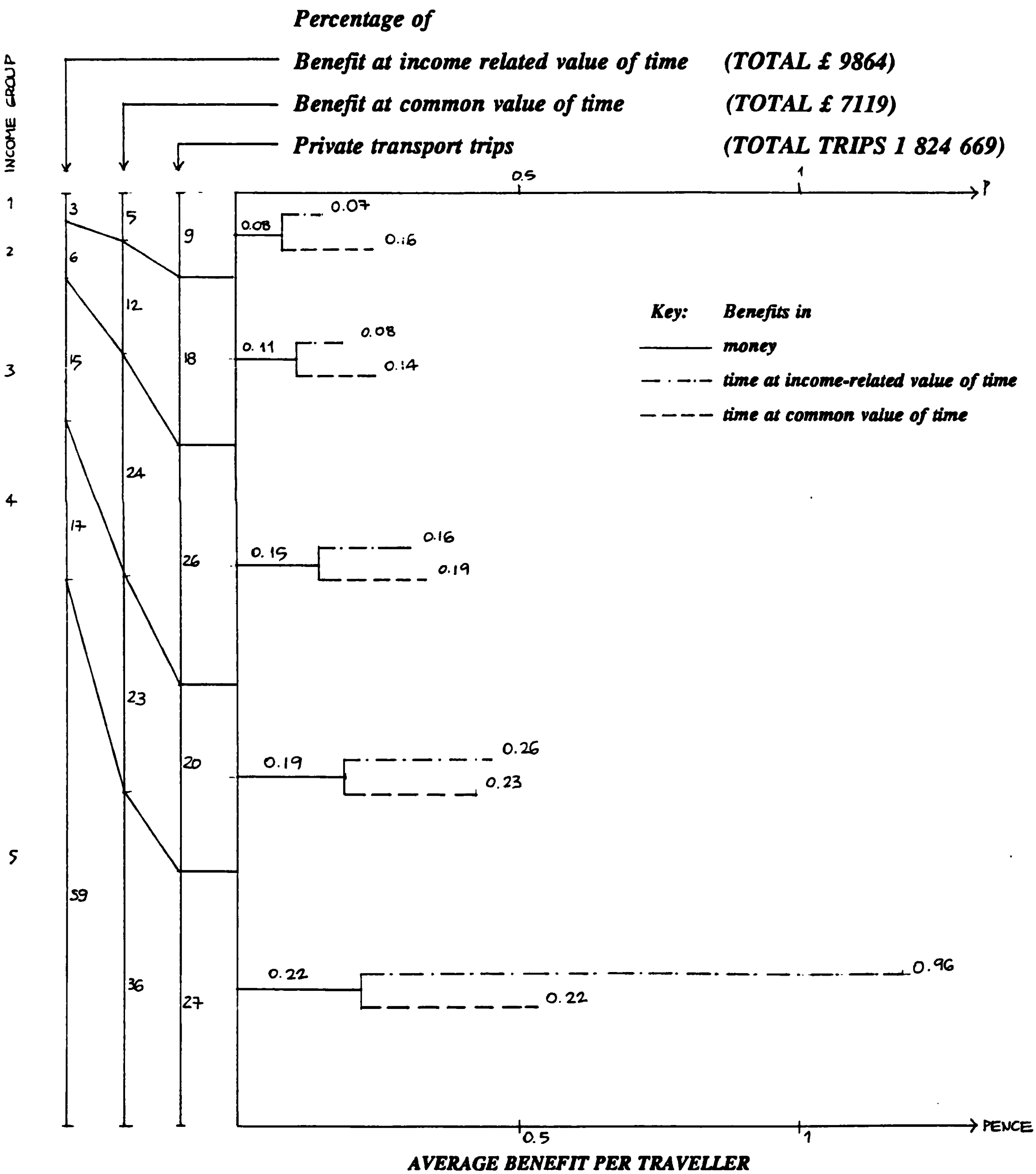
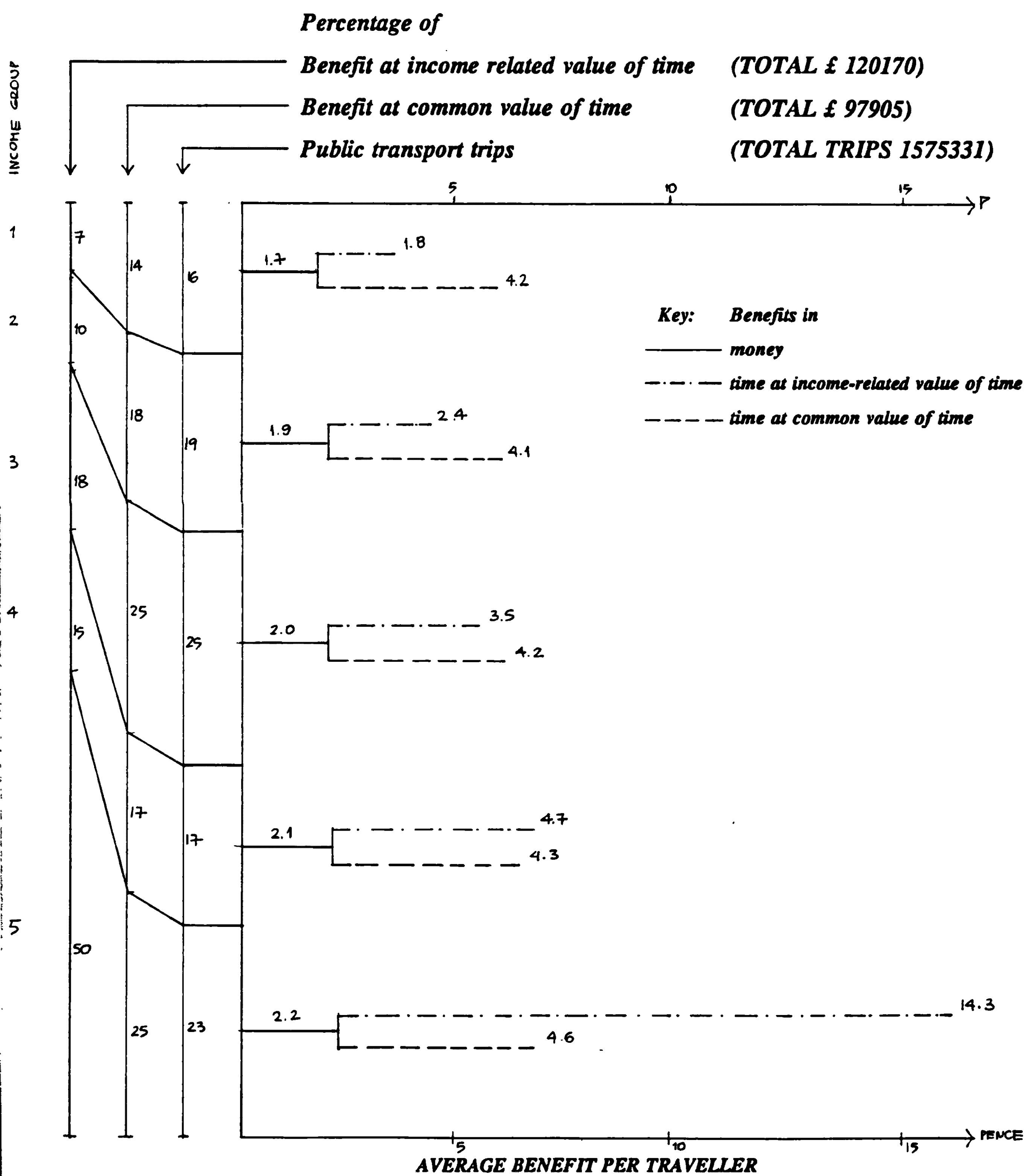


Figure 6.6 **Public transport user benefits per weekday from rail investment scenario compared with do-minimum scenario with high income growth**



As illustrated, a disproportionate amount of the private transport benefits would accrue to the highest income travellers, and average benefits, whether estimated with income related or a common value of time, are correspondingly greater for this group of travellers. With high income growth, the same is true of benefits to public transport users. Nevertheless, benefits to private transport users from rail improvements account to less than 10% of the benefits enjoyed by travellers by public transport.

With low income growth benefits to public transport users are more uniform through the income spectrum, both in absolute terms or in terms of average benefits. They also represent almost all the benefits accruing to the lowest income travellers.

Irrespective of income category, the proportion of the total benefit derived from the reduction in money cost is consistently higher for private transport users compared to public transport users. Average money cost savings by users of public transport differ by only about 20 per cent across the income groups, whereas some considerable percentage differences are found for private transport users.

According to the modelling exercises from which the data used here were drawn, improvements in the highway network generate benefits solely to private transport users. The benefits from highway investment scenario compared with the 'do-minimum' are illustrated in **Figure 6.7** with low income growth and in **Figure 6.8** with the high income growth assumption.

Figure 6.7 Private transport user benefits per weekday from highway investment scenario compared with do-minimum scenario with low income growth

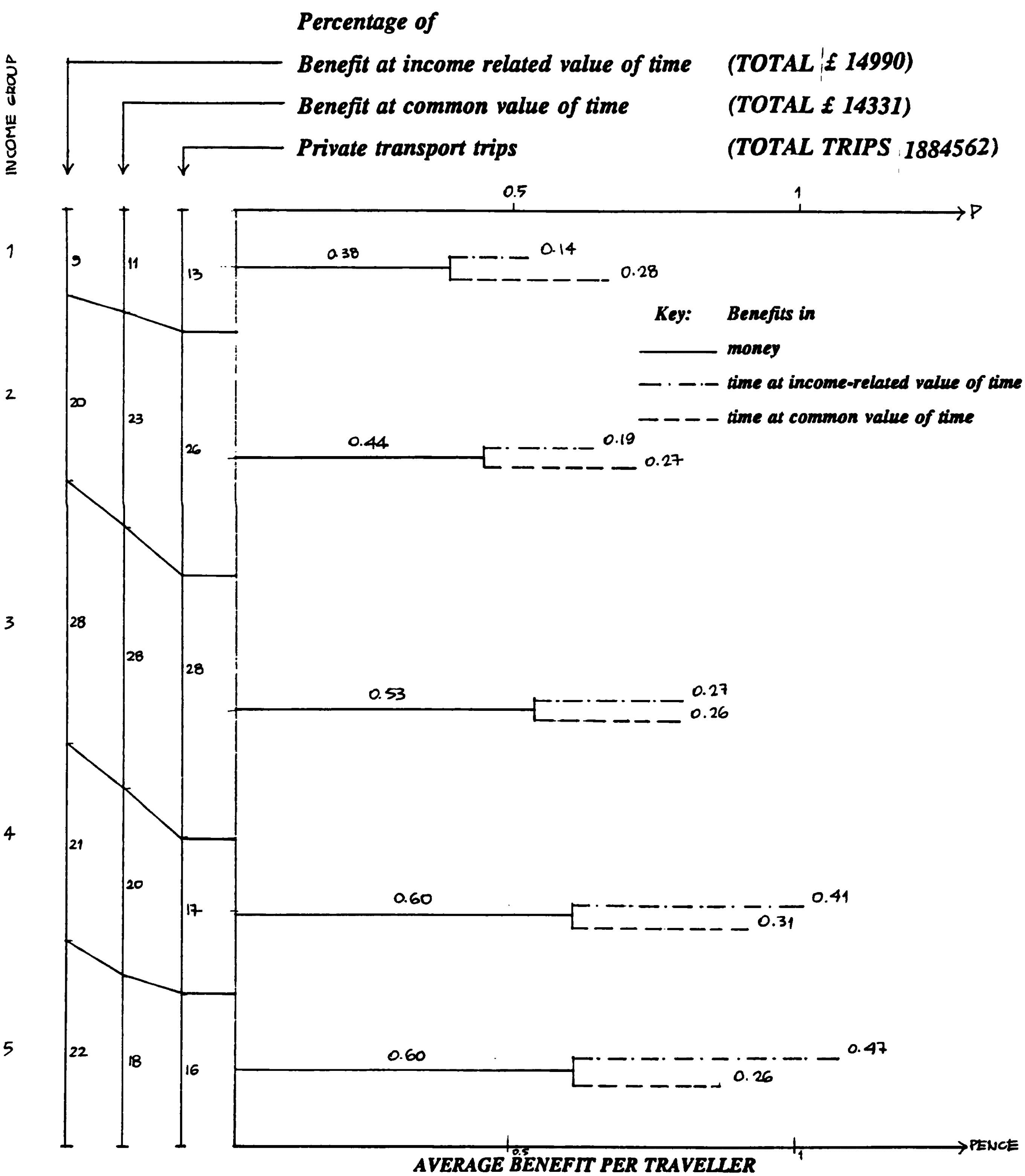
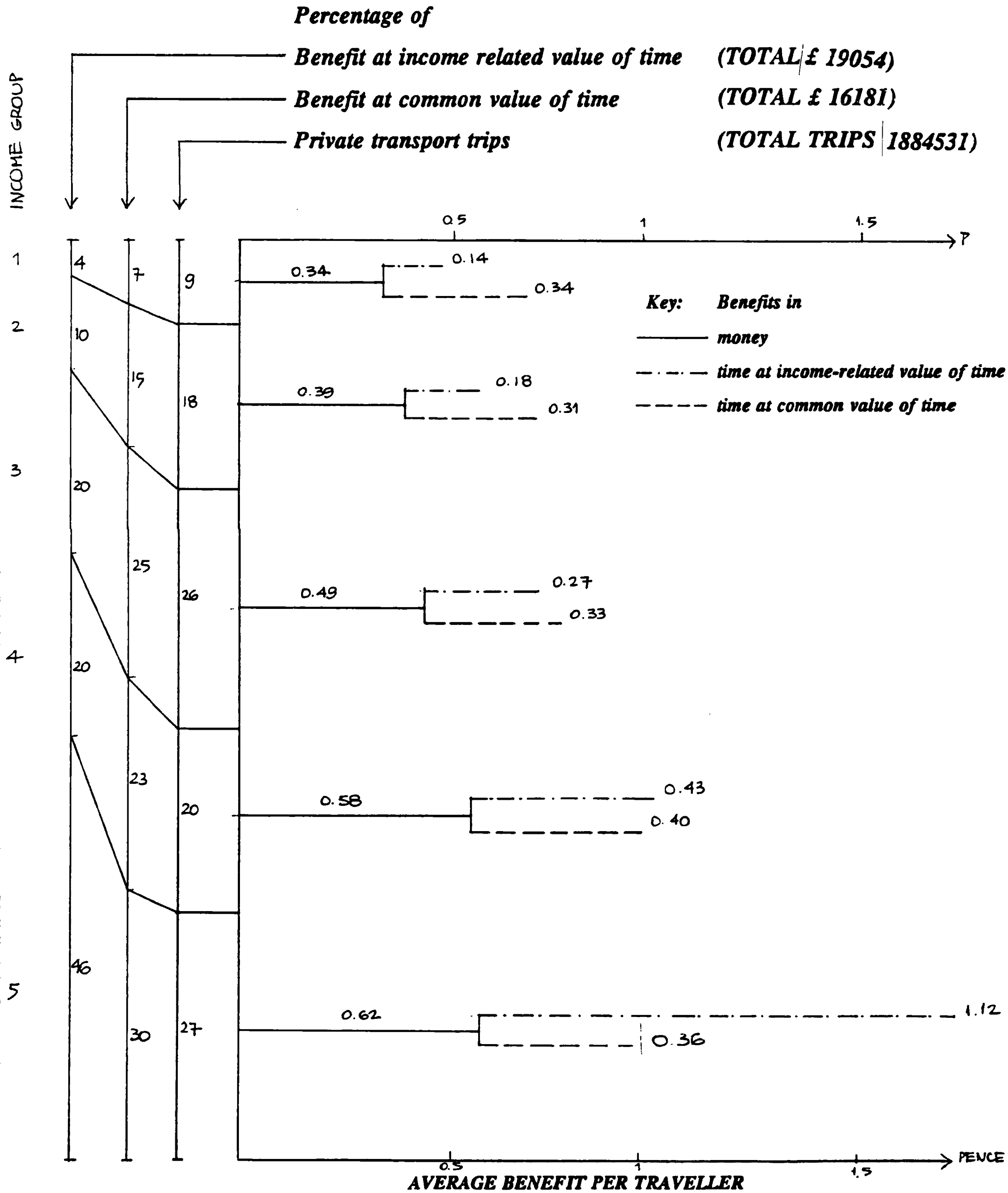


Figure 6.8 Private transport user benefits per weekday from highway investment scenario compared with do-minimum scenario with high income growth



Again the result shows that above average benefits would accrue to the highest income travellers as a result of considerable differences in average benefits per traveller between the income groups. These differences are the result of both changes in travel costs and travel times, although travel cost savings represent the larger share of these benefits except in the highest income group with high growth and income-related value of time. These results also reflect the fact that private transport users in the lowest income categories travel considerably lower distances, and would therefore enjoy corresponding smaller reductions in travel cost.

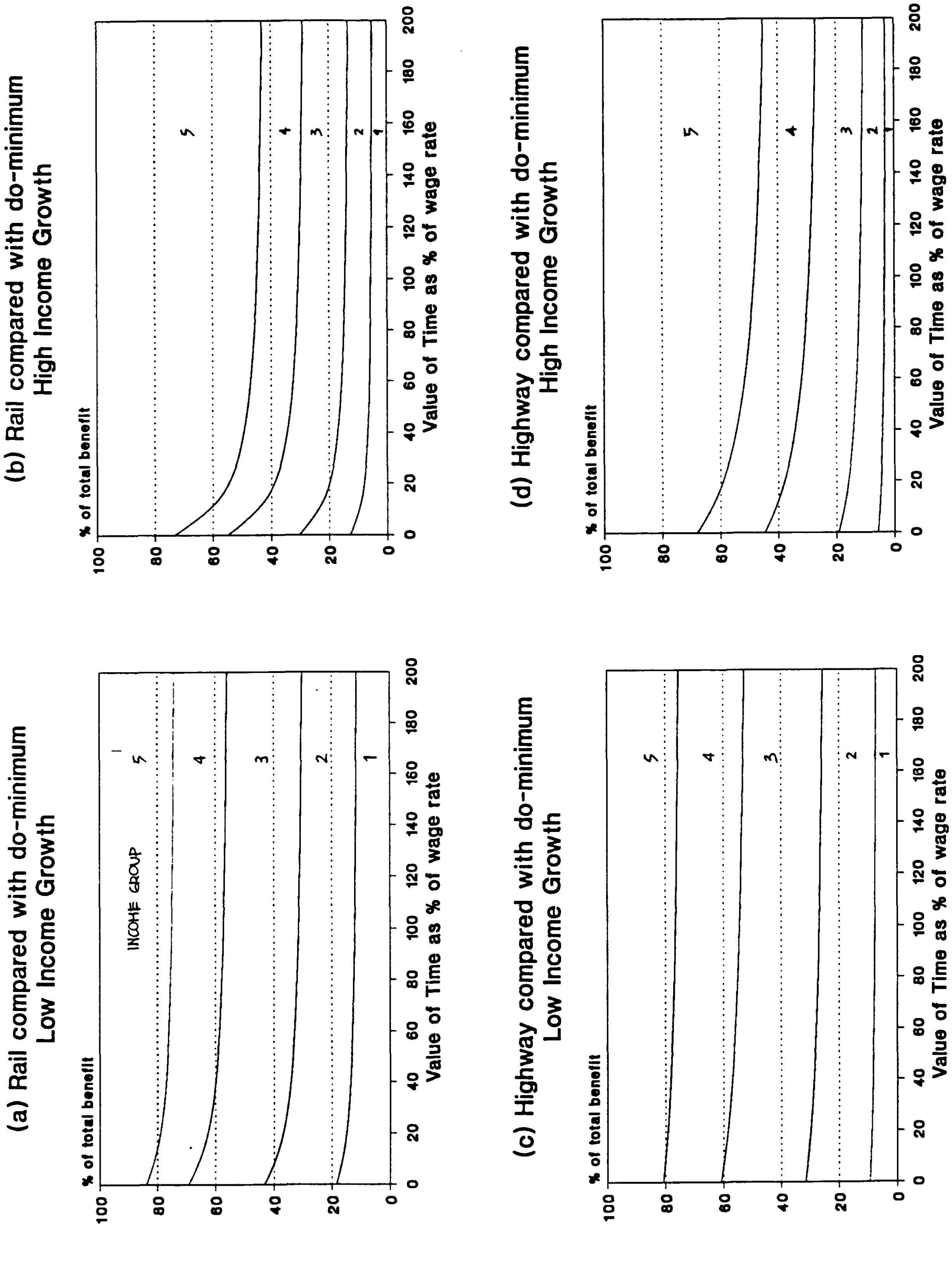
Throughout the results presented in **Figures 6.3** to **6.8**, it is clear that the value of time plays a major role in the evaluation. Changes in the value of time affect not only the estimated overall benefit figure, but also and more strongly the distribution of these benefits across the population.

The use of a common value of time in estimating changes in consumer surplus leads to a more homogeneous distribution of estimated benefit across the income spectrum. Yet, in the case of private transport users, the highest income travellers are still estimated to enjoy greater average benefits than those in the lower income groups, and there is a slight effect in this direction also for public transport users.

The choice of value of time is therefore important as it would affect differently the estimation of benefits to both private and public transport users, as well as to the various income groups. In particular, benefits to public transport users are rather more sensitive to differences in the value of time than those to private transport users, as travel time savings represent a larger proportion of their total benefits.

The effects of the value given to time as a percentage of wage rate upon the distribution of the estimated user benefits among the various income groups with income-related values of time is illustrated in **Figure 6.9**.As it shows, these are particularly strong in the case of rail improvements and when there are larger proportions of travellers in the higher income groups, as there are under the high income assumption. Furthermore, these effects are accentuated for values of time below about 40% of the average wage rate.

Figure 6.9 Distribution of total user benefits across the various income groups with different values of time



6.3.2 Benefits as estimated by the Compensating Variation (CV). The estimates of CV for public transport and private transport users taken together in each income group are presented for a range of values of the elasticity of utility with respect to available time, β, in **Tables 6.6** and **6.7** for the rail scenario compared with the 'do-minimum' scenario. The corresponding **Tables 6.8** and **6.9** for the highway scenario give the estimates of CV for private transport users. Also, the Marshallian measures of consumer surplus estimated with the income related and common values of time are also presented in these tables.

As the tables show, the value of the elasticity affects both the overall estimates of CV and their distribution across the income groups.

In the case of rail scenario compared with the 'do-minimum' scenario with low income growth (**Table 6.6**) the estimated total value of CV is similar to the Marshallian measures for β just over 0.4. The Marshallian measure estimated with income related values of time gives a similar distribution of estimated benefit over the income groups to the distribution of CV when β is chosen to give a total CV equal to the total change in consumer surplus. Similarly, the estimated total CV with the high income assumption (**Table 6.7**) corresponds with the estimated total benefit given by the Marshallian measure with income related values of time when β is just over 0.5, but in this case the distribution over the income groups of the change in consumer surplus favours the highest income group at the expense of the other 4 groups compared with the distribution of CV when β is chosen to give the same estimated total benefit.

Similarly, in the case of the highway scenario compared with the do-minimum scenario, estimates of the total change in consumer surplus with income-related values of time are similar to total CV for β just over 0.4 in the case of low income growth (**Table 6.8**) and just over 0.5 for the high income growth assumption (**Table 6.9**). Once again, the Marshallian measure gives a similar distribution over income groups to that of CV with low income growth but with high income growth it gives a higher estimate of benefit for the highest income group and lower estimates for the other 4 groups than their CV counterparts.

Table 6.6 Estimated values of Compensating Variation (in weekday morning peak at 1981 prices) for different values of β (and percentages in each income group)

Railway scenario compared with do-minimum scenario with low income growth assumption

Beta	Income Categories 1	2	3	4	5	Total
0.0	6210 (18.38)	8365 (24.76)	8748 (25.90)	5006 (14.82)	5453 (16.14)	33782 (100.00)
0.1	7038 (16.84)	9781 (23.41)	10798 (25.84)	6505 (15.57)	7665 (18.34)	41787 (100.00)
0.2	8072 (15.59)	11546 (22.30)	13357 (25.80)	8375 (16.18)	10427 (20.14)	51777 (100.00)
0.3	9400 (14.55)	13812 (21.38)	16642 (25.76)	10775 (16.68)	13972 (21.63)	64601 (100.00)
0.4	11167 (13.67)	16828 (20.60)	21015 (25.73)	13972 (17.11)	18692 (22.89)	81674 (100.00)
0.5	13633 (12.92)	21040 (19.94)	27122 (25.70)	18438 (17.47)	25287 (23.96)	105520 (100.00)
0.6	17317 (12.27)	27331 (19.36)	36249 (25.68)	25112 (17.79)	35146 (24.90)	141155 (100.00)
0.7	23417 (11.70)	37754 (18.86)	51376 (25.66)	36181 (18.07)	51501 (25.72)	200229 (100.00)
0.8	35470 (11.18)	58354 (18.40)	81305 (25.64)	58100 (18.32)	83905 (26.46)	317134 (100.00)
0.9	70463 (10.71)	118249 (17.97)	168570 (25.61)	122172 (18.56)	178756 (27.16)	658210 (100.00)
ΔMCS_1	12116 (13.60)	18293 (20.54)	22912 (25.73)	15263 (17.14)	20472 (22.99)	89056 (100.00)
ΔMCS_2	18436 (19.97)	23207 (25.14)	23343 (25.29)	13094 (14.19)	14222 (15.41)	92302 (100.00)

ΔMCS_1 change in consumer surplus estimated using the rule-of-half measure at income-related value of time

ΔMCS_2 change in consumer surplus estimated using the rule-of-half measure at common value of time

Table 6.7 Estimated values of Compensating Variation (in weekday morning peak at 1981 prices) for different values of β (and percentages in each income group)

Railway scenario compared with do-minimum scenario with high income growth assumption

Beta	Income Categories					Total
	1	2	3	4	5	
0.0	4313 (12.76)	5897 (17.45)	8313 (24.60)	6120 (18.11)	9153 (27.08)	33796 (100.00)
0.1	4929 (11.28)	6959 (15.92)	10387 (23.77)	8058 (18.44)	13368 (30.59)	43701 (100.00)
0.2	5699 (10.17)	8286 (14.78)	12976 (23.15)	10477 (18.69)	18615 (33.21)	56053 (100.00)
0.3	6687 (9.30)	9988 (13.89)	16299 (22.67)	13582 (18.89)	25351 (35.26)	71907 (100.00)
0.4	8002 (8.60)	12253 (13.17)	20722 (22.28)	17716 (19.05)	34317 (36.90)	93010 (100.00)
0.5	9838 (8.03)	15417 (12.59)	26899 (21.96)	23490 (19.18)	46844 (38.24)	122488 (100.00)
0.6	12580 (7.55)	20141 (12.09)	36127 (21.69)	32119 (19.29)	65570 (39.37)	166537 (100.00)
0.7	17121 (7.15)	27969 (11.68)	51420 (21.46)	46424 (19.38)	96622 (40.33)	239556 (100.00)
0.8	26095 (6.79)	43437 (11.31)	81659 (21.26)	74735 (19.46)	158118 (41.17)	384044 (100.00)
0.9	52172 (6.48)	88394 (10.97)	169693 (21.07)	157345 (19.53)	337902 (41.95)	805506 (100.00)
ΔMCS_1	8690 (6.68)	13338 (10.26)	22622 (17.40)	19366 (14.89)	66019 (50.77)	130034 (100.00)
ΔMCS_2	14731 (14.03)	18920 (18.01)	25621 (24.40)	18412 (17.53)	27340 (26.03)	105024 (100.00)

ΔMCS_1 change in consumer surplus estimated using the rule-of-half measure at income-related value of time

ΔMCS_2 change in consumer surplus estimated using the rule-of-half measure at common value of time

Table 6.8 Estimated values of Compensating Variation (in weekday morning peak at 1981 prices) for different values of β (and percentages in each income group)

Highway scenario compared with do-minimum scenario with low income growth assumption

Beta	Income Categories					Total
	1	2	3	4	5	
0.0	916 (9.55)	2109 (21.98)	2812 (29.31)	1911 (19.92)	1847 (19.25)	9595 (100.00)
0.1	967 (9.32)	2240 (21.60)	3015 (29.07)	2094 (20.19)	2054 (20.19)	10370 (100.00)
0.2	1029 (9.09)	2400 (21.19)	3264 (28.82)	2320 (20.49)	2311 (20.41)	11324 (100.00)
0.3	1107 (8.83)	2602 (20.75)	3581 (28.56)	2610 (20.82)	2637 (21.03)	12537 (100.00)
0.4	1211 (8.55)	2873 (20.29)	4005 (28.56)	2995 (20.82)	3073 (21.03)	14157 (100.00)
0.5	1358 (8.27)	3250 (19.80)	4595 (28.00)	3532 (21.52)	3678 (22.41)	16413 (100.00)
0.6	1576 (7.97)	3811 (19.28)	5471 (27.68)	4329 (21.90)	4579 (23.17)	19766 (100.00)
0.7	1936 (7.65)	4739 (18.72)	6921 (27.34)	5648 (22.32)	6066 (23.97)	25310 (100.00)
0.8	2644 (7.31)	6558 (18.14)	9758 (26.99)	8223 (22.74)	8971 (24.81)	36154 (100.00)
0.9	4673 (6.99)	11740 (17.56)	17804 (26.63)	15502 (23.18)	17149 (25.65)	66868 (100.00)
ΔMCS_1	1277 (8.52)	3026 (20.19)	4225 (28.19)	3187 (21.26)	3275 (21.85)	14990 (100.00)
ΔMCS_2	1569 (10.95)	3308 (23.08)	4086 (28.51)	2792 (19.48)	2577 (17.98)	14331 (100.00)

ΔMCS_1 change in consumer surplus estimated using the rule-of-half measure at income-related value of time

ΔMCS_2 change in consumer surplus estimated using the rule-of-half measure at common value of time. Due to computational problems,the common value of time adopted was 100.6 pence/hour rather than 115 pence/hour.

Table 6.9 Estimated values of Compensating Variation (in weekday morning peak at 1981 prices) for different values of β (and percentages in each income group)
Highway scenario compared with do-minimum scenario with high income growth assumption

Beta	Income Categories 1	2	3	4	5	Total
0.0	555 (5.77)	1294 (13.45)	2450 (25.47)	2229 (23.17)	3092 (32.14)	9620 (100.00)
0.1	587 (5.55)	1380 (13.05)	2641 (24.98)	2458 (23.25)	3505 (33.16)	10571 (100.00)
0.2	628 (5.34)	1488 (12.66)	2880 (24.50)	2746 (23.36)	4012 (34.13)	11754 (100.00)
0.3	679 (5.12)	1626 (12.26)	3183 (24.01)	2112 (15.93)	4659 (35.14)	13259 (100.00)
0.4	749 (4.91)	1810 (11.86)	3588 (23.50)	3600 (23.58)	5519 (36.15)	15266 (100.00)
0.5	846 (4.68)	2065 (11.43)	4152 (22.99)	4280 (23.70)	6718 (37.20)	18061 (100.00)
0.6	990 (4.46)	2446 (11.01)	4992 (22.47)	5293 (23.82)	8500 (38.25)	22221 (100.00)
0.7	1228 (4.22)	3075 (10.57)	6380 (21.93)	6964 (23.94)	11443 (39.34)	29090 (100.00)
0.8	1696 (3.99)	4311 (10.14)	9097 (21.39)	10234 (24.06)	17193 (40.42)	42531 (100.00)
0.9	3045 (3.78)	7833 (9.72)	16818 (20.86)	19489 (24.18)	33420 (41.46)	80605 (100.00)
ΔMCS_1	791 (4.15)	1912 (10.03)	3798 (19.93)	3843 (20.17)	8710 (45.71)	19054 (100.00)
ΔMCS_2	1118 (6.91)	2377 (14.69)	4080 (25.21)	3727 (23.03)	4880 (30.16)	16181 (100.00)

ΔMCS_1 change in consumer surplus estimated using the rule-of-half measure at income-related value of time

ΔMCS_2 change in consumer surplus estimated using the rule-of-half measure at common value of time

The increase in associated values of time for the high income growth assumption imply that the Marshallian measure should provide similar results for higher values of β than in the case of low income growth assumption. The higher value of β expresses the fact that, reduction in travel times would translate into greater utility (whether or not evaluated in money terms) than in the case of low income growth. In addition, the distributions of benefits estimated by the two measures are considerably different, with changes in consumer surplus greatly overestimating the benefits derived by the high income travellers as compared with CV estimates (both in the case of highway or rail improvements).

As it seen, in the measures represented by the travellers' monetary valuation of changes in utility level estimated by the Compensating Variation, the parameter of the elasticity of utility with respect to available time, β, plays an explicit role. It influence both the estimate of total benefits as well as their distribution across the various income groups. It plays a similar role to the choice of value of time in the rule-of-half measure.

When β is equal to zero, benefits are estimated solely from the changes in transport cost. In this case the distribution of benefits across the income spectrum is very similar to those for travel cost savings estimated with the rule-of-half.

As β approaches to one, travel time savings (expressed by the ratios of available time before and after improvements in the transport system) evaluated in money terms represent almost the whole of the estimated benefit. As a result, the proportion of benefits accruing to the highest income groups shows a positive correlation with the β value. The effect of the elasticity figure on the distribution of estimated benefits across the various income groups is illustrated in **Figure 6.10**.

In order to try to make an explicit value judgement on the evaluation, benefits have been weighted by the ratios of the marginal utility of income associated to each income group for the different values of the β parameter. This is illustrated in Figure 6.11. As it shown, irrespective of the elasticity figure, benefits would be more homogeneously distributed across the population. Nevertheless, the countervailing effect of weighting CV is quite different for benefits derived from rail and highway improvements.

The results of the evaluation are further discussed in the next chapter.

Figure 6.10 Distribution of estimated values of CV across the various income groups with different values of β

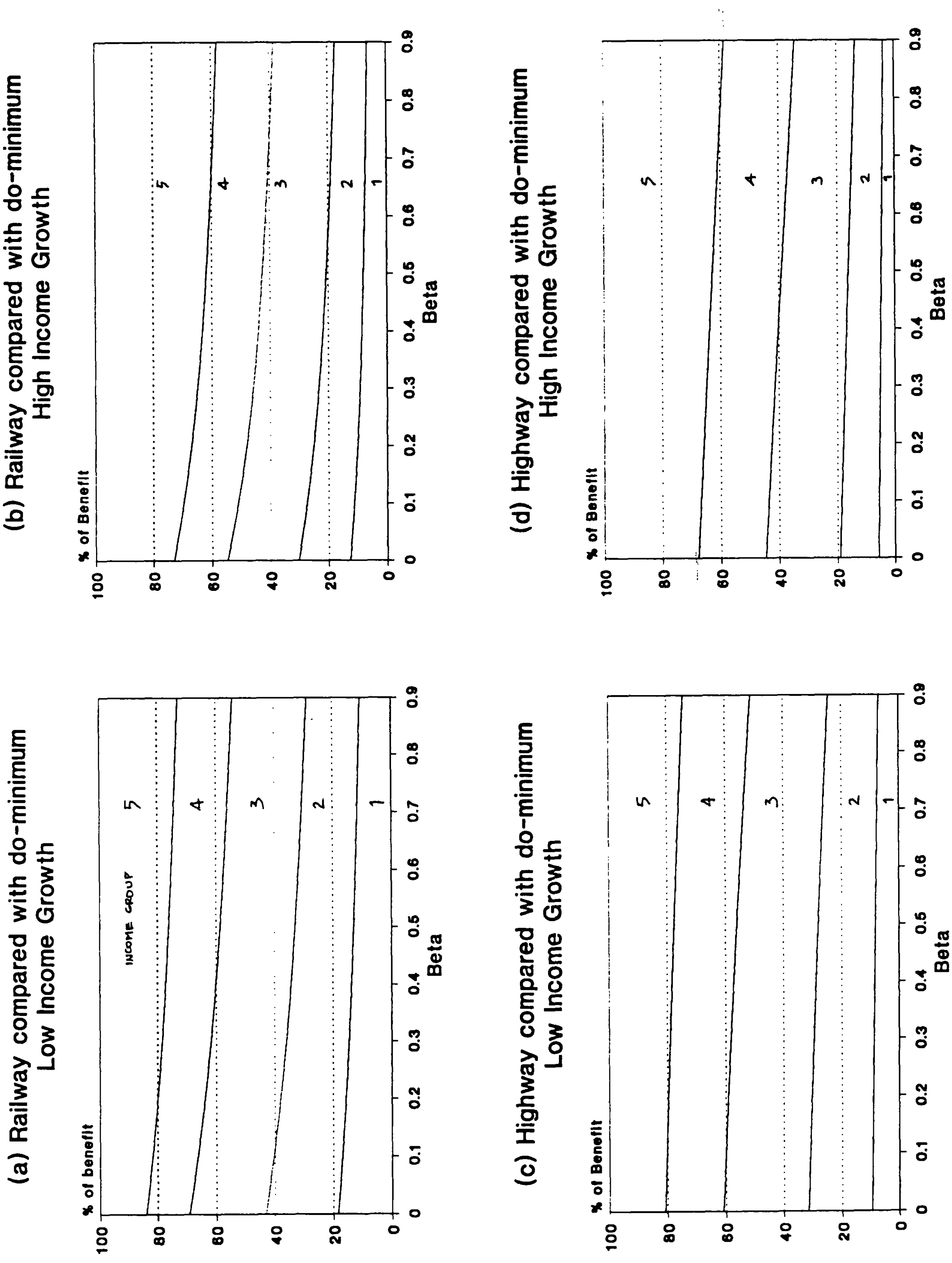
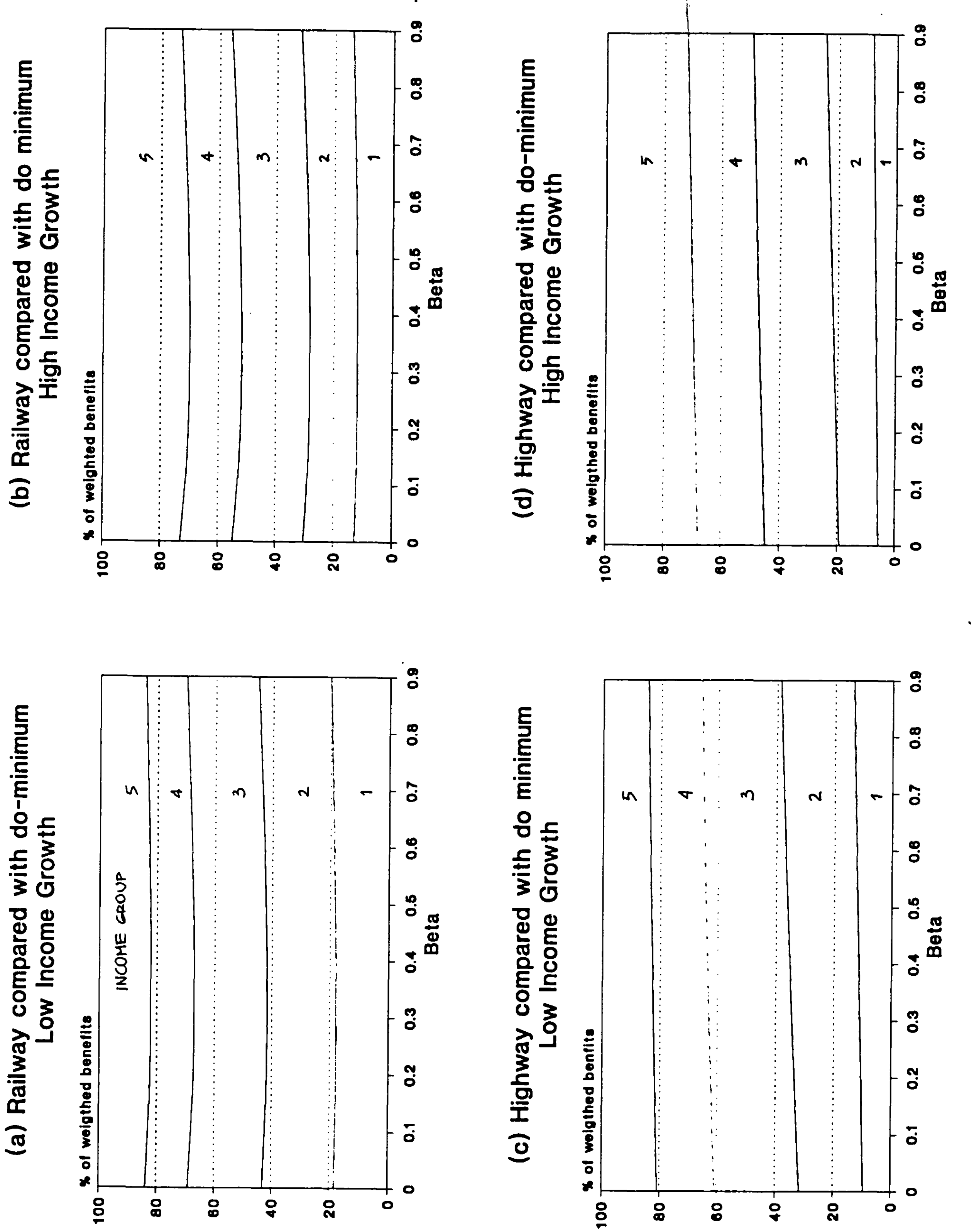


Figure 6.11 Distribution of estimated values of CV weighted by the ratios of the marginal utility of income across the various income groups with different values of β



CHAPTER 7
DISCUSSION, CONCLUSIONS AND SUGGESTION FOR FURTHER RESEARCH

7.1 Discussion of results

In the previous chapter, the results from the evaluation of user benefits from changes in the transport system considered are presented separately for each income category. Changes in the transport system are the consequence of railway or highway investments, and user benefits are calculated in terms of savings in travel time, fares paid and vehicle operating cost.

As in most of the applied work in transport project appraisal, the rule-of-half is used to estimate differences in consumer surplus. The measure is an approximation to changes in 'willingness to pay' and the changes in generalised cost within the system, where the generalised cost is used to refer to a linear combination of the various elements of cost which might affect the demand for travel. For this purpose, time is converted into money units through the value of time, as required for evaluation.

The results presented also examined the implications of using different values of time in the estimation of user benefits, and for this purpose the changes in consumer surplus were estimated with a common value of time and with an income-related value of time.

Rail investments provide benefits for public and, to a small extent, private transport users. Benefits to the latter group of travellers account to a small proportion of the total benefits and it is largely as a result of a reduction in congestion, and therefore operating cost and time, due to shifts of demand to the public mode. Nevertheless, a disproportionate amount of private transport benefits would accrue to the highest income travellers, and average benefits, whether estimated with income-related or a common value of time, are correspondingly greater for this group than to their lower income counterparts.

Benefits accruing to public transport users are rather more sensitive to differences in the value of time than those to private transport users, as travel time savings represent a larger proportion of their total benefit. In addition, irrespective of the value of time adopted, the distributions of benefits to users of public transport are more uniform through the income spectrum than those benefits derived by users of the private mode.

In contrast, according to the modelling exercise from which the data used in this research were drawn, improvements in the highway network would generate benefits solely to private transport users. These benefits will generally accrue to high income travellers, and result from a reduction in both travel cost and travel time, although travel cost savings represent the larger share of these benefits. This reflects the fact that private transport users of the highest income category travel considerably greater average distances than their lower income counterparts, and would therefore enjoy a correspondingly greater reduction in operating costs.

As regards the type of investment, improvements in the railway network generate a more uniform distribution of benefits across the income spectrum, both to private and to public transport users, than improvements in the road system. Nevertheless, irrespective of the kind of intervention, rail or road, highest income travellers would generally enjoy a comparatively larger share of the total benefits estimated from changes in the transport system than the other income groups. Moreover, benefits accruing to the top income groups are, in general, greater than their proportion of actual trips. Thus, estimated average benefit per traveller of the highest income group are considerably greater than the estimated figures for their lower income counterparts, particularly for users of the private mode.

It is also true, as the results illustrate, that the use of a common value of time in the evaluation of user benefits leads to a more homogenous estimated distribution of the total benefits across the population, than if benefits are estimated with income-related values of time. Nevertheless, even then, average benefits estimated with a common value of time are still higher for travellers in the highest income group.

Therefore in the estimation of changes in consumer surplus, the choice of value of time plays a key role as it would affect differently the estimation of benefits both to private and to public transport users, as well as their distribution across the various income groups.

Although the use of behavioral values of time is a standard and accepted practice incorporated in most transport models, it remains an arbitrary issue in the evaluation of user benefits. They represent the amount of money an individual would be willing to pay to save a unit of time for himself. Nevertheless, for evaluation purposes what is required in principle is the amount of money that a public agency would be prepared to pay to save a unit of time for an individual. The rationale and welfare foundations of cost and benefit analysis suggest that if the underlying income distribution is considerable equitable, then 'willingness to pay' is the correct criterion for judging the appropriateness of public sector investment. In this case any revealed variation in travellers' value of time should be taken into account. This would result, as illustrated, in favouring projects which would give greater benefit to those with higher incomes.

Against this background the commonly accepted assumptions concerning household and personal incomes in transport demand modelling have been reconsidered and alternative measures of user benefits have been examined. In the resulting utility-maximizing framework, the problem may be expressed in terms of an individual who chooses the consumption of goods and available time, or leisure, subject to constraints on his overall income and time availability. In addition, income is treated as an exogenous variable, where neither are working hours under the individual control, nor are additional earnings possible.

In the measure represented by the travellers' monetary valuation of changes in utility level estimated by the Compensating Variation (CV), the parameter of the elasticity of utility with respect to available time, β, plays an explicit role. It influences both the estimate of total benefits, as well as their distribution across the various income groups. In many ways, it plays a similar role to the choice of value of time discussed previously.

In fact a trade-off between travel cost and time savings is reflected by the elasticity parameter. As β increases, the effect of changes in available time (or leisure) on utility levels would increase relative to that of changes in disposable income. Hence, the effect of travel time savings, expressed through the ratios of available time before and after improvements in the transport system, would also increase relative to the effect of changes in money cost. At the other (lower) extreme, when β is equal to zero, benefits are estimated solely from the changes in money cost.

As a result, the proportion of benefits accruing to the highest income groups shows a positive correlation with β values. This is particularly evident for improvements in the public transport network, as the effect of travel time savings is more pronounced than in the case of a highway intervention. The elasticity parameter is, therefore, also important in that it would affect differently the estimation of benefits from railway and highway investment.

Implicit in the valuation in money terms of changes in utility are the expressions for the value of time and the marginal utility of income. The value of time not only shows a positive correlation with income (as is expressed by the ratios of income and available time), but also, and in particular, with β, as previously discussed.

Similarly, the marginal utility of income decreases with income and the strength of this effect increases with β. Moreover, in the expression for the marginal utility of income, the effects of both travel time and travel cost themselves are rather weak. The marginal utility of income is determined mainly by income itself (decreasing with it), and available time, which has a positive effect on it.

Despite the controversy surrounding the use of distribution weights in economic analysis, it is traditionally held by economists that these should be somehow related with a measure of the marginal utility of income. For this purpose, benefits have been weighted by the estimates of marginal utility of income associated with each income category, and this has been done for the different values of the β parameter. The results clearly show that, irrespective of the elasticity figure, weighted benefits would be more homogeneously distributed across the population than unweighted ones. Nevertheless, the effect of weighting is quite different for benefits derived from rail and highway improvements.

In the case of railway investment, the distribution of weighted benefit remained very similar, whether the estimated CV is determined solely by changes in travel cost (i.e when β is equal to 0), or whether this measure of benefit is determined largely by the savings in travel time (as β tends to one). In the case of improvements in the highway system, however, the proportion of benefit accruing to the lowest income groups tended to increase with β. These findings suggest that, in the case of highway investment, the countervailing effect of weighting CV by marginal utility of income is more than sufficient to offset the increase in value attached to benefits derived from travel time savings as β increases (and consequently the positive relation between β and the proportion of benefits accruing to the highest income groups).

Comparison between estimates of user benefits in terms of the Marshallian measure of consumer surplus and in terms of the CV, absolute figures were found to be comparable for β between 0.4 and 0.6, depending on the assumption about income growth and correspondingly the income-related values of time adopted in the estimation of differences in consumer surplus.

With the higher values of time associated with the high income growth assumption, the Marshallian measure gave similar estimates of total benefit to those given by the CV for β between 0.5 and 0.6, rather than between 0.4 and 0.5 as was the case with the low income growth assumption. At the higher value of β, reduction in travel times would translate into greater utility, (whether or not evaluated in money terms) than in the case of low income growth, as required to match the larger differences in consumer surplus resulting from the higher value of time. With high income growth and β between 0.5 and 0.6, the distribution of benefits across income categories was found to differ considerably between the two measures, with changes in consumer surplus greatly overestimating the benefits derived by the high income travellers as compared with CV estimates (both for highway and for rail improvements). In the case of low income growth and β between 0.4 and 0.5, however, the two measures gave similar distributions of estimated benefits over the income categories.

These results suggest that if the CV measure representing the travellers' monetary valuation of gains in utility is to be used in place of the consumer surplus without changing the total estimated benefit in circumstances like those represented by the scenarios, then β should be close to 0.5. This would imply that the estimates of elasticity of utility with respect to available time and cost are similar. That is to say, changes in either time or cost would have a similar impact in term of changes in utility level, whether or not evaluated in money terms, if they formed similar proportions of available time and income respectively.

However, the differences in estimates between the consumer surplus and CV for the proportion of benefits accruing to the different income groups under the high growth assumption reflect the substantial effect of attaching differential values to benefits derived from money and time savings by people in different income groups between the lowest and highest incomes. The results show that, in the cases considered, the use of CV with the same value of β for all income groups moderates the favouring of higher income groups that results from using income-related values of time in estimating changes in consumer surplus.

On the other hand, it may be that the actual parameter for the elasticity of utility with respect to available time should have a positive relation with income, indicating a greater value for β for the higher income categories. This would have the effect that lower income groups would derive a greater utility from changes in disposable income, whereas higher income groups would derive a greater benefit from changes in available time. The elasticity parameter should then take different values, being specific to each income category.

There are thus a number of considerations influencing, and implications of, the choice of β if measures of benefit based on CV in the ways considered here are to replace the standard consumer surplus measure.

In particular, if it were decide/that the choice of β should be consistent with travellers' behaviour, then it should be calibrated accordingly. Unless an explicit attempt is made to try to calibrate the elasticity parameter of the utility function through, for instance, revealed analysis of modal choice, the figure adopted would be largely arbitrary.

Nevertheless, aggregation of benefits for project evaluation will always carry with it implicit value judgements, since the (money equivalent) utility of various individuals or groups of individuals has to be added. For this purpose, if the objective of the evaluation is to be understood and value judgements made explicit, then reporting user benefits in a disaggregated fashion and providing results for a range of β values may well be a good compromise. The evaluation can then just indicate the consequences for distribution and allow the decision maker to apply his own 'weights' to assess the implications of alternative investment policies. Alternatively, the corresponding ratios for the marginal utility of income could also be calculated and used for weighting benefits to each income group. In any case, the final decision will be in the hands of decision makers in accordance with political and social ideologies embedded in government thinking.

Although there are a number of assumptions underlying this research, the results from the application of different evaluation techniques to the scenarios considered here should not be seen as confined to these scenarios. Rather, they provide an indication of the potential practical implications of the choice of measures of benefit and disaggregation by income group for the evaluation of transport projects. There are, however, some issues that should be emphasized before firm conclusions are drawn.

First, the monetary evaluation of changes in utility level are affected by the choice of utility function used to represent travellers' choice. In this study, travellers' choice is assumed to be subject to a trade-off between goods and leisure. Thus the characteristics of the selected journey (travel cost and time) would directly affect travellers' budget and time constraints. These are, however, represented only rudimentarily within the LTS model which generated the data, and have had no further influence in the construction of the scenarios. In addition, a very restrictive assumptions is made on the form of utility, implying a unit elasticity of substitution between goods and leisure. Thus a more general form could be considered and further constraints incorporated, and hence the utility maximizing framework expanded. This has implications for forecasting as well as for evaluation and opens up a whole area of research into the use of alternative utility functions to explain current travel patterns and forecast future ones.

Second, as discussed previously, when wide differences in income exist, travellers in the various income categories will perceive differently the benefits derived from changes in travel cost and time savings. In these case having an income-related value of time may not be appropriate and, unless a common value of time is adopted for equity reasons, another form of evaluating travel time savings is required. Similarly, different values of β should be calibrated in order to depict the differences in which travellers perceive gains in utility levels.

Third, when the cost of travel has a substantial impact on travellers' budgets, then the Marshallian measure of consumer surplus may not represent a good approximation to actual change in travellers' welfare from improvements in transport system. In this case, a more rigorous form of evaluation of user benefits is called for.

Finally, in terms of distributional issues, non working and leisure trip should also be investigated and included in the evaluation of user benefits. In many ways the increase in accessibility and questions of transport need (particularly for the elderly and disabled) may well represent an important factor in assessing the distributional implications in the evaluation of transport changes in large urban areas.

7.2 Conclusions

The evaluation of highway and some public transport projects in Great Britain has relied heavily on Cost-Benefit Analysis. This involves the aggregation of individuals' assessments of the costs and benefits to them of a given action, policy, project or programme, and it will, if properly undertaken, reflect individuals' preferences.

Concepts of economic efficiency and the estimation of user benefits provide the starting point for evaluation. If interest lies only in efficiency, the increase in real resources is an adequate measure of project benefit and the problem reduces to one of relative valuation of resources of different kinds. If, however, there is interest in income distribution as well, the distribution of resources among different groups in society must also be examined.

In this respect, an alternative framework for the evaluation of user benefits from transport policies and projects has been explored in this research, in which the measures of user benefits provided to specific income groups under alternative investment scenarios are estimated. The commonly accepted assumptions concerning household and personal incomes in transport demand modelling have been reconsidered, and alternative measures of user benefit and the value of time are derived from the theory of trade-off between goods and leisure. These are compared with the traditional measure of consumer's surplus for different income groups separately.

The framework has been applied to a data set which resulted from modelling exercises relating to alternative investment policies considered in the London Assessment Studies, including a 'do-minimum' policy and rail and highway investment policies. These policies have been tested by the London Transportation Studies Model, and their output matrices of journeys and travel cost by different transport modes form the basis on which hypothetical but realistic alternative scenarios have been constructed for analysis.

The main findings from the results are summarized as follows.

(i) The framework demonstrated clear differences between the policies in terms of distribution of benefits across the income spectrum, with improvements in the railway network generating a more uniform distribution both to private and public transport users, than improvements in the road system in the hypothetical scenarios.

(ii) In the estimation of the changes in consumer surplus, the value of time plays a key role in determining both the estimate of total benefits, and their estimated distribution over the income categories. The choice of value of time is particularly important in two distinct situations: firstly, in the evaluation of benefits to public transport users, since, irrespective of income category, time savings represent a larger proportion of the total benefit figure to them than to users of the private mode; and secondly for users of both modes, when large differences in income exist between the high and low income categories.

(iii) As expected, the use of common value of time in the evaluation of user benefits leads to a more homogeneous estimated distribution of benefits across the population, than does the use of income-related value of time.

(iv) Irrespective of the value of time adopted in the evaluation, the high income groups, with correspondingly greater mobility, were found to enjoy a larger share of the benefits derived from changes in transport system than their lower income counterparts.

(v) In the measure representing the travellers' monetary valuation of changes in utility level as estimated by the Compensating Variation (CV), the elasticity of utility with respect to available time, β, plays an explicit role, and was found to affect differently the estimation of benefits from railway and highway investment, as well as their distribution across the income spectrum.

(vi) A trade-off between travel cost and time savings is reflected by the elasticity parameter, and, in this respect, the proportion of benefits accruing to the highest income groups was found to show a positive correlation with β. This effect was found to be particularly strong for improvements in the rail network, as travel time savings formed a larger proportion of the benefits than in the case of highway improvements.

(vii) As expected the distribution of benefits as estimated by the CV across the income groups was made more homogeneous when benefits were weighted by the marginal utility of income then when they were unweighted. This effect was found to be stronger for benefits derived from highway improvements than those from rail improvements. In the case of highway investment the countervailing effect of weighting

CV in this way is more than sufficient to offset the increase in benefits derived from travel time savings as β increases.

(viii) Estimates of total user benefits according to the Marshallian measure of consumer surplus and CV in the scenarios studies were found to be comparable for β between 0.4 and 0.6, depending on the assumption of income growth and correspondingly, the income-related values of time adopted in the estimation of differences in consumer surplus.

(ix) When large differences in income exists between the highest and lowest income groups, the distribution of benefits across income categories differ considerably between the measures, with changes in consumer surplus greatly overestimating the benefits derived by the high income travellers as compared with CV estimates. This suggests either that weight given to benefits accruing to the highest income travellers by the use of an income-related value of time, could be moderated by using CV with the same β for all income groups in place of consumer surplus; or, that the parameter for the elasticity of utility with respect to available time should have a positive relation with income, i.e. β should be higher for the higher income categories.

(x) Unless an explicit attempt is made to try to calibrate the elasticity parameter of the utility function through, for instance, analysis of modal choice, the figure adopted would be largely arbitrary. Nevertheless, reporting user benefits in a disaggregated fashion and providing results for a range of β values may well be a good compromise.

This research has considered distributional aspects of the evaluation of benefits to users, but any distributional impact of a transport policy or project will depend not only on the relative importance of particular income groups in the use of, and benefits derived from, that service or facility in which changes are made, but also on their importance as contributors to the taxes (or capital raised) which finance the changes. These considerations become even more important when it is argued that there is a potential redistributive case for transport investment. If one accepts such arguments, one still needs analysis of distributional impacts to try to secure that precise instruments chosen are capable of achieving the distributional objectives that are being pursued.

Income distribution policies, whether pursued directly through the fiscal system or indirectly through individual projects, are ultimately the responsibility of public agencies and decision makers, and are therefore generally influenced by the political process. In this respect, objectives of efficiency in resource allocation must be balanced with distributional justice and equity considerations. The outcome of such policies will be particular to every single state. It is nevertheless in the general interest if implicit judgements, and their implications for the various social groups, are made clear, as is the kinds of analysis developed and demonstrated in this research.

7.3 Suggestions for further work

As stressed throughout this thesis, despite all their relevance, distributional issues have not formed any substantial part of research on modelling in transport planning and evaluation. In this respect, the issues addressed here have a number of potential implications and there is scope for further research to be undertaken.

In addition, there are many assumptions underlying this research and, although the results should not be seen as confined to the scenarios constructed, there are a series of specific points where further work is still required and is likely to yield useful comparative results.

In **Chapter 5** a considerable effort was put in estimating the number of travellers in each category who would change their behaviour as a result of improvements in transport system. Despite considerable investigation of alternative approaches, a simple assumption had to be adopted. Although for this research it was reasonable to proceed on this basis, it would be preferable to have a theoretically firmer basis for estimating the welfare differences associated with this group of travellers.

Another area where further work is required relates to the utility maximizing framework adopted in this research. The utility function presented could be calibrated under different situations, in order to depict the differences in how travellers perceive gains in utility levels, to understand travel behaviour, and to assess the implications for the evaluation of user benefits. In addition, the monetary evaluation of changes in utility level are affected by the choice of utility function used to represent travellers' choices. Thus, there is a great scope to test alternative, less restrictive, forms, as well as to incorporate further constraints. This has implications for forecasting as well as for evaluation and opens up a whole area of research into the use of alternative utility functions to explain current travel patterns and forecast future ones.

Furthermore, the estimation of more rigorous welfare measures, which consider a demand model explicitly in their derivation, permits a better interpretation of benefits in terms of demand parameters and their underlying meaning. However, except in isolated experiments the rule-of-half has not been sufficiently compared with its alternatives. Further comparisons are still required, if firm conclusions are to be drawn.

At the more general level, additional investigation is required in order to assess the implications for policy concerning distributional issues and the evaluation of transport changes in large urban areas. In particular, the economic evaluation of transport projects also involves the estimation of values for a number of items which were previously regarded as intangibles, other than travel time. These include accident costs, and widespread environmental externalities, such as reductions in noise, pollution and congestion levels. The distributional implications of these, together with the more straightforward items, such as government expenditures, vehicle operating costs, and travel times, should be further investigated for a detailed evaluation of the operational consequences under consideration.

Moreover, changes in the transport system would also result in other benefits to non-users including contribution to economic development, job creation and land use regeneration. These benefits in turn, would have different social distributions. Furthermore, the source used for financing such projects would have different incidence on the various income groups. Finally, the outcome of economic evaluation of investment in transport infrastructure will be critically affected by the pricing policy adopted, as well as the institutional and political structure in which complementary and competing services operate. These issues should also be investigated, if an assessment of the potential redistributive case for transport investment is to be carried out.

CHAPTER 8
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APPENDIX 1

MAXIMUM LIKELIHOOD ESTIMATION OF THE PARAMETERS OF THE NORMAL DISTRIBUTION FROM GROUPED DATA BY THE EXPECTATION MAXIMIZATION ALGORITHM

In this appendix a method is described to estimate the parameters, mean and variance, for the normal distribution for grouped data. The method is used to estimate lognormal income distributions of households and for trips arriving in any district by each mode.

Suppose that the logarithm of household income is normally distributed with mean μ and variance σ^2. Suppose we have N independent observations $y_1, y_2, \ldots y_N$ taken from this population $N(\mu,\sigma^2)$.

The observations are grouped in income categories, so that $L_i \leq y_i \leq U_i$, where L_i and U_i are the respective lower and upper limits, given by the logarithm of the respective incomes, for the income category in which the logarithm of the income of the household **i** lies.

Four different situations may be specified:

i. $L_i = U_i$. The ith observation is exactly specified (i.e. this is a particular case of a continuous distribution).

ii. $L_i = -\infty$. The ith observation is censored on the left at U_i.

iii. $U_i = \infty$. The ith observation is censored on the right at L_i.

iv. $L_i < U_i$ and both limits are finite. In this case the ith observation is confined to be in the interval (L_i,U_i).

The data from the Greater London Transportation Survey on household income is a specific case where there are 12 categories all observations are confined to an interval (L_i,U_i), except for the highest income category (household income exceeding the £20000 threshold), where observations are censored on the right, and the lowest income category (household income less then the £3000 threshold), where if we assume that minimum income is positive and just above zero, since the logarithm transformation is not defined for values equal to zero, then observations are censored on the left.

Suppose that there are $\mathbf{n_1}$, $\mathbf{n_2}$, ... $\mathbf{n_{12}}$ observations in the twelve income categories, where:

$$\sum_{i=1}^{12} n_i = N$$

Let Z(x) be the probability density function for the standard normal distribution:

$$Z(x) = \frac{1}{\sqrt{2\Pi}} \exp^{-\frac{x^2}{2}}$$

and its integral over interval (x,y) be denoted by:

$$Q(x,y) = \int_x^y Z(t)dt$$

Also, let:

$$\phi(x,\mu,\sigma^2) = \frac{1}{\sigma\sqrt{2\pi}} \exp^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

so that Z(x) = ϕ(x,0,1).

The problem of estimating the parameters μ and σ^2 of a normal population of grouped data may be treated similarly to estimates from incomplete data. The EM algorithm may therefore be separated into two steps:

A.1 First step

For this first step, suppose that a complete data set is given comprising n_k observations in category **k** ($1 \leq K \leq 12$) and let be estimates of $x_1, x_2, \ldots x_n$ the expected values of the logarithms of income for the observations. Suppose also that for the first iteration, for $L_i \leq x_i \leq U_i$, x_i take any value within the interval L_i and U_i (e.g. mid-point in the case of finite intervals). Estimates of μ and σ^2 may thus be obtained:

$$\hat{\mu} = \bar{x} = \frac{1}{N}\sum_{i=1}^{12} x_i . n_i$$

$$\hat{\sigma}^2 = \frac{1}{N-1}\sum_{i=1}^{12} n_i (x_i - \bar{x})^2 = \frac{1}{N-1}\sum_{i=1}^{12} n_i (x_i^2 - \bar{x}^2)$$

A.2 Second Step

Given $(\hat{\mu}, \hat{\sigma}^2)$ and the number of observations ($n_1, n_2, \ldots n_{12}$), the new expected value $\hat{x}_i$ of the logarithm observation for each category **i** may be re-estimated by:

$$\hat{x}_i = E(x_i | L_i < x_i < U_i)$$

where the expectation is based on the distribution $N(\hat{\mu}, \hat{\sigma}^2)$ and thus $\hat{x}_i$ may be calculated:

$$\hat{x}_i = \frac{\int_{L_i}^{U_i} x \phi(x, \hat{\mu}, \hat{\sigma}^2) dx}{\int_{L_i}^{U_i} \phi(x, \hat{\mu}, \hat{\sigma}^2) dx}$$

Similarly $\widehat{x_i^2}$ may be estimated by:

$$E(x_i^2|L_i<x_i<U_i)$$

so that:

$$\widehat{x_i^2}=\frac{\int_{L_i}^{U_i} x^2\phi(x,\hat{\mu},\hat{\sigma}^2)\,dx}{\int_{L_i}^{U_i}\phi(x,\hat{\mu},\hat{\sigma}^2)\,dx}$$

Let $x = \hat{\mu} + \hat{\sigma}h$

$$h_i=\frac{L_i-\hat{\mu}}{\hat{\sigma}}$$

and

$$H_i=\frac{U_i-\hat{\mu}}{\hat{\sigma}}$$

It therefore implies that:

$$dx=\hat{\sigma}\,dh$$

Hence:

$$\hat{x}_i=\frac{\int_{h_i}^{H_i}(\hat{\mu}+\hat{\sigma}h)\phi(h,0,1)dh}{\int_{h_i}^{H_i}\phi(h,0,1)dh}$$

which may be written as:

$$\hat{x}_i = \frac{\hat{\mu} Q(h_i,H_i) + \hat{\sigma}\left[-Z(h)\right]_{h_i}^{H_i}}{Q(h_i,H_i)}$$

$$\hat{x}_i = \hat{\mu} + \hat{\sigma}\left[\frac{Z(h_i) - Z(H_i)}{Q(h_i,H_i)}\right]$$

Similarly

$$\widehat{x_i^2} = \frac{\int_{h_i}^{H_i} (\hat{\mu} + \hat{\sigma} h)^2 Z(h)dh}{\int_{h_i}^{H_i} Z(h)dh}$$

$$\widehat{x_i^2} = \frac{\hat{\mu}^2 \int_{h_i}^{H_i} Z(h)dh + 2\hat{\mu}\hat{\sigma}\int_{h_i}^{H_i} hZ(h)dh + \sigma^2 \int_{h_i}^{H_i} h^2 Z(h)dh}{Q(h_i,H_i)}$$

The last term of the numerator should be integrated by parts thus:

$$\widehat{x_i^2} = \frac{\hat{\mu}^2 Q(h_i,H_i) + 2\hat{\mu}\hat{\sigma}\left[Z(h_i) - Z(H_i)\right] + \hat{\sigma}^2\left[h.-(Z(h))\right]_{h_i}^{H_i} - \hat{\sigma}^2 \int_{h_i}^{H_i} (-Z(h))dh}{Q(h_i,H_i)}$$

and therefore $\widehat{x_i^2}$ may be written as:

$$\widehat{x_i^2} = \hat{\mu}^2 + \hat{\sigma}^2 + 2\hat{\mu}\hat{\sigma}\frac{Z(h_i) - Z(H_i)}{Q(h_i,H_i)} - \hat{\sigma}^2\frac{H_i Z(H_i) - h_i Z(h_i)}{Q(h_i,H_i)}$$

This calculation is made for each category **i**. The estimate values for each category should be used to make new estimates $\tilde{\mu}$ and $\tilde{\sigma}^2$ of the new parameters (μ,σ^2) of the distribution, where:

$$\hat{\mu}=\frac{1}{N}\sum_{i=1}^{12}\hat{x}_i \cdot n_i$$

$$\hat{\sigma}^2=\frac{1}{N-1}\sum_{i=1}^{12}n_i x_i^2-\hat{\mu}^2$$

Identifications are made until $\hat{\mu}$, $\hat{\sigma}^2$ converge to $\tilde{\mu}$ and $\tilde{\sigma}^2$, say.

Finally, the estimated mean ξ and the standard deviation ρ of the income itself are given by:

$$\xi=e^{\tilde{\mu}+\frac{1}{2}\tilde{\sigma}^2}$$

$$\rho^2=e^{2\tilde{\mu}+\tilde{\sigma}^2}(e^{\tilde{\sigma}^2}-1)$$

APPENDIX 2

ESTIMATED NUMBER OF TRIPS BY EACH INCOME CATEGORY AT ANY DISTRICT FOR THE FORECAST YEAR FOR THE DO-MIMINUM SCENARIO

A.2.1 Under the low growth assumption

A.2.1.1 Trips by public transport

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
CENTRAL LONDON												
Sector 0												
0	118.79	129.75	122.62	72.26	104.01	547.43	2451.19	2354.70	2147.67	1138.67	1216.30	9308.53
1	186.25	224.82	215.41	127.93	183.43	937.84	1498.58	3675.82	4322.61	2540.45	2749.91	14787.37
2	166.84	171.95	160.25	95.13	135.38	729.55	4203.12	4509.06	4268.78	2174.93	1986.88	17142.77
10	245.94	274.80	260.94	154.72	220.53	1156.93	2856.66	6508.92	7127.94	3839.79	3558.14	23891.45
20	20.46	15.18	13.42	7.79	10.97	67.82	329.10	560.83	626.76	348.43	337.80	2202.92
21	60.86	64.41	60.85	36.18	51.53	273.83	1079.45	1748.96	1654.94	877.36	927.97	6288.68
30	493.40	522.30	493.40	293.37	417.84	2220.31	3176.17	4615.26	4406.54	2267.96	2158.33	16624.26
31	78.18	114.69	111.88	66.94	96.90	468.59	1107.58	1505.60	1614.87	961.47	1192.80	6382.32
32	439.37	535.76	517.84	307.11	443.85	2243.93	8448.59	11203.42	11042.10	6318.62	7873.13	44885.86
33	330.61	374.68	355.79	210.96	303.84	1575.88	7347.41	12446.62	13385.98	7809.38	9203.76	50193.15
34	101.62	78.66	69.61	40.72	57.42	348.03	3356.29	6873.04	7523.22	4410.24	5200.48	27363.27
35	94.72	33.72	22.96	12.02	15.78	179.20	3584.73	7033.40	7208.76	3862.08	3812.03	25501.00
36	140.99	91.61	78.23	44.76	63.17	418.76	4177.58	7531.63	8970.22	5502.44	6538.49	32720.36
37	421.92	407.91	378.14	222.33	318.61	1748.91	3557.32	6462.83	7458.70	4682.85	6302.09	28463.79
38	159.89	126.80	113.88	66.20	93.68	560.45	3724.51	8711.28	10527.08	6562.70	8155.75	37681.32
39	636.10	688.38	647.72	383.40	551.87	2907.47	974.09	2014.31	2336.33	1468.12	1983.11	8775.96
40	139.91	147.45	139.28	82.19	117.95	626.78	2514.78	5387.46	6204.67	3681.02	4190.88	21978.81
41	205.22	194.36	178.52	105.11	150.16	833.37	2416.67	6304.14	8008.63	4797.93	4963.44	26490.81
42	139.07	135.58	126.28	74.49	106.48	581.90	2610.72	3978.76	4240.37	2466.62	2897.70	16194.17
43	229.90	203.37	185.69	108.76	155.62	883.34	2532.42	5032.99	5384.86	2855.20	2593.18	18398.65
44	254.59	313.34	301.59	178.86	258.51	1306.89	2502.15	3095.02	3306.00	1829.37	1814.54	12547.08
50	238.06	212.24	194.69	114.42	162.40	921.81	3543.17	2312.69	1740.72	892.54	1125.03	9614.15
51	249.57	243.32	226.59	133.66	191.10	1044.24	2420.04	3691.54	3498.39	1810.08	1771.84	13191.89
52	145.69	181.18	174.37	104.17	149.46	754.87	1987.83	3736.22	4009.57	2327.51	2727.63	14788.76
60	9.63	18.24	18.24	11.02	15.91	73.04	548.94	1197.08	1315.24	793.57	1024.72	4879.55
70	37.83	33.73	30.95	18.19	25.82	146.52	1721.49	1978.20	1748.33	986.64	1406.87	7841.53
71	3.07	2.74	2.51	1.48	2.10	11.90	411.19	645.00	566.05	287.97	299.36	2209.57
80	53.11	100.58	100.58	60.75	87.71	402.73	2986.38	8914.59	11130.78	6971.87	8473.36	38476.98

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
81	85.06	88.83	83.55	49.52	70.70	377.66	2130.06	5967.21	7716.58	4997.93	6388.61	27200.39
82	81.07	153.54	153.53	92.74	133.89	614.77	4080.86	10762.62	13294.13	8006.80	8734.37	44878.78
83	141.43	149.05	140.80	83.09	119.24	633.61	3233.90	7210.74	9372.13	6284.64	8819.60	34921.01
84	72.76	117.17	114.81	68.98	99.69	473.41	5051.40	13500.87	15794.03	9162.02	9651.73	53160.05
INNER LONDON SECTORS 1,2 AND 3												
Sector 1												
100	1359.51	799.37	460.95	175.04	128.36	2923.23	1031.29	777.47	511.73	191.16	120.56	2632.21
101	2336.24	2227.40	1596.19	645.73	442.58	7248.14	974.85	902.05	828.79	452.51	533.82	3692.02
102	1570.38	2061.10	1786.30	713.21	405.68	6536.67	2009.78	1039.51	935.62	478.62	456.44	4919.97
103	615.40	677.50	658.60	361.69	385.98	2699.17	380.23	411.17	387.05	198.33	189.15	1565.93
104	2453.96	2419.88	1993.85	911.72	724.26	8503.67	1263.13	607.54	425.99	211.33	263.90	2771.89
105	1493.02	1674.36	1523.23	737.44	616.55	6044.60	1594.99	911.61	592.32	244.98	198.75	3542.65
106	2728.88	3434.40	3394.47	1850.32	1890.25	13298.32	1443.30	1334.65	944.63	348.72	200.91	4272.21
110	1945.26	1829.86	1159.46	379.16	181.34	5495.08	2043.26	2075.07	1304.09	463.80	277.47	6163.69
111	3323.67	3279.82	1639.90	394.63	131.54	8769.56	1950.91	1844.18	1454.00	549.83	301.60	6100.52
112	2267.49	2145.58	1176.42	347.44	152.38	6089.31	1413.59	1956.97	1906.71	1053.56	1209.36	7540.19
113	2634.99	2614.19	1289.76	305.10	104.01	6948.05	1260.38	1542.61	1209.91	522.50	396.01	4931.41
114	1350.15	1374.43	1141.31	539.09	461.37	4866.35	1618.30	1016.49	769.87	347.97	298.51	4051.14
115	2290.64	2038.06	2020.64	1132.26	1228.06	8709.66	2120.90	1137.51	940.62	501.82	615.05	5315.90
116	288.95	196.64	371.21	353.15	794.60	2004.55	326.28	116.99	92.70	49.37	60.49	645.83
120	1549.69	1375.91	1037.96	468.29	391.04	4822.89	1421.97	1963.84	1467.43	591.97	401.78	5846.99
121	2176.00	1706.19	1261.09	562.55	469.82	6175.65	1253.45	1323.71	1034.29	491.39	481.53	4584.37
122	1913.65	1641.85	1153.73	477.02	354.99	5541.24	1796.72	1655.39	1171.84	451.65	286.99	5362.59
123	2450.72	2519.52	2063.77	902.90	662.13	8599.04	2486.48	1794.10	1402.19	684.65	710.19	7077.61
124	2429.24	2480.94	2408.57	1374.85	1653.96	10347.56	1716.60	877.36	592.52	278.88	312.23	3777.59
125	2880.25	3012.26	2964.25	1584.13	1584.13	12025.02	1733.46	1766.14	1435.16	606.79	417.34	5958.89
130	2293.47	1720.10	1270.53	605.95	625.49	6515.54	1557.05	1803.92	1444.28	633.72	487.56	5926.53
131	1831.63	2135.50	2034.21	1131.06	1316.75	8449.15	2513.94	818.64	545.41	279.16	404.49	4561.64
132	1987.27	2758.04	2470.15	1160.79	919.35	9295.60	969.27	1060.29	943.62	483.84	497.64	3954.66

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
133	2360.87	2854.79	2667.10	1195.26	800.13	9878.15	1783.14	2161.89	1499.36	487.37	220.22	6151.98
134	1802.18	2430.45	2182.44	1033.35	826.69	8275.11	2149.04	1581.78	1045.18	385.20	234.20	5395.40
135	997.21	1062.16	947.53	450.84	370.61	3828.35	822.90	539.97	354.23	130.50	79.34	1926.94
136	1566.59	1768.24	1884.56	1132.29	1388.21	7739.89	1629.44	1078.51	1020.68	543.13	555.08	4826.84
Sector 2												
200	1093.03	1133.66	816.09	358.19	295.41	3696.38	1042.62	1640.91	1310.03	565.99	424.29	4983.84
201	2821.06	2978.34	2231.30	992.78	815.85	9839.33	1783.92	1919.60	1594.11	750.33	661.12	6709.08
202	2579.64	2883.69	2334.42	1088.74	912.19	9798.68	2861.95	2186.28	2158.85	1322.48	2003.94	10533.50
203	1146.71	1129.54	974.92	506.79	541.15	4299.11	1950.44	865.36	661.34	360.31	529.21	4366.66
204	1624.91	1555.76	1479.70	905.80	1348.32	6914.49	914.92	1255.45	1286.79	583.01	374.10	4414.27
210	927.70	1277.53	1018.10	424.54	283.02	3930.89	645.19	407.57	372.07	203.67	234.25	1862.75
211	1562.66	1449.42	1234.27	662.43	758.68	5667.46	1050.87	1117.28	1015.77	553.08	660.62	4397.62
212	1427.54	1182.84	1136.21	739.99	1345.97	5832.55	3101.50	3029.85	2668.07	1342.41	1312.93	11454.76
213	760.36	573.93	647.03	493.50	1188.05	3662.87	1531.46	1538.19	1559.93	998.64	1766.69	7394.91
214	823.77	964.52	1055.59	620.94	670.62	4135.44	857.27	864.64	708.99	359.59	399.72	3190.21
220	2941.33	2591.86	1980.30	1009.56	1184.30	9707.35	2404.64	1642.96	1324.52	707.87	933.55	7013.54
221	2181.05	1724.73	1508.17	904.90	1415.35	7734.20	2008.06	2053.49	1678.12	842.63	913.01	7495.31
230	2987.26	2529.43	2311.97	1407.79	2208.96	11445.41	2209.36	1537.38	1299.47	753.22	1247.22	7046.65
231	1649.25	1500.75	1547.65	1055.21	2055.72	7808.58	1204.28	1665.80	1488.57	735.61	683.29	5777.55
232	2301.26	2126.36	1923.85	1141.42	1702.94	9195.83	2219.33	1655.41	1386.09	750.26	976.49	6987.58
233	1155.72	1204.25	1032.21	516.10	494.05	4402.33	1035.72	1416.61	1350.74	726.38	789.28	5318.73
Sector 3												
300	1525.49	1678.77	1948.83	1094.85	1051.06	7299.00	1204.28	936.25	716.40	323.09	276.69	3456.71
301	1043.41	842.60	858.35	511.86	681.16	3937.38	484.24	563.72	406.94	146.73	79.48	1681.11
302	3133.17	3616.25	3505.83	1821.93	1725.31	13802.49	2508.84	2189.90	1691.74	746.27	599.69	7736.44
303	2257.61	2532.09	1523.37	404.86	144.10	6862.03	1081.50	1295.81	1034.10	389.91	212.06	4013.38
304	1970.95	2123.72	1871.63	901.44	779.21	7646.95	1507.63	1407.62	1048.95	425.88	290.60	4680.68
310	2606.22	2460.21	1525.77	481.82	226.31	7300.33	2062.28	2922.86	1960.27	719.71	438.27	8103.39
311	4153.18	4037.82	2909.80	1089.57	628.10	12818.47	1899.42	1795.77	1186.78	435.25	265.01	5582.23
312	2189.82	2674.37	2422.78	1136.84	894.56	9318.37	2904.11	2613.72	1963.68	823.59	601.90	8907.00

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
313	5007.55	5799.13	4250.40	1445.48	688.32	17190.88	2639.33	1981.16	1397.69	537.05	337.35	6892.58
314	1186.58	1374.16	1007.17	342.52	163.10	4073.53	2077.29	3420.90	2488.42	958.16	601.97	9546.74
320	2871.10	2418.13	1079.16	226.49	59.95	6654.83	2325.69	1701.38	1013.39	335.62	178.17	5554.25
321	1564.77	1583.69	1044.76	354.56	184.37	4732.15	3302.28	2932.85	2306.80	1046.92	888.13	10476.98
322	2323.68	1798.43	1050.51	348.27	188.41	5709.30	1494.86	1688.48	1189.70	405.05	198.36	4976.45
323	2714.11	2992.47	2000.78	661.13	313.17	8681.66	2031.01	1641.43	957.83	317.30	172.67	5120.24
324	4254.12	3553.93	1994.44	572.87	244.00	10619.36	15209.62	17662.03	10989.41	3129.37	1191.48	48181.91
330	2113.63	1934.24	1778.27	951.53	1037.32	7814.99	1672.44	2374.00	1859.59	772.02	534.57	7212.62
331	2586.64	2067.53	1897.46	1065.08	1306.74	8923.45	2885.98	2491.19	1935.92	944.85	1001.22	9259.16
332	3751.99	3355.02	2906.83	1434.21	1344.57	12792.62	3623.54	2704.71	2152.75	1020.78	952.42	10454.20
340	1255.41	1147.50	762.60	273.38	158.28	3597.17	1205.32	1280.83	1128.61	637.27	913.64	5165.67
341	2436.69	2592.69	1656.65	520.02	222.87	7428.92	1981.92	1341.67	1010.05	454.71	391.95	5180.30
342	1496.18	1047.76	870.98	439.80	461.35	4316.07	755.47	653.76	397.49	125.00	58.69	1990.41
343	3398.75	2289.76	1452.05	518.59	311.15	7970.30	1596.90	1147.88	891.15	443.35	493.23	4572.51
344	3548.13	3141.27	1873.41	605.55	293.32	9461.68	2566.06	2422.34	1566.22	567.55	343.69	7465.86
OUTER LONDON SECTORS 4,5,6,7 AND 8												
Sector 4												
400	2040.33	3363.78	3308.64	1444.77	860.25	11017.77	546.76	496.03	561.20	289.34	229.63	2122.96
401	1540.69	2957.13	4261.75	2248.91	1428.86	12437.34	1517.79	895.54	754.35	360.19	322.59	3850.46
402	929.79	1321.57	1436.49	793.99	741.76	5223.60	298.19	401.75	442.02	207.61	136.92	1486.49
403	1000.91	1600.15	2074.27	1112.86	809.95	6598.14	545.62	741.65	787.94	336.66	186.28	2598.15
410	758.13	977.22	904.20	452.10	386.02	3477.67	271.86	316.30	293.89	113.94	57.78	1053.77
411	1489.75	2490.32	3079.55	1912.21	2145.69	11117.52	726.67	384.47	405.51	238.29	289.55	2044.49
412	187.15	341.48	384.01	183.50	120.31	1216.45	11.70	25.85	27.98	16.45	19.99	101.97
413	677.80	1019.10	1398.86	870.08	846.04	4811.88	287.91	226.05	197.35	115.43	191.73	1018.47
414	866.27	1118.16	1554.36	1099.73	1505.22	6143.74	707.17	670.71	652.18	354.54	387.72	2772.32
415	1386.03	1773.29	1773.30	944.40	903.64	6780.66	555.57	854.79	853.51	426.22	360.74	3050.83

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
416	1399.84	1645.86	1866.45	1298.03	2265.19	8475.37	1358.89	1288.09	1218.45	612.53	556.60	5034.56
417	802.10	926.00	805.35	391.27	342.36	3267.08	324.20	192.64	180.19	90.57	82.30	869.90
418	131.71	130.93	152.09	113.68	256.36	784.77	143.92	224.17	125.49	30.08	9.08	532.74
420	1711.76	1750.65	977.45	291.78	131.30	4862.94	2271.15	1561.70	1351.56	707.05	799.12	6690.58
421	1518.63	2115.24	1857.62	786.44	501.70	6779.63	1011.91	1013.00	750.17	265.83	136.12	3177.03
422	798.75	1013.38	935.98	439.84	330.76	3518.71	637.12	215.20	153.79	54.46	27.88	1088.45
423	978.08	1263.81	1362.72	835.21	1055.01	5494.83	838.87	789.52	546.65	196.89	110.82	2482.75
424	966.83	1228.68	1274.00	735.19	830.87	5035.57	93.65	378.36	469.16	168.34	58.20	1167.71
425	1604.68	1966.31	1966.30	1039.65	956.78	7533.72	820.31	1254.22	907.58	322.66	170.72	3475.49
426	657.50	757.38	715.76	352.33	291.30	2774.27	870.79	1120.29	859.35	361.69	264.96	3477.08
427	459.09	623.20	544.26	251.36	195.27	2073.18	383.25	709.31	650.24	328.10	316.05	2386.95
428	832.82	1078.49	456.94	73.70	14.74	2456.69	632.47	777.48	424.91	109.50	38.40	1982.76
431	1052.68	1459.91	1126.34	437.54	255.59	4332.06	790.14	659.95	539.34	122.73	25.54	2137.70
432	125.73	202.40	248.90	145.55	138.66	861.24	26.18	156.24	130.03	29.60	6.16	348.21
440	12.03	19.37	23.89	13.93	13.27	82.49	1.29	7.70	6.40	1.46	0.31	17.16
441	540.46	869.91	1073.51	625.60	551.57	3661.05	64.42	384.42	319.97	72.84	15.15	856.80
Sector 5												
500	1704.33	2556.50	2844.24	1748.60	2224.49	11078.16	608.74	544.33	405.04	189.94	189.69	1937.74
501	1028.46	1423.41	1892.37	1406.94	2468.32	8219.50	517.84	519.43	563.22	309.51	297.80	2207.80
502	2619.96	3341.55	2808.69	1287.78	1032.45	11090.43	5323.26	5484.02	4837.44	2300.40	1932.18	19877.30
503	1741.26	2758.63	2797.76	1389.10	1095.63	9782.38	1047.30	617.69	523.55	248.17	208.37	2645.08
504	2949.89	4214.13	3629.59	1617.68	1169.08	13580.37	1628.79	2058.30	1784.37	879.95	841.81	7193.22
510	1431.80	2295.26	3005.70	1945.50	2262.47	10940.73	789.37	1059.49	997.50	489.05	416.99	3752.40
511	2705.10	3692.94	3951.28	2294.78	2568.34	15212.44	2994.33	1645.26	1503.75	864.99	1152.65	8160.98
520	1859.17	2298.80	2179.73	1254.72	1566.11	9158.53	2223.75	1826.37	1727.56	949.42	1080.64	7807.74
521	1618.64	2286.33	2610.07	1628.76	2003.07	10146.87	1063.92	932.40	849.57	477.04	620.33	3943.26
522	471.13	764.15	804.37	433.79	402.19	2875.63	239.46	257.13	237.00	133.20	173.21	1040.00
530	1338.96	1828.04	2028.49	1250.76	1571.48	8017.73	1129.07	1655.71	1499.39	664.02	460.41	5408.60
531	1963.95	2959.13	2395.49	942.34	554.84	8815.75	1530.12	1005.26	826.44	428.42	490.03	4280.27
532	1202.74	1455.01	1455.01	827.25	926.99	5867.00	1325.27	644.65	543.85	296.17	367.19	3177.13

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
533	1206.37	1615.95	1794.69	1161.71	1675.53	7454.25	603.22	591.11	504.32	272.64	350.81	2322.10
540	778.99	969.22	1059.80	683.89	1037.15	4529.05	247.45	236.02	212.65	123.92	190.03	1010.07
552	900.74	1326.28	1858.21	1305.00	1709.27	7099.50	522.29	640.36	749.81	449.73	507.91	2870.10
560	148.17	226.71	360.58	314.17	733.65	1783.28	22.19	61.39	79.23	53.79	80.78	297.38
561	850.48	1097.21	1280.97	845.23	1181.22	5255.11	473.02	483.32	603.12	408.73	613.66	2581.85
562	642.25	907.67	1226.13	928.89	1618.92	5323.86	459.82	266.10	318.30	215.19	323.00	1582.41
570	433.02	611.95	826.67	626.27	1091.50	3589.41	331.84	192.03	229.69	155.29	233.11	1141.96
581	330.93	467.67	631.75	478.60	834.14	2743.09	159.56	92.34	110.44	74.66	112.07	549.07
Sector 6												
600	911.99	1004.62	1460.60	1196.98	2550.71	7124.90	713.04	623.58	698.92	481.92	918.38	3435.84
601	676.03	763.13	945.61	671.88	1094.92	4151.57	725.49	605.16	803.22	554.32	769.92	3458.11
602	388.50	465.14	568.20	417.56	808.70	2648.10	554.75	367.15	347.69	200.74	258.43	1728.76
603	334.56	464.77	542.91	322.54	342.57	2007.35	160.68	171.15	170.37	99.31	128.22	729.73
604	1091.58	1400.07	1779.77	1297.25	2357.19	7925.86	477.83	651.41	652.17	396.09	597.46	2774.96
610	271.29	588.86	731.87	334.39	178.76	2105.17	604.59	358.36	351.76	183.35	163.08	1661.14
611	656.77	1030.24	1184.76	695.41	734.05	4301.23	326.85	742.66	812.57	431.42	385.83	2699.33
612	766.49	1237.84	1268.67	634.33	502.18	4409.51	370.21	670.96	702.93	275.82	128.26	2148.18
613	917.10	1380.48	1337.03	656.45	530.95	4822.01	1541.32	1431.79	1108.96	403.42	205.66	4691.15
614	655.16	966.94	1174.78	754.57	962.41	4513.86	709.99	2040.22	2266.03	880.05	384.98	6281.27
615	304.03	464.88	530.27	270.44	199.74	1769.36	723.98	1271.27	1036.38	387.27	204.00	3622.90
616	686.22	711.64	1087.80	894.63	1697.78	5078.07	1269.20	1762.44	2289.83	1472.27	1770.80	8564.54
620	1464.60	2349.62	2247.81	1033.84	720.54	7816.41	725.65	1108.40	1118.73	577.37	520.24	4050.39
621	377.57	721.56	855.80	461.46	380.36	2796.75	1585.93	2144.52	2179.32	1187.02	1224.28	8321.07
622	488.96	803.87	792.82	381.22	290.05	2756.92	298.43	403.56	410.08	223.37	230.38	1565.82
623	680.19	1289.08	1804.72	998.35	729.57	5501.91	446.25	552.61	595.75	343.62	384.72	2322.95
624	238.83	382.47	466.38	269.50	256.59	1613.77	136.58	136.57	141.18	82.90	102.69	599.92
625	422.01	523.18	659.04	471.15	809.34	2884.72	185.23	146.36	147.84	86.45	106.95	672.83
626	1041.46	1479.98	1808.88	1144.25	1370.37	6844.94	389.44	444.65	464.67	273.37	338.83	1910.96
630	1773.86	2456.84	2542.21	1384.94	1337.51	9495.36	2308.23	2890.75	2655.22	1379.32	1415.87	10649.39
631	1598.65	2331.73	2473.04	1298.35	1121.70	8823.47	2598.35	2646.67	2439.47	1212.28	1080.07	9976.84

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
632	665.91	858.21	717.58	341.57	295.65	2878.92	636.76	480.40	473.89	274.66	340.97	2206.68
633	1514.04	2495.49	2092.26	897.77	608.66	7608.22	551.04	1085.06	1161.40	451.13	202.20	3450.83
634	608.56	1015.39	1018.76	447.18	272.34	3362.23	196.81	506.98	548.03	213.16	95.56	1560.54
635	1125.06	2086.36	2214.53	1025.37	662.22	7113.54	390.22	1286.89	1269.26	538.08	315.48	3799.93
636	1345.00	1572.61	1669.19	1013.93	1296.73	6897.46	674.68	913.43	797.14	395.34	381.85	3162.44
640	319.80	583.98	848.16	531.15	497.78	2780.87	160.39	348.76	334.57	167.51	149.94	1161.17
641	668.62	1238.92	1484.74	821.03	703.04	4916.35	322.77	461.60	568.37	301.11	230.15	1884.00
652	249.95	377.42	445.28	273.13	311.21	1656.99	7.96	35.36	45.33	24.15	18.49	131.29
Sector 7												
700	1663.74	1796.83	1737.69	998.25	1205.29	7401.80	623.01	883.30	889.60	436.56	346.61	3179.08
701	2572.70	3286.70	2867.36	1394.02	1212.69	11333.47	2848.66	2208.70	1763.63	892.22	1005.90	8719.11
702	2426.61	2678.26	2148.00	970.64	781.91	9005.42	2131.70	1106.35	815.03	384.31	377.64	4815.03
703	1292.05	1499.69	1107.47	438.37	276.86	4614.44	1668.62	1693.73	1436.21	673.95	573.26	6045.77
704	765.58	851.63	694.37	338.28	317.50	2967.36	475.92	1131.60	1031.42	414.44	231.77	3285.15
705	1593.41	2212.57	2321.82	1356.67	1611.62	9096.09	1245.91	1413.23	1393.47	731.35	703.79	5487.75
710	1393.59	2300.67	2424.35	1203.93	923.56	8246.10	347.00	388.27	418.35	232.69	235.17	1621.48
711	1050.03	1260.04	1489.15	1005.49	1546.42	6351.13	134.53	206.63	244.71	143.18	150.05	879.10
712	1512.37	2494.87	3013.72	1865.64	2152.65	11039.25	968.38	988.58	1253.57	769.77	831.09	4811.39
713	1256.41	1574.40	1822.57	1225.39	1876.86	7755.63	600.74	726.64	700.06	256.33	110.86	2394.63
720	1767.79	1736.77	1651.49	1023.45	1573.95	7753.45	1293.97	1675.64	1497.13	667.65	475.87	5610.26
721	1400.83	2234.02	2581.94	1483.24	1464.93	9164.96	1109.35	1053.17	1267.83	797.47	987.65	5215.47
722	1141.04	1736.67	2073.96	1169.74	1054.92	7176.33	890.01	825.73	747.28	403.80	470.71	3337.53
723	1386.83	2056.66	2462.32	1566.07	1981.18	9453.06	599.50	491.85	461.68	266.19	359.64	2178.86
724	985.03	1438.03	1474.91	747.99	611.03	5256.99	478.49	549.82	469.33	233.15	231.62	1962.41
725	1955.68	2381.33	2680.44	1760.11	2714.95	11492.51	873.82	1288.58	1354.29	749.61	781.04	5047.34
730	3412.18	5214.84	4490.56	1850.95	1110.58	16079.11	2172.50	2368.04	1977.78	779.14	444.50	7741.96
731	1329.84	2049.41	2559.47	1557.54	1621.30	9117.56	590.52	759.43	684.37	350.36	355.08	2739.76
732	101.53	129.55	158.14	95.70	99.20	584.12	16.74	21.51	19.36	9.92	10.06	77.59
733	1374.72	2226.08	2009.74	844.37	516.40	6971.31	372.39	581.69	425.25	153.24	82.49	1615.06
734	1911.34	2619.23	2700.14	1466.37	1415.81	10112.89	1796.26	2064.74	1681.00	728.66	533.36	6804.02

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
740	483.01	624.88	787.01	557.33	922.12	3374.35	172.48	207.94	156.67	71.79	66.96	675.84
743	63.25	101.08	130.27	92.97	152.97	540.54	73.42	138.24	131.38	69.14	71.71	483.89
746	606.69	988.68	956.56	410.87	243.96	3206.76	37.16	91.47	103.08	61.10	72.09	364.90
750	1035.99	1531.73	1671.56	985.14	1131.32	6355.74	611.76	609.18	609.16	365.82	520.72	2716.64
757	335.85	496.54	541.87	319.36	366.74	2060.36	131.21	130.65	130.65	78.45	111.67	582.63
758	183.46	271.25	296.02	174.46	200.35	1125.54	55.30	55.05	55.05	33.06	47.05	245.51
774	682.08	1008.48	1100.53	648.61	744.86	4184.56	371.83	370.28	370.27	222.35	316.50	1651.23
775	741.60	1096.47	1196.56	705.20	809.85	4549.68	771.22	767.95	767.96	461.17	656.45	3424.75
Sector 8												
800	816.26	1435.35	1394.08	591.57	339.35	4576.61	390.73	526.80	423.07	167.64	101.06	1609.30
801	2289.25	4277.28	4683.92	2274.18	1551.26	15075.89	3492.33	2663.44	2041.50	801.30	481.52	9480.09
802	2293.57	3527.70	3341.42	1501.89	1001.27	11665.85	693.45	1605.12	1124.04	266.13	66.66	3755.40
803	428.48	728.11	883.93	503.39	449.46	2993.37	239.30	206.46	180.54	65.74	29.88	721.92
810	1499.61	2131.37	1832.84	840.05	645.66	6949.53	1030.28	1291.49	1272.77	569.07	366.07	4529.68
811	1346.74	1485.62	921.67	303.01	159.92	4216.96	745.62	422.67	303.21	79.27	22.05	1572.82
812	1147.27	1832.29	1576.11	640.47	373.14	5569.28	699.17	869.32	675.28	178.50	49.53	2471.80
813	1307.71	2116.67	1715.24	632.57	316.28	6088.47	2121.29	1685.52	982.19	266.85	96.44	5152.29
820	1186.68	2287.07	2258.29	942.16	510.63	7184.83	1717.06	1409.39	1093.92	486.74	393.45	5100.56
821	1028.06	1646.37	2033.76	1281.34	1460.14	7449.67	768.44	837.05	663.96	280.25	196.71	2746.41
822	1244.47	1886.79	1947.01	943.39	675.76	6697.42	427.56	520.64	491.81	273.10	329.69	2042.80
823	1256.72	2218.65	2342.76	1132.60	814.54	7765.27	564.86	441.55	436.75	242.54	262.99	1948.69
824	1094.77	1935.25	2168.32	1087.70	783.99	7070.03	594.78	623.94	419.04	160.79	107.36	1905.91
830	403.19	474.46	474.46	287.12	397.08	2036.31	182.29	205.11	170.45	90.86	117.70	766.41
831	1271.90	1621.98	1452.78	746.81	740.98	5834.45	755.01	550.72	439.48	232.12	299.77	2277.10
832	790.54	1092.15	1142.41	685.45	859.09	4569.64	309.10	244.21	238.25	135.91	163.60	1091.07
833	2364.04	3124.29	2666.05	1239.30	1010.19	10403.87	2023.16	2059.43	1651.90	678.58	439.58	6852.65
834	874.56	1382.74	1083.34	393.94	196.97	3931.55	1571.19	846.16	520.07	213.56	181.75	3332.73
835	2611.80	3618.88	2910.60	1184.16	752.55	11077.99	1518.46	1732.15	1603.20	735.39	534.46	6123.66
840	41.48	37.11	45.15	35.63	84.68	244.05	36.03	31.40	21.39	7.83	4.58	101.23
841	337.35	399.43	436.70	304.24	593.99	2071.71	127.44	111.05	75.59	27.69	16.20	357.97

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
842	1310.93	1667.16	1702.78	1033.07	1410.67	7124.61	762.10	703.13	480.94	176.37	103.23	2225.77
843	4.62	9.36	16.52	13.15	18.70	62.35	4.86	8.11	5.74	2.13	1.25	22.09
850	90.31	100.31	88.01	48.04	57.26	383.93	90.81	36.81	22.43	8.00	4.63	162.68
CORDON CROSSING												
6411	1081.47	1521.39	1600.82	898.17	1014.26	6116.11	146.74	172.63	160.89	84.25	87.26	651.77
6462	2305.60	3243.47	3412.80	1914.82	2162.31	13039.00	74.40	87.50	81.56	42.71	44.23	330.40
6463	609.78	857.82	902.61	506.43	571.88	3448.52	74.81	88.00	82.03	42.96	44.50	332.30
6474	2912.76	4097.62	4311.54	2419.07	2731.74	16472.73	153.95	181.09	168.78	88.39	91.53	683.74
6515	855.98	1204.17	1267.04	710.90	802.78	4840.87	43.51	51.17	47.70	24.98	25.87	193.23
6527	4337.41	6101.79	6420.36	3602.26	4067.87	24529.69	568.51	668.76	623.28	326.41	338.03	2524.99
6558	686.59	965.86	1016.29	570.21	643.90	3882.85	88.36	103.94	96.87	50.73	52.53	392.43
6579	207.62	292.07	307.32	172.43	194.71	1174.15	0.00	0.00	0.00	0.00	0.00	0.00
6590	4161.55	5854.37	6160.02	3456.19	3902.91	23535.04	422.64	497.17	463.37	242.66	251.31	1877.15
6601	45.15	63.51	66.83	37.50	42.34	255.33	2.94	3.45	3.23	1.69	1.75	13.06
6632	799.89	1125.26	1184.02	664.31	750.18	4523.66	160.73	189.06	176.21	92.28	95.56	713.84
6633	113.81	160.12	168.47	94.52	106.75	643.67	4.03	4.75	4.43	2.32	2.40	17.93
6654	2628.78	3698.12	3891.19	2183.23	2465.42	14866.74	440.86	518.61	483.35	253.12	262.14	1958.08
6685	830.67	1168.57	1229.58	689.88	779.05	4697.75	69.41	81.66	76.10	39.86	41.27	308.30
6706	1651.26	2322.96	2444.24	1371.39	1548.64	9338.49	197.20	231.98	216.19	113.22	117.25	875.84
6717	1508.70	2122.43	2233.23	1253.00	1414.95	8532.31	286.95	337.55	314.61	164.75	170.62	1274.48
6728	44.42	62.49	65.75	36.89	41.66	251.21	0.00	0.00	0.00	0.00	0.00	0.00
6749	2433.75	3423.75	3602.52	2021.26	2282.51	13763.79	562.18	661.28	616.32	322.76	334.25	2496.79
6760	2925.99	4116.23	4331.13	2430.07	2744.16	16547.58	367.84	432.73	403.29	211.20	218.73	1633.79
6771	394.01	554.28	583.21	327.22	369.52	2228.24	40.56	47.71	44.48	23.29	24.12	180.16
6782	772.26	1086.40	1143.12	641.37	724.27	4367.42	352.09	414.16	386.00	202.15	209.34	1563.74
6783	1669.25	2348.26	2470.86	1386.32	1565.50	9440.19	256.95	302.25	281.71	147.53	152.78	1141.22
6824	406.05	571.24	601.05	337.23	380.81	2296.38	0.00	0.00	0.00	0.00	0.00	0.00
6855	6250.78	8793.47	9252.55	5191.32	5862.31	35350.43	393.78	463.21	431.71	226.09	234.15	1748.94
6867	3055.09	4297.85	4522.23	2537.28	2865.23	17277.68	26.38	31.00	28.91	15.14	15.68	117.11

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
6878	114.88	161.61	170.05	95.41	107.74	649.69	103.22	121.46	113.19	59.28	61.39	458.54
6889	787.29	1107.55	1165.37	653.85	738.37	4452.43	139.29	163.87	152.71	79.97	82.83	618.67
Total	327746.65	402668.82	384327.10	201695.78	212209.16	1528647.51	327746.67	402668.72	384327.08	201695.88	212209.08	1528647.43

A.2.1.2 Trips by private transport

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
CENTRAL LONDON												
Sector 0												
0	126.96	213.06	221.01	143.79	183.72	888.54	217.35	405.96	491.64	338.16	413.91	1867.02
1	164.61	299.28	314.28	205.77	261.87	1245.81	238.41	743.13	887.76	551.70	519.63	2940.63
2	208.77	334.02	343.74	222.66	282.51	1391.70	529.95	1147.08	1211.16	693.57	599.64	4181.40
10	333.30	573.75	595.20	388.05	495.18	2385.48	531.51	1438.65	1684.05	1049.07	1016.31	5719.59
20	13.38	16.38	15.87	10.14	12.72	68.49	84.27	129.27	128.64	84.81	125.79	552.78
21	168.66	277.29	286.56	186.03	238.02	1156.56	424.14	650.37	647.43	426.84	632.94	2781.72
30	719.94	1183.47	1222.89	793.89	1015.80	4935.99	479.25	1582.62	2145.66	1377.42	1207.35	6792.30
31	72.84	152.01	163.44	107.04	137.46	632.79	107.19	287.94	497.67	429.54	650.82	1973.16
32	680.97	1262.46	1325.31	864.33	1105.29	5238.36	936.36	2263.17	3013.92	2351.88	3945.21	12510.54
33	648.03	1115.52	1157.16	754.47	962.76	4637.94	1379.43	2636.88	3024.45	1933.44	2039.19	11013.39
34	570.33	725.01	709.83	455.04	573.36	3033.57	289.05	1106.07	1704.24	1375.38	2052.93	6527.67
35	556.92	361.62	271.59	154.11	181.59	1525.83	428.43	973.89	1155.84	773.58	907.71	4239.45
36	586.47	648.90	610.89	385.53	480.57	2712.36	918.09	1667.40	1750.83	1092.15	1217.61	6646.08
37	621.03	955.44	971.37	629.01	800.22	3977.07	771.15	1791.09	2221.11	1610.79	2326.77	8720.91
38	383.94	504.21	497.88	318.57	402.96	2107.56	427.68	1363.50	1747.05	1186.47	1322.49	6047.19
39	369.30	615.51	638.61	415.47	528.36	2567.25	307.11	850.89	909.75	511.23	417.90	2996.88
40	272.43	447.84	460.89	300.42	382.50	1864.08	644.16	1023.00	1058.52	702.90	993.21	4421.79
41	281.67	422.52	429.54	276.39	352.08	1762.20	160.44	764.16	1301.64	1086.90	1557.72	4870.86
42	214.86	330.60	337.47	217.65	276.90	1377.48	566.97	681.33	756.21	524.19	729.66	3258.36
43	441.75	634.83	637.47	410.01	518.46	2642.52	751.53	1141.92	1170.12	781.80	1149.06	4994.43
44	168.03	311.52	327.03	213.30	272.73	1292.61	439.11	697.05	750.87	505.32	693.69	3086.04
50	161.16	232.98	233.97	150.45	191.25	969.81	312.87	705.57	727.41	428.37	415.89	2590.11
51	352.74	542.70	554.01	357.27	454.47	2261.19	312.84	910.11	1121.31	752.94	855.09	3952.29
52	161.67	299.73	314.64	206.46	263.67	1246.17	225.06	673.56	816.96	529.26	550.98	2795.82
60	95.46	236.22	258.87	172.26	220.47	983.28	140.70	395.31	395.16	200.10	135.33	1266.60
70	186.09	269.07	270.18	173.79	220.86	1119.99	232.11	561.27	465.57	194.07	100.71	1553.73
71	39.09	56.55	56.79	36.51	46.41	235.35	83.28	201.45	167.07	69.63	36.15	557.58
80	225.75	560.88	612.09	407.28	521.34	2327.34	667.38	1341.90	1539.39	1076.55	1552.05	6177.27

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
81	195.96	319.92	329.25	214.62	271.92	1331.67	203.52	894.30	1239.03	799.80	699.93	3836.58
82	356.94	886.77	967.74	643.92	824.22	3679.59	665.58	1576.05	2106.72	1528.17	1938.87	7815.39
83	228.51	375.57	386.52	251.94	320.79	1563.33	445.53	1184.85	1427.70	969.12	1175.40	5202.60
84	340.53	763.86	827.49	544.26	700.17	3176.31	584.25	1546.20	2080.89	1649.76	2915.73	8776.83
INNER LONDON SECTORS 1,2 AND 3												
Sector 1												
100	489.90	451.50	287.67	119.64	78.33	1427.04	456.00	702.06	573.60	278.88	210.27	2220.81
101	898.02	1299.75	1020.12	452.94	275.73	3946.56	422.82	1087.89	1170.99	658.68	534.00	3874.38
102	736.20	1476.93	1404.24	618.03	313.53	4548.93	850.41	1879.74	2020.89	957.75	511.32	6220.11
103	227.55	381.72	408.66	245.49	233.52	1496.94	186.69	433.44	579.09	402.03	445.92	2047.17
104	1219.17	1859.85	1685.70	845.97	603.36	6214.05	805.77	1335.21	1329.51	658.86	416.64	4545.99
105	691.62	1194.63	1194.66	637.14	473.70	4191.75	716.61	1380.90	1372.23	631.41	339.36	4440.51
106	1354.20	2570.01	2787.45	1660.62	1522.23	9894.51	978.33	1814.97	1838.01	1049.73	946.23	6627.27
110	1049.37	1503.87	1045.26	375.96	169.41	4143.87	924.66	1166.19	1162.56	765.21	1100.58	5119.20
111	1455.15	2118.45	1167.18	308.52	87.39	5136.69	1599.96	1708.44	1335.18	637.44	472.29	5753.31
112	1458.00	2021.19	1226.40	400.02	152.64	5258.25	1260.21	2067.72	1892.43	985.74	778.83	6984.93
113	1263.87	1842.45	1001.34	262.56	75.66	4445.88	529.08	1304.43	1506.99	806.34	531.00	4677.84
114	647.79	1000.50	912.30	471.42	359.49	3391.50	638.55	1031.22	1184.16	720.42	653.58	4227.93
115	1008.84	1439.55	1563.45	961.65	926.25	5899.74	1779.00	1911.42	1528.32	761.49	616.08	6596.31
116	117.93	142.98	293.34	306.60	611.73	1472.58	149.22	230.43	329.97	257.97	370.02	1337.61
120	876.15	1185.15	989.58	492.84	367.65	3911.37	855.54	1081.65	1050.75	683.31	987.66	4658.91
121	933.93	1147.41	937.77	457.44	335.46	3812.01	692.55	1127.13	1065.69	597.21	555.45	4038.03
122	941.31	1233.33	956.70	434.16	284.31	3849.81	777.90	1372.92	1423.41	767.82	574.41	4916.46
123	822.03	1298.43	1167.72	560.67	362.55	4211.40	746.01	1800.09	1907.34	1086.03	925.83	6465.30
124	1074.15	1697.85	1815.66	1136.52	1212.75	6936.93	586.17	865.29	917.76	636.72	1014.84	4020.78
125	1405.29	2300.40	2488.38	1458.99	1288.95	8942.01	1184.10	2320.11	2406.39	1425.54	1387.83	8723.97
130	1186.44	1373.79	1114.41	586.02	537.99	4798.65	899.01	1412.31	1322.16	795.75	942.90	5372.13
131	772.35	1348.98	1412.49	862.29	888.78	5284.89	999.48	1029.99	1054.74	653.73	709.47	4447.41
132	880.23	1784.31	1748.61	904.05	636.42	5953.62	539.94	1091.01	1512.42	967.11	805.17	4915.65

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
133	953.01	1797.45	1839.66	904.74	536.82	6031.68	831.81	1776.63	2193.81	1389.57	1304.37	7496.19
134	1010.85	2021.67	1994.55	1031.19	732.69	6790.95	673.38	1449.93	2222.22	1567.89	1510.53	7423.95
135	555.87	920.07	900.90	472.80	341.82	3191.46	244.29	545.43	743.10	572.40	872.61	2977.83
136	787.74	1372.59	1605.33	1050.33	1157.76	5973.75	660.69	1158.03	1338.00	956.34	1466.55	5579.61
Sector 2												
200	492.96	753.51	600.96	286.38	208.92	2342.73	765.18	1637.19	1597.38	822.21	591.15	5413.11
201	1387.59	2174.58	1801.80	883.65	648.93	6896.55	1216.08	2398.38	2299.68	1142.73	765.90	7822.77
202	966.84	1620.27	1439.64	733.11	552.48	5312.34	838.05	1854.09	2284.50	1481.46	1495.71	7953.81
203	514.23	784.29	744.09	425.19	402.21	2870.01	675.39	1509.84	1348.50	650.94	440.37	4625.04
204	676.47	1008.12	1051.77	702.63	925.20	4364.19	439.92	1098.84	1257.99	818.31	932.31	4547.37
210	415.68	828.93	721.92	331.08	194.16	2491.77	538.20	729.45	696.06	414.72	456.33	2834.76
211	759.96	1086.81	1021.44	600.60	616.92	4085.73	743.73	1214.43	1175.25	702.93	774.69	4611.03
212	892.17	1170.96	1226.73	875.43	1427.49	5592.78	1560.03	2198.10	2535.72	1786.02	2554.89	10634.76
213	574.86	715.20	887.22	746.88	1597.86	4522.02	717.06	1328.49	1512.84	1081.53	1718.16	6358.08
214	552.63	1035.09	1236.87	798.24	767.55	4390.38	353.16	944.40	1095.78	703.59	756.18	3853.11
220	1484.64	1977.15	1667.58	928.77	978.03	7036.17	1266.18	2064.87	2171.91	1416.00	1824.78	8743.74
221	1085.49	1358.28	1300.23	853.29	1201.53	5798.82	1120.02	1518.24	1654.86	1122.72	1546.56	6962.40
230	1203.00	1592.37	1599.33	1063.89	1494.99	6953.58	1093.65	1595.61	1684.56	1061.55	1202.22	6637.59
231	667.20	956.61	1079.25	804.54	1398.12	4905.72	680.31	1038.54	1162.89	760.47	888.51	4530.72
232	931.32	1340.91	1324.05	864.00	1144.53	5604.81	628.95	1146.90	1499.55	1106.91	1532.31	5914.62
233	531.84	853.38	802.29	441.72	372.60	3001.83	529.38	953.40	1003.65	669.81	944.97	4101.21
Sector 3												
300	792.18	1436.97	1823.88	1129.95	957.99	6140.97	726.93	1700.76	1858.53	1058.28	870.72	6215.22
301	598.59	793.38	885.48	580.86	687.09	3545.40	638.01	850.05	757.47	384.33	292.50	2922.36
302	1246.80	2235.93	2368.89	1346.55	1130.40	8328.57	2221.71	3112.38	2666.31	1291.14	912.66	10204.20
303	1122.75	1902.96	1251.18	371.07	114.18	4762.14	1385.88	1826.01	1546.71	744.18	523.20	6025.98
304	822.03	1355.91	1318.14	699.21	533.85	4729.14	1648.20	2079.69	1673.94	711.78	392.61	6506.22
310	1034.43	1477.20	1010.28	350.19	144.93	4017.03	2158.92	2299.95	1704.63	835.74	721.92	7721.16
311	1647.54	2471.40	1953.78	801.93	415.53	7290.18	853.62	1956.72	1692.15	681.81	316.17	5500.47
312	899.52	1690.23	1673.01	859.41	607.35	5729.52	1395.27	2450.49	2614.53	1479.15	1223.34	9162.78

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
313	2109.66	3747.03	3022.80	1133.55	493.29	10506.33	1178.94	2185.59	2533.89	1427.04	1062.03	8387.49
314	521.97	927.06	747.87	280.47	122.07	2599.44	709.23	2526.12	2955.99	1665.03	1239.15	9095.52
320	1259.64	1587.06	778.11	181.05	46.20	3852.06	661.38	1028.07	817.71	338.40	178.56	3024.12
321	778.68	1196.16	864.84	321.42	149.10	3310.20	990.42	1806.27	1628.37	850.08	693.72	5968.86
322	943.74	1111.02	713.34	261.99	126.24	3156.33	1052.19	1244.73	945.84	432.99	302.19	3977.94
323	1011.39	1676.52	1230.09	451.02	195.90	4564.92	1055.73	1259.37	984.54	484.23	395.46	4179.33
324	2975.79	3795.63	2327.97	738.87	273.30	10111.56	5057.43	9564.33	7763.37	2874.45	1180.20	26439.78
330	853.02	1227.42	1241.61	725.07	696.63	4743.75	683.94	1193.67	1299.93	856.29	1087.53	5121.36
331	1318.38	1675.41	1689.15	1036.83	1139.82	6859.59	1456.71	2136.27	2030.40	1250.76	1562.52	8436.66
332	1600.44	2239.02	2125.83	1155.87	969.96	8091.12	990.96	2494.71	2659.20	1558.95	1433.76	9137.58
340	820.11	1139.64	836.61	329.37	168.00	3293.73	1128.30	1368.45	1370.19	725.91	538.98	5131.83
341	1329.93	2140.44	1512.54	519.39	205.50	5707.80	1271.40	2072.55	1536.72	646.65	380.28	5907.60
342	632.04	713.04	656.34	364.62	337.62	2703.66	539.43	529.11	406.41	215.43	223.74	1914.12
343	1718.19	1841.76	1285.86	505.35	263.91	5615.07	1607.73	1374.78	1093.92	579.03	563.61	5219.07
344	1813.74	2409.45	1595.28	562.65	251.55	6632.67	1765.32	2012.16	1719.90	907.41	804.09	7208.88
OUTER LONDON SECTORS 4,5,6,7 AND 8												
Sector 4												
400	1876.50	4615.62	4978.77	2391.03	1256.01	15117.93	575.58	3116.97	4326.81	2042.88	867.33	10929.57
401	1318.38	4043.10	6398.64	3709.11	2091.87	17561.10	1926.93	4300.23	4506.72	2284.32	1450.59	14468.79
402	958.56	2056.38	2457.81	1482.90	1228.92	8184.57	742.77	1967.91	2292.90	1438.02	1427.55	7869.15
403	933.75	2349.12	3322.17	1965.78	1267.92	9838.74	886.23	2327.85	2606.25	1501.38	1233.81	8555.52
410	1104.72	2119.86	2164.62	1179.33	895.71	7464.24	1260.21	1721.40	1533.24	855.42	840.90	6211.17
411	1377.51	3491.85	4725.21	3219.54	3219.54	16033.65	2434.89	3466.53	3024.36	1608.27	1415.10	11949.15
412	407.82	1129.68	1386.60	729.99	424.14	4078.23	84.45	512.37	1075.50	383.16	68.49	2123.97
413	984.18	2353.02	3506.88	2398.26	2081.49	11323.83	941.37	2282.13	2774.13	1560.75	1086.48	8644.86
414	932.52	1907.94	2883.33	2240.22	2744.01	10708.02	1539.24	2335.95	3427.20	2228.46	1712.73	11243.58
415	930.18	1798.80	1962.93	1155.87	984.90	6832.68	1034.22	1703.64	1616.88	864.72	696.15	5915.61
416	1585.50	2856.93	3574.89	2707.35	4218.06	14942.73	4002.48	5303.04	5151.51	3206.70	3904.23	21567.96
417	628.23	1091.97	1039.62	553.47	426.30	3739.59	132.96	492.27	632.70	400.47	363.03	2021.43

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
418	117.06	179.43	229.77	189.27	378.57	1094.10	14.46	210.99	501.51	372.72	257.82	1357.50
420	1440.09	2124.60	1297.74	432.57	175.23	5470.23	1185.09	3201.24	3403.05	1798.77	1259.34	10847.49
421	1231.56	2567.76	2455.08	1151.07	652.02	8057.49	730.59	2298.39	1961.85	739.56	303.45	6033.84
422	597.12	1139.97	1151.64	597.15	399.42	3885.30	286.47	677.01	643.68	330.69	244.38	2182.23
423	811.38	1581.18	1865.49	1255.23	1414.71	6927.99	571.38	1579.38	1756.65	1011.06	838.23	5756.70
424	786.90	1493.91	1696.80	1082.01	1088.16	6147.78	421.74	950.67	1021.38	605.25	563.94	3562.98
425	985.02	1838.28	2004.75	1158.45	943.41	6929.91	1327.68	1282.26	1278.81	867.84	1301.73	6058.32
426	382.89	674.31	695.97	378.09	274.53	2405.79	703.77	1205.97	1107.00	496.98	269.76	3783.48
427	322.47	638.64	611.40	309.90	215.67	2098.08	361.17	895.77	979.56	525.48	367.74	3129.72
428	645.12	1185.33	552.66	100.02	15.00	2498.13	488.22	1517.73	1358.88	554.13	256.35	4175.31
431	2250.15	4539.78	3842.34	1644.84	855.33	13132.44	3752.13	4721.67	3569.01	1673.82	1245.81	14962.44
432	185.13	453.00	610.56	391.95	330.90	1971.54	166.77	409.35	377.79	182.55	119.70	1256.16
440	105.69	261.39	352.29	226.14	190.92	1136.43	110.04	270.12	249.27	120.45	79.02	828.90
441	525.87	1300.53	1752.90	1125.24	949.95	5654.49	500.34	1227.81	1133.19	547.53	359.13	3768.00
Sector 5												
500	1406.88	3161.94	3830.55	2590.83	2939.07	13929.27	1122.87	1988.01	2089.80	1284.12	1346.58	7831.38
501	1276.05	2820.72	4113.57	3341.22	5238.48	16790.04	1196.79	2356.71	3469.02	2726.91	3726.63	13476.06
502	3156.66	5928.33	5466.39	2752.44	1944.00	19247.82	4137.84	10210.56	11524.65	6755.46	5726.28	38354.79
503	1447.56	3418.08	3795.21	2067.90	1447.56	12176.31	813.42	1697.82	1778.70	1014.48	869.40	6173.82
504	2619.39	5464.29	5152.02	2515.29	1630.62	17381.61	2431.59	4245.45	3866.61	1916.70	1330.05	13790.40
510	1593.60	4003.47	5674.83	4022.91	4158.96	19453.77	1834.29	4227.30	4829.07	2790.36	2226.45	15907.47
511	2893.98	5961.09	6999.99	4477.02	4427.55	24759.63	3832.80	7032.93	6972.15	3982.35	3665.46	25485.69
520	1889.43	3409.14	3587.13	2259.09	2532.93	13677.72	2509.38	4075.71	4359.75	2810.58	3314.85	17070.27
521	1395.87	3008.58	3781.08	2574.93	2818.86	13579.32	1425.18	2886.42	3442.98	2193.81	2148.18	12096.57
522	573.42	1383.48	1588.65	941.61	773.28	5260.44	619.98	1406.40	1610.37	869.10	579.57	5085.42
530	946.50	1963.14	2410.11	1630.11	1805.37	8755.23	1440.21	2072.85	2072.22	1350.48	1860.84	8796.60
531	1609.62	3541.17	3146.52	1370.76	706.14	10374.21	768.60	2066.52	2320.32	1282.50	940.71	7378.65
532	1049.91	1950.93	2146.83	1339.80	1331.97	7819.44	1296.96	2597.52	2507.49	1286.16	917.25	8605.38
533	1174.62	2382.81	2919.75	2069.58	2640.09	11186.85	698.55	1600.32	1920.03	1384.65	2083.95	7687.50
540	1091.70	2085.00	2488.26	1770.30	2389.89	9825.15	1024.98	1616.67	1912.56	1402.74	2182.41	8139.36

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
552	1696.83	3959.28	6047.67	4655.40	5395.08	21754.26	2027.28	4617.27	5747.64	3688.86	3510.96	19592.01
560	348.00	809.76	1405.38	1338.45	2790.66	6692.25	730.38	537.87	748.83	696.93	1438.29	4152.30
561	1543.08	3041.61	3917.01	2819.07	3531.24	14852.01	1913.22	3404.97	3856.56	2583.96	3186.00	14944.71
562	1137.12	2535.45	3764.76	3104.01	4825.05	15366.39	728.49	2144.82	3171.33	2442.06	3241.89	11728.59
570	1057.38	2357.67	3500.82	2886.39	4486.77	14289.03	731.79	2154.42	3185.49	2452.98	3256.35	11781.03
581	285.15	635.82	944.07	778.38	1209.99	3853.41	144.24	424.50	627.66	483.30	641.58	2321.28
Sector 6												
600	548.73	976.35	1553.58	1403.94	2651.07	7133.67	523.02	954.93	1332.75	1021.74	1438.17	5270.61
601	652.50	1157.82	1573.62	1228.20	1784.73	6396.87	424.11	1461.75	2082.66	1582.83	2172.03	7723.38
602	616.56	1146.00	1541.37	1246.50	2137.83	6688.26	235.29	1103.01	1769.13	1365.84	1658.07	6131.34
603	586.95	1268.01	1622.43	1057.62	996.72	5531.73	477.54	807.36	818.19	532.05	727.56	3362.70
604	1104.18	2195.52	3068.55	2477.97	3980.16	12826.38	1125.30	2170.56	2664.51	1911.81	2670.99	10543.17
610	343.35	1175.91	1596.48	798.24	377.64	4291.62	48.93	840.57	2019.51	1391.25	801.75	5102.01
611	976.26	2294.19	2889.69	1864.62	1737.69	9762.45	1173.66	2759.91	3626.52	2382.66	2291.19	12233.94
612	1007.07	2452.05	2741.04	1497.51	1059.66	8757.33	1018.68	2143.65	2085.81	1105.41	858.06	7211.61
613	1251.84	2806.86	2963.34	1603.92	1144.26	9770.22	2162.28	3863.25	4333.59	2621.64	2422.08	15402.84
614	789.27	1763.22	2334.15	1645.68	1863.99	8396.31	2752.05	4213.23	3936.87	2308.95	2508.78	15719.88
615	360.12	865.59	1077.00	601.26	396.45	3300.42	243.60	1397.58	2073.99	1282.02	931.68	5928.87
616	490.44	835.59	1386.57	1247.31	2107.08	6066.99	573.66	1884.27	3334.53	2171.04	1458.81	9422.31
620	1520.82	3592.47	3772.11	1904.01	1197.48	11986.89	806.28	2763.84	3736.68	2094.69	1315.08	10716.57
621	835.92	2393.67	3106.11	1842.78	1348.83	9527.31	2207.91	4425.63	5868.54	4071.45	4502.37	21075.90
622	838.59	2026.56	2187.27	1160.01	782.67	6995.10	1327.50	2135.61	2043.18	1232.25	1419.21	8157.75
623	1107.69	3397.95	5209.17	3173.40	2065.71	14953.92	1760.85	4057.29	5239.11	3229.11	2661.15	16947.51
624	494.70	1226.22	1626.18	1036.74	873.60	5257.44	719.79	1440.09	1588.20	949.62	873.78	5571.48
625	596.07	1147.26	1563.87	1230.60	1871.52	6409.32	470.58	1185.27	1550.67	1149.96	1647.78	6004.26
626	1171.50	2614.32	3502.20	2441.67	2589.66	12319.35	1437.06	3269.91	3923.79	2138.94	1406.76	12176.46
630	1268.67	2640.51	3022.14	1805.04	1557.51	10293.87	1723.50	3870.42	4436.64	2462.58	1780.26	14273.40
631	1263.57	2826.84	3276.60	1895.28	1445.58	10707.87	2050.02	3910.65	4077.87	2263.17	1816.32	14118.03
632	648.69	1220.79	1124.10	584.22	447.24	4025.04	440.16	1558.50	1805.10	885.84	480.60	5170.20
633	1258.32	2927.19	2704.05	1267.26	758.58	8915.40	855.18	1846.35	1994.16	1155.30	1003.11	6854.10

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
634	524.76	1325.07	1447.53	699.72	380.49	4377.57	278.85	1032.84	789.72	228.00	61.50	2390.91
635	1095.60	3055.05	3539.64	1801.41	1042.92	10534.62	1349.40	2957.01	3207.93	1701.96	1168.77	10385.07
636	1352.13	2416.77	2832.00	1895.10	2139.99	10635.99	966.30	1404.33	1841.04	1289.88	1457.97	6959.52
640	912.45	2608.80	4138.02	2840.07	2364.60	12863.94	1355.13	3510.57	3875.34	2067.60	1421.01	12229.65
641	1611.12	4555.59	5981.55	3629.67	2759.28	18537.21	2001.48	4780.11	5730.30	3556.77	3287.22	19355.88
652	1237.83	2845.71	3687.96	2475.66	2501.19	12748.35	844.62	1466.73	1697.82	1080.48	1107.09	6196.74
Sector 7												
700	1585.41	2617.47	2777.10	1755.63	1893.96	10629.57	1622.19	2382.36	2448.57	1490.10	1548.39	9491.61
701	2054.73	3847.71	3690.69	1963.11	1518.12	13074.36	1506.30	3383.94	3557.97	2157.18	2224.59	12829.98
702	1391.55	2279.79	2013.30	999.24	717.99	7401.87	572.34	1271.49	1418.46	886.47	917.22	5065.98
703	1180.56	2015.37	1639.68	715.50	405.48	5956.59	1591.23	2632.62	2431.71	1321.14	1156.14	9132.84
704	823.50	1342.14	1205.70	641.52	536.91	4549.77	673.26	2185.95	2441.61	1348.62	1004.79	7654.23
705	1452.69	2966.94	3397.80	2191.35	2314.44	12323.22	1437.09	3798.69	4719.57	2943.96	2633.94	15533.25
710	1467.42	3616.11	4166.40	2279.73	1546.02	13075.68	1257.42	2359.56	2264.16	1286.61	1230.12	8397.87
711	1266.63	2342.07	3023.22	2246.49	3071.01	11949.42	916.02	1697.76	1942.98	1298.61	1578.87	7434.24
712	1311.24	3278.04	4335.96	2950.23	3024.72	14900.19	1168.92	4123.02	5003.70	2987.43	2477.97	15761.04
713	1391.79	2651.10	3380.16	2478.78	3366.90	13268.73	1600.26	2423.73	2642.76	1768.71	2299.02	10734.48
720	1161.78	1735.02	1819.08	1230.54	1696.77	7643.19	1170.69	1912.29	2043.63	1343.46	1716.84	8186.91
721	1521.33	3635.97	4609.68	2905.77	2540.64	15213.39	2574.03	4601.67	4686.30	2631.03	2223.30	16716.33
722	1146.00	2738.94	3575.46	2211.75	1764.81	11436.96	1213.71	2507.58	3271.11	2176.29	2152.50	11321.19
723	1842.66	4131.48	5411.64	3782.34	4247.85	19415.97	1388.58	3346.56	4359.39	2890.77	2872.02	14857.32
724	1009.08	2211.81	2478.21	1380.36	1017.09	8096.55	730.80	1929.54	2089.35	1142.10	851.76	6743.55
725	1627.11	3019.77	3694.11	2667.96	3664.80	14673.75	2461.77	3903.84	3835.83	2261.91	2304.09	14767.44
730	3374.73	7530.03	7093.86	3214.05	1721.79	22934.46	3973.08	5392.53	4821.42	2652.54	2481.42	19320.99
731	1303.38	3130.80	4264.17	2833.32	2634.99	14166.66	928.53	2460.30	3072.78	1926.03	1734.84	10122.48
732	60.60	122.31	163.47	108.96	100.62	555.96	154.89	87.69	81.66	48.00	42.27	414.51
733	1516.71	3606.36	3561.42	1651.50	898.80	11234.79	1075.26	2161.20	1872.21	875.40	563.55	6547.62
734	2477.70	5133.75	5768.04	3448.92	2973.21	19801.62	3378.84	6116.31	6046.89	3249.54	2534.46	21326.04
740	587.46	1155.78	1589.97	1238.76	1819.80	6391.77	444.63	1224.21	1475.19	906.57	811.95	4862.55
743	88.38	210.42	295.29	230.19	339.48	1163.76	115.80	389.49	474.90	292.47	262.17	1534.83

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
746	617.97	1508.37	1591.05	749.31	394.08	4860.78	601.35	1007.64	865.41	416.25	287.64	3178.29
750	893.07	1949.97	2326.86	1507.56	1540.32	8217.78	556.29	2044.83	2868.24	1928.88	1848.75	9246.99
757	1074.45	2346.09	2799.51	1813.77	1853.22	9887.04	397.83	1462.56	2051.49	1379.58	1322.25	6613.71
758	321.30	701.61	837.24	542.43	554.22	2956.80	129.90	477.66	669.99	450.57	431.88	2160.00
774	1395.06	3046.08	3634.86	2354.97	2406.18	12837.15	618.78	2274.81	3190.83	2145.81	2056.65	10286.88
775	1484.37	3241.02	3867.45	2505.66	2560.11	13658.61	1099.14	4040.52	5667.60	3811.44	3653.13	18271.83
Sector 8												
800	781.14	2054.64	2179.32	1017.45	525.12	6557.67	671.88	1779.99	1779.33	823.59	448.74	5503.53
801	2252.61	6348.21	7622.46	4050.15	2457.39	22730.82	3394.17	6436.89	6771.24	3827.49	3164.97	23594.76
802	2248.11	5234.16	5405.79	2677.14	1595.97	17161.17	1794.96	3877.86	4009.08	2120.97	1518.33	13321.20
803	558.42	1444.62	1918.02	1195.74	952.92	6069.72	418.32	1066.59	1543.71	889.80	545.70	4464.12
810	1075.62	2230.62	2115.12	1061.16	729.12	7211.64	1865.13	4001.52	3689.52	1692.33	972.75	12221.25
811	922.29	1490.76	1017.66	369.72	170.94	3971.37	358.95	1350.66	1017.51	284.13	73.05	3084.30
812	993.84	2354.19	2206.17	979.74	507.51	7041.45	824.43	1830.36	1814.43	960.42	726.06	6155.70
813	1432.17	3393.03	3027.78	1220.70	547.86	9621.54	2555.46	4801.80	4099.77	1683.39	809.70	13950.12
820	897.87	2556.15	2758.35	1261.89	614.76	8089.02	982.65	2925.42	3764.46	2207.70	1616.85	11497.08
821	754.08	1850.94	2502.24	1722.42	1739.55	8569.23	1256.04	1664.94	1962.75	1314.42	1462.95	7661.10
822	1102.17	2547.60	2881.89	1526.76	975.69	9034.11	481.74	1572.81	2489.82	1690.29	1419.54	7654.20
823	1292.22	3449.97	3986.34	2121.18	1340.97	12190.68	1485.66	2082.00	2473.14	1534.02	1355.82	8930.64
824	948.60	2535.81	3099.36	1709.34	1098.87	9391.98	754.08	1636.80	2158.68	1332.12	1060.11	6941.79
830	493.26	881.04	960.12	640.08	786.93	3761.43	674.85	745.20	624.00	337.32	320.01	2701.38
831	1041.03	1963.29	1928.37	1089.93	964.20	6986.82	1355.55	1606.74	1251.24	650.67	626.52	5490.72
832	700.02	1430.22	1635.42	1074.18	1200.93	6040.77	273.03	889.62	981.84	532.02	382.83	3059.34
833	1686.60	3308.31	3092.07	1578.48	1135.23	10800.69	1997.67	3332.73	2990.79	1538.10	1197.15	11056.44
834	436.17	1000.98	863.94	343.89	153.78	2798.76	681.09	1692.00	1386.36	526.71	226.32	4512.48
835	1283.61	2621.97	2308.92	1033.14	579.18	7826.82	505.47	2376.72	2776.98	1339.53	697.71	7696.41
840	184.53	267.15	353.28	305.82	648.57	1759.35	159.66	271.77	279.57	185.07	263.19	1159.26

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
841	335.73	604.89	722.07	551.07	956.46	3170.22	332.10	463.35	588.63	434.22	595.11	2413.41
842	1296.72	2445.81	2741.01	1834.38	2213.88	10531.80	1963.08	2536.08	2293.68	1372.17	1649.43	9814.44
843	30.33	98.52	188.76	163.95	207.36	688.92	255.81	182.52	149.13	88.02	105.57	781.05
850	371.76	616.53	593.43	353.28	376.38	2311.38	291.39	545.37	364.53	126.51	53.88	1381.68
CORDON CROSSING												
2411	308.01	652.95	753.00	460.74	455.49	2630.19	127.89	289.29	339.12	214.86	216.57	1187.73
2412	146.55	310.65	358.26	219.21	216.69	1251.36	86.85	196.41	230.28	145.86	147.06	806.46
2413	49.29	104.46	120.45	73.71	72.87	420.78	2.67	6.00	6.99	4.44	4.47	24.57
2424	279.00	591.42	682.02	417.33	412.53	2382.30	109.14	246.87	289.44	183.33	184.80	1013.58
2435	1095.33	2321.70	2677.44	1638.30	1619.58	9352.35	709.20	1604.10	1880.46	1191.30	1200.81	6585.87
2446	219.93	466.17	537.57	328.95	325.17	1877.79	74.49	168.42	197.43	125.07	126.06	691.47
2457	252.36	534.93	616.89	377.46	373.14	2154.78	104.16	235.68	276.24	175.02	176.43	967.53
2468	463.26	981.90	1132.35	692.88	684.96	3955.35	254.70	576.03	675.27	427.80	431.19	2364.99
2479	599.46	1270.65	1465.35	896.64	886.38	5118.48	362.37	819.48	960.69	608.58	613.44	3364.56
2480	164.52	348.75	402.18	246.09	243.27	1404.81	72.42	163.98	192.18	121.74	122.73	673.05
2501	190.95	404.79	466.83	285.63	282.39	1630.59	45.39	102.60	120.24	76.20	76.80	421.23
2512	457.68	970.11	1118.76	684.54	676.74	3907.83	267.90	605.94	710.34	450.00	453.60	2487.78
2523	696.03	1475.34	1701.39	1041.06	1029.15	5942.97	496.50	1122.93	1316.37	833.94	840.60	4610.34
2534	695.52	1474.26	1700.13	1040.28	1028.40	5938.59	462.93	1047.00	1227.36	777.54	783.75	4298.58
2545	208.59	442.11	509.88	312.00	308.40	1780.98	106.14	240.06	281.46	178.29	179.70	985.65
2556	66.48	140.82	162.39	99.36	98.25	567.30	8.79	19.83	23.22	14.70	14.79	81.33
2557	257.49	545.73	629.31	385.08	380.67	2198.28	197.19	446.07	522.93	331.29	333.93	1831.41
2558	57.45	121.83	140.52	85.98	85.02	490.80	94.20	213.21	249.90	158.31	159.57	875.19
2561	213.39	452.28	521.55	319.14	315.48	1821.84	166.32	376.14	440.94	279.33	281.55	1544.28
2562	102.33	217.02	250.23	153.12	151.35	874.05	113.43	256.53	300.72	190.50	192.06	1053.24
2571	210.39	445.98	514.32	314.70	311.10	1796.49	89.25	201.78	236.58	149.85	151.08	828.54
2572	152.91	324.09	373.80	228.72	226.11	1305.63	19.50	44.10	51.69	32.76	33.03	181.08
2583	1034.37	2192.52	2528.49	1547.16	1529.46	8832.00	478.50	1082.19	1268.61	803.67	810.12	4443.09
2594	354.90	752.25	867.51	530.82	524.76	3030.24	232.38	525.54	616.05	390.27	393.36	2157.60

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
2605	175.68	372.39	429.45	262.77	259.80	1500.09	93.78	212.19	248.73	157.59	158.82	871.11
2606	167.76	355.65	410.13	250.95	248.10	1432.59	79.50	179.82	210.84	133.56	134.64	738.36
2607	221.88	470.37	542.43	331.89	328.11	1894.68	122.43	276.81	324.51	205.59	207.21	1136.55
2608	81.12	171.99	198.36	121.35	120.00	692.82	8.55	19.38	22.74	14.40	14.55	79.62
2609	238.08	504.66	581.97	356.10	352.02	2032.83	142.62	322.68	378.24	239.64	241.56	1324.74
2610	859.56	1821.99	2101.17	1285.68	1270.98	7339.38	439.05	993.03	1164.15	737.49	743.43	4077.15
2621	192.66	408.39	470.97	288.18	284.88	1645.08	113.19	256.02	300.15	190.17	191.67	1051.20
2622	64.98	137.67	158.79	97.17	96.06	554.67	11.04	25.11	29.43	18.63	18.78	102.99
2623	76.68	162.54	187.47	114.72	113.40	654.81	54.51	123.15	144.42	91.50	92.19	505.77
2624	236.58	501.42	578.25	353.82	349.77	2019.84	147.54	333.60	391.08	247.74	249.72	1369.68
2625	107.58	228.03	263.01	160.92	159.09	918.63	33.87	76.65	89.85	56.91	57.33	314.61
2636	684.12	1450.20	1672.41	1023.33	1011.63	5841.69	409.83	926.97	1086.66	688.38	693.90	3805.74
2641	43.65	92.55	106.74	65.31	64.59	372.84	49.29	111.45	130.65	82.77	83.40	457.56
2642	56.70	120.27	138.69	84.87	83.88	484.41	45.18	102.18	119.79	75.90	76.50	419.55
2643	110.31	233.85	269.70	165.03	163.11	942.00	68.13	154.05	180.60	114.42	115.35	632.55
2644	530.61	1124.70	1297.02	793.62	784.56	4530.51	317.40	717.78	841.41	533.04	537.30	2946.93
2651	1835.40	3890.49	4486.59	2745.30	2713.92	15671.70	814.17	1841.52	2158.83	1367.61	1378.53	7560.66
2662	113.61	240.81	277.71	169.92	168.00	970.05	54.33	122.97	144.15	91.32	92.04	504.81
2663	151.56	321.27	370.50	226.71	224.13	1294.17	60.75	137.49	161.16	102.09	102.90	564.39
2664	255.96	542.55	625.68	382.86	378.48	2185.53	77.28	174.72	204.84	129.75	130.80	717.39
2675	429.15	909.69	1049.10	641.94	634.59	3664.47	241.41	545.97	640.05	405.48	408.72	2241.63
2676	255.63	541.86	624.84	382.35	377.97	2182.65	36.48	82.47	96.63	61.23	61.71	338.52
2687	825.39	1749.66	2017.71	1234.62	1220.49	7047.87	512.22	1158.54	1358.19	860.40	867.27	4756.62
2698	217.92	461.88	532.62	325.92	322.17	1860.51	28.80	65.13	76.32	48.33	48.72	267.30
2699	136.95	290.34	334.83	204.87	202.53	1169.52	61.41	138.90	162.87	103.17	104.01	570.36
2700	178.26	377.85	435.75	266.64	263.58	1522.08	84.63	191.43	224.40	142.14	143.28	785.88
2701	344.91	731.10	843.09	515.88	509.97	2944.95	129.15	292.11	342.45	216.93	218.67	1199.31
2702	175.71	372.54	429.60	262.86	259.86	1500.57	13.29	30.06	35.25	22.32	22.47	123.39
2713	355.56	753.66	869.13	531.81	525.72	3035.88	119.97	271.35	318.09	201.51	203.13	1114.05
2714	89.88	190.53	219.69	134.43	132.90	767.43	5.58	12.66	14.88	9.42	9.48	52.02

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
2715	117.84	249.78	288.03	176.25	174.24	1006.14	7.59	17.19	20.10	12.72	12.84	70.44
2726	394.29	835.71	963.75	589.71	582.96	3366.42	280.38	634.14	743.40	470.91	474.69	2603.52
2727	168.81	357.81	412.65	252.48	249.60	1441.35	111.06	251.19	294.45	186.54	188.01	1031.25
2728	58.50	124.05	143.04	87.54	86.52	499.65	10.05	22.71	26.61	16.89	17.04	93.30
2739	1321.17	2800.38	3229.50	1976.10	1953.51	11280.66	961.17	2173.89	2548.47	1614.42	1627.32	8925.27
2740	213.18	451.95	521.16	318.90	315.24	1820.43	77.76	175.89	206.19	130.59	131.67	722.10
2741	144.63	306.60	353.61	216.36	213.90	1235.10	65.61	148.41	174.00	110.22	111.09	609.33
2742	210.66	446.52	514.98	315.12	311.52	1798.80	61.08	138.09	161.85	102.54	103.35	566.91
2753	849.03	1799.61	2075.37	1269.90	1255.35	7249.26	500.55	1132.08	1327.14	840.75	847.44	4647.96
2754	259.74	550.56	634.86	388.47	384.03	2217.66	129.48	292.86	343.26	217.47	219.18	1202.25
2755	138.18	292.89	337.80	206.70	204.33	1179.90	16.08	36.39	42.66	27.03	27.24	149.40
2766	204.18	432.78	499.08	305.37	301.89	1743.30	115.14	260.43	305.34	193.41	194.94	1069.26
2767	307.47	651.69	751.59	459.87	454.62	2625.24	209.04	472.77	554.22	351.09	353.88	1941.00
2768	124.80	264.54	305.04	186.66	184.50	1065.54	88.44	200.07	234.54	148.59	149.76	821.40
2779	228.84	485.01	559.32	342.24	338.34	1953.75	9.87	22.32	26.19	16.59	16.71	91.68
2780	162.96	345.45	398.40	243.78	240.96	1391.55	199.17	450.39	528.00	334.50	337.14	1849.20
2781	894.12	1895.22	2185.65	1337.37	1322.10	7634.46	461.28	1043.31	1223.04	774.78	780.99	4283.40
2792	382.44	810.69	934.89	572.07	565.50	3265.59	276.93	626.46	734.40	465.21	468.99	2571.99
2813	302.58	641.40	739.68	452.61	447.45	2583.72	138.45	313.05	367.02	232.50	234.36	1285.38
2814	249.42	528.72	609.78	373.11	368.85	2129.88	207.87	470.16	551.22	349.17	352.02	1930.44
2825	398.97	845.73	975.33	596.79	589.98	3406.80	205.17	464.04	543.96	344.61	347.34	1905.12
2826	133.50	282.96	326.31	199.65	197.37	1139.79	14.88	33.75	39.54	25.02	25.23	138.42
2837	601.50	1274.97	1470.36	899.70	889.41	5135.94	362.37	819.51	960.75	608.61	613.47	3364.71
2848	346.41	734.25	846.72	518.10	512.16	2957.64	117.36	265.35	311.13	197.07	198.66	1089.57
2849	90.09	190.92	220.17	134.73	133.17	769.08	9.15	20.73	24.39	15.45	15.60	85.32
2850	173.70	368.19	424.62	259.83	256.83	1483.17	19.26	43.53	51.03	32.34	32.61	178.77
2851	641.73	1360.26	1568.64	959.85	948.87	5479.35	398.31	900.81	1056.03	668.97	674.31	3698.43
2852	199.74	423.42	488.31	298.80	295.38	1705.65	165.30	373.95	438.33	277.68	279.90	1535.16
2853	32.52	68.97	79.53	48.66	48.09	277.77	8.91	20.16	23.64	14.97	15.09	82.77
2854	106.86	226.53	261.24	159.84	158.04	912.51	50.58	114.33	134.04	84.93	85.62	469.50

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
2865	760.74	1612.50	1859.61	1137.87	1124.88	6495.60	539.85	1221.09	1431.42	906.81	914.04	5013.21
2866	119.34	252.96	291.72	178.50	176.46	1018.98	67.11	151.68	177.84	112.65	113.55	622.83
2877	64.80	137.37	158.43	96.93	95.82	553.35	10.47	23.73	27.81	17.64	17.76	97.41
2878	57.96	122.79	141.60	86.64	85.68	494.67	6.69	15.18	17.82	11.28	11.37	62.34
2879	165.57	350.94	404.73	247.65	244.83	1413.72	69.27	156.66	183.66	116.34	117.27	643.20
2880	43.29	91.77	105.81	64.74	63.99	369.60	28.35	64.08	75.12	47.61	48.00	263.16
2881	482.04	1021.71	1178.28	720.99	712.74	4115.76	476.34	1077.36	1263.00	800.10	806.52	4423.32
Total	245024.43	481686.36	529139.82	315432.69	304094.52	1875377.82	245024.73	481686.63	529139.85	315432.51	304094.40	1875378.12

A.2.2 Under the high growth assumption

A.2.2.1 Trips by public transport

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
CENTRAL LONDON												
Sector 0												
0	88.69	102.37	118.24	83.21	154.38	546.89	1963.68	1790.40	2113.86	1415.94	2036.89	9320.77
1	134.50	177.78	207.88	146.74	273.72	940.62	817.06	2388.53	3899.85	3011.79	4610.12	14727.35
2	127.32	137.57	155.86	109.03	201.96	731.74	3359.29	3268.87	4181.94	2800.45	3566.81	17177.36
10	180.13	215.92	251.71	176.66	329.07	1153.49	1623.70	4315.51	6698.25	4832.95	6379.75	23850.16
20	16.81	12.40	13.14	8.94	16.40	67.69	231.68	370.07	576.83	428.28	593.18	2200.04
21	45.78	51.26	58.94	41.39	77.02	274.39	659.47	1309.03	1643.17	1102.19	1566.01	6279.87
30	371.16	415.61	477.84	335.60	624.53	2224.74	2184.16	3362.99	4355.93	2911.28	3811.69	16626.05
31	51.97	89.41	107.20	76.31	142.32	467.21	811.75	1061.75	1485.08	1115.80	1886.79	6361.17
32	316.09	423.68	499.90	351.95	654.57	2246.19	5901.62	8357.89	10582.51	7502.78	12421.15	44765.95
33	244.02	294.40	343.20	240.87	450.26	1572.75	4788.71	8703.69	12429.66	9221.98	14869.75	50013.79
34	83.53	64.04	68.22	46.64	85.97	348.40	1912.95	4755.01	6967.32	5202.83	8405.77	27243.88
35	88.79	30.50	22.96	13.81	23.50	179.56	2094.38	4930.97	6943.77	4850.17	6637.20	25456.49
36	119.65	75.72	76.98	51.87	94.13	418.35	2850.13	4932.41	7937.86	6312.02	10542.39	32574.81
37	327.38	327.37	367.64	255.59	474.43	1752.41	2276.31	4405.65	6666.83	5263.10	9676.22	28288.11
38	130.16	103.24	110.52	76.30	140.81	561.03	2087.92	5688.56	9299.09	7453.66	12925.03	37454.26
39	476.35	543.16	627.39	438.59	816.18	2901.67	563.76	1369.95	2091.11	1650.75	3041.51	8717.08
40	105.40	117.95	134.89	94.11	175.68	628.03	1484.46	3581.06	5621.13	4322.48	6875.91	21885.04
41	159.33	155.16	173.51	120.96	224.40	833.36	1401.12	3859.92	6989.93	5645.23	8492.88	26389.08
42	107.65	108.82	122.20	85.54	158.29	582.50	1808.83	2795.61	3940.00	2914.68	4685.70	16144.82
43	181.26	163.59	181.27	125.56	232.56	884.24	1583.01	3376.85	5103.72	3627.22	4689.25	18380.05
44	181.47	246.75	291.14	204.97	382.53	1306.86	1980.20	2111.10	3064.88	2241.67	3148.58	12546.43
50	188.24	170.70	189.16	131.03	242.68	921.81	2937.49	2017.24	1831.16	1111.80	1753.71	9651.40
51	192.14	195.27	219.29	153.50	284.03	1044.23	1589.40	2718.97	3473.64	2314.27	3090.91	13187.19
52	103.42	142.67	168.33	118.51	221.93	754.86	1196.06	2615.76	3741.04	2760.47	4418.09	14731.42
60	5.54	14.08	17.44	12.48	23.43	72.97	283.80	838.95	1213.34	916.57	1598.24	4850.90
70	29.92	27.13	30.07	20.83	38.72	146.67	1155.63	1624.61	1758.70	1174.40	2107.91	7821.25
71	2.43	2.20	2.44	1.69	3.14	11.90	236.88	507.38	584.02	371.16	508.70	2208.14
80	30.58	77.66	96.16	68.80	129.16	402.36	1342.15	5671.30	9739.94	7918.30	13556.74	38228.43

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
81	63.89	71.07	81.28	56.71	105.48	378.43	1077.97	3739.09	6614.50	5548.44	10022.86	27002.86
82	46.68	118.53	146.78	105.02	197.14	614.15	2208.61	6774.87	11728.38	9358.91	14605.06	44675.83
83	106.54	119.24	136.36	95.14	177.59	634.87	1978.42	4573.24	7937.06	6791.82	13352.16	34632.70
84	46.30	90.70	110.08	78.43	146.93	472.44	2518.88	8760.73	14332.86	10969.12	16370.59	52952.18
INNER LONDON SECTORS 1,2 AND 3												
Sector 1												
100	1079.45	749.78	565.98	268.40	250.90	2914.51	813.44	665.50	612.92	303.52	259.45	2654.83
101	1712.28	1835.61	1835.62	964.97	899.67	7248.15	757.53	697.65	824.11	555.68	861.18	3696.15
102	1125.43	1459.14	1923.70	1105.80	922.59	6536.66	1824.51	776.16	934.11	618.35	806.61	4959.74
103	456.16	504.75	645.11	445.36	647.80	2699.18	290.44	302.08	386.42	256.22	334.26	1569.42
104	1831.95	1891.59	2130.18	1269.59	1405.92	8529.23	1075.95	559.82	471.03	272.51	414.87	2794.18
105	1106.15	1239.15	1559.50	991.31	1154.52	6050.63	1321.56	822.78	696.86	359.92	376.65	3577.77
106	1956.81	2502.58	3314.60	2289.60	3234.73	13298.32	1108.38	1070.84	1107.15	562.48	454.44	4303.29
110	1423.22	1522.14	1434.21	659.41	456.09	5495.07	1390.79	1827.26	1612.22	760.03	613.60	6203.90
111	2315.16	2885.18	2332.70	841.88	394.63	8769.55	1570.21	1361.91	1630.40	880.42	702.25	6145.19
112	1590.90	1913.96	1560.43	640.02	396.21	6101.52	950.02	1455.44	1861.19	1288.02	1974.08	7528.75
113	1809.83	2322.96	1837.56	651.81	312.04	6934.20	852.61	1229.49	1334.89	755.25	777.75	4949.99
114	990.76	1078.18	1204.44	728.50	849.91	4851.79	1365.42	837.97	843.20	485.15	552.21	4083.95
115	1802.90	1498.06	1959.68	1384.84	2064.18	8709.66	1847.81	936.69	964.87	622.20	976.19	5347.76
116	256.84	112.36	258.85	313.02	1067.49	2008.56	302.79	97.22	95.08	61.20	96.02	652.31
120	1163.48	1134.51	1144.17	651.74	728.98	4822.88	883.88	1584.13	1670.46	896.62	833.64	5868.73
121	1675.28	1421.82	1403.28	791.27	871.64	6163.29	865.37	1110.63	1123.04	660.29	838.35	4597.68
122	1431.07	1381.15	1325.68	704.44	698.89	5541.23	1358.01	1356.90	1363.62	705.06	615.87	5399.46
123	1823.01	1951.98	2218.55	1289.86	1315.65	8599.05	1996.22	1506.63	1504.20	902.09	1206.41	7115.55
124	1829.68	1871.04	2336.21	1643.62	2656.67	10337.22	1435.69	817.31	671.85	372.82	512.62	3810.29
125	2196.19	2184.18	2892.24	1992.17	2736.24	12001.02	1329.45	1342.81	1563.41	894.99	861.41	5992.07
130	1772.23	1498.59	1387.81	801.41	1055.52	6515.56	1096.15	1420.66	1575.61	906.95	950.87	5950.24
131	1325.20	1637.50	2000.45	1367.40	2118.62	8449.17	2275.15	780.48	603.07	350.49	601.29	4610.48
132	1346.52	2042.98	2553.73	1578.67	1755.12	9277.02	706.88	820.48	962.52	621.25	849.85	3960.98

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
133	1748.44	1985.51	2746.12	1708.92	1669.41	9858.40	1268.48	1671.03	1816.39	863.22	571.40	6190.52
134	1240.03	1802.18	2256.85	1405.36	1570.70	8275.12	1720.86	1338.51	1251.92	618.21	514.00	5443.50
135	737.40	794.70	974.28	611.31	703.01	3820.70	680.58	457.55	424.25	209.44	174.14	1945.96
136	1186.57	1271.88	1768.23	1318.42	2218.03	7763.13	1422.60	793.30	1000.43	683.26	951.79	4851.38
Sector 2												
200	786.55	956.41	904.71	494.82	542.83	3685.32	606.37	1292.76	1438.83	818.47	837.86	4994.29
201	2054.37	2437.72	2437.72	1376.13	1523.57	9829.51	1302.02	1510.00	1685.45	1018.84	1207.96	6724.27
202	1893.03	2285.38	2461.93	1471.27	1687.05	9798.66	2386.13	1662.28	2020.68	1491.09	2940.94	10501.12
203	884.73	893.32	979.22	635.63	906.21	4299.11	1734.76	754.20	679.72	431.26	781.96	4381.90
204	1272.27	1223.86	1403.65	1016.43	1984.45	6900.66	713.80	809.12	1268.00	832.27	802.73	4425.92
210	640.74	978.79	1108.51	621.08	585.71	3934.83	563.21	311.27	362.34	248.03	381.22	1866.07
211	1222.95	1155.01	1234.27	809.64	1234.27	5656.14	770.71	872.44	1012.86	678.08	1059.59	4393.68
212	1159.51	938.10	1054.63	792.43	1870.37	5815.04	2390.95	2330.62	2719.04	1741.49	2289.71	11471.81
213	654.34	427.70	544.68	482.53	1546.29	3655.54	1157.35	1181.36	1449.88	1092.70	2462.84	7344.13
214	654.06	666.47	960.38	732.71	1130.11	4143.73	613.02	715.64	744.70	460.99	659.37	3193.72
220	2242.39	2232.69	2077.38	1261.96	1892.93	9707.35	1951.64	1396.16	1370.74	868.61	1437.59	7024.74
221	1771.13	1423.09	1469.50	1020.92	2049.56	7734.20	1429.75	1696.40	1768.24	1088.19	1522.20	7504.78
230	2392.09	2048.73	2220.41	1579.47	3216.16	11456.86	1773.32	1310.56	1306.70	873.34	1772.87	7036.79
231	1336.61	1172.46	1399.13	1102.11	2813.90	7824.21	799.02	1264.29	1526.61	970.17	1220.36	5780.45
232	1813.39	1721.35	1868.62	1307.11	2512.97	9223.44	1778.98	1372.44	1414.06	915.43	1512.21	6993.12
233	877.81	939.58	1054.26	666.08	864.58	4402.31	700.81	1058.12	1331.88	903.63	1317.32	5311.76
Sector 3												
300	1175.14	1102.15	1810.15	1357.62	1861.25	7306.31	955.07	771.23	786.05	451.09	512.23	3475.67
301	815.03	641.80	826.85	598.48	1055.23	3937.39	343.75	441.99	477.05	241.21	186.03	1690.03
302	2263.61	2677.68	3505.83	2332.62	3022.73	13802.47	1935.92	1774.43	1860.50	1060.33	1144.48	7775.66
303	1557.68	2044.89	2010.57	816.58	425.44	6855.16	802.17	950.38	1159.21	625.90	496.10	4033.76
304	1420.90	1619.53	1955.66	1207.01	1428.55	7631.65	1144.55	1131.79	1187.08	642.13	601.39	4706.94
310	1861.59	2073.28	1941.89	854.14	569.42	7300.32	1170.99	2483.92	2362.55	1158.13	960.93	8136.52
311	3012.35	3255.90	3409.71	1730.49	1410.03	12818.48	1375.88	1530.30	1430.03	700.35	581.06	5617.62
312	1537.53	1984.82	2515.96	1556.17	1714.58	9309.06	2219.59	2118.57	2202.12	1212.58	1203.09	8955.95

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
313	3510.44	4439.68	5041.96	2477.96	1738.02	17208.06	2136.18	1616.57	1622.47	840.15	728.42	6943.79
314	831.84	1052.03	1194.74	587.18	411.84	4077.63	1117.06	2770.51	2889.51	1499.01	1299.83	9575.92
320	2005.12	2258.25	1652.05	526.26	213.17	6654.85	1819.43	1499.60	1284.77	577.48	420.41	5601.69
321	1096.76	1318.95	1281.13	595.66	439.65	4732.15	2532.24	2373.57	2508.65	1458.17	1652.12	10524.75
322	1701.37	1632.86	1347.40	588.06	439.62	5709.31	1085.23	1314.63	1420.29	693.73	491.34	5005.22
323	1861.59	2435.72	2453.13	1148.27	791.61	8690.32	1507.12	1480.85	1226.89	544.61	401.67	5161.14
324	3076.54	3150.79	2662.80	1082.09	636.52	10608.74	10740.62	14100.82	14163.21	6054.51	3419.45	48478.61
330	1591.09	1497.49	1801.66	1185.51	1715.87	7791.62	1055.40	1862.02	2070.06	1149.34	1098.67	7235.49
331	2022.76	1655.79	1915.37	1288.84	2085.41	8968.17	2151.55	2119.72	2090.29	1243.47	1684.90	9289.93
332	2817.20	2663.53	3047.70	1882.40	2381.82	12792.65	2925.02	2202.43	2305.45	1377.25	1695.86	10506.01
340	906.49	971.23	924.47	442.45	356.12	3600.76	836.05	1055.12	1137.70	758.97	1366.71	5154.55
341	1686.38	2117.25	2094.96	928.62	601.74	7428.95	1628.80	1114.69	1111.90	634.93	723.29	5213.61
342	1177.11	858.04	927.03	573.46	780.42	4316.06	572.43	554.50	505.95	224.02	148.57	2005.47
343	2632.84	2010.53	1803.10	853.68	678.15	7978.30	1266.11	980.94	955.86	575.21	813.27	4591.39
344	2535.73	2743.89	2403.26	1050.25	719.09	9452.22	1838.81	2093.37	1906.87	919.55	755.46	7514.06
OUTER LONDON SECTORS 4,5,6,7 AND 8												
Sector 4												
400	1455.80	2205.75	3341.71	2117.52	1930.03	11050.81	472.03	311.68	524.89	378.65	443.48	2130.73
401	1180.36	1540.69	3615.65	2969.56	3106.23	12412.49	1311.05	699.64	793.51	486.15	585.69	3876.04
402	679.07	888.02	1337.24	982.04	1326.80	5213.17	236.75	247.85	425.76	290.88	290.22	1491.46
403	757.26	921.88	1824.04	1442.11	1639.66	6584.95	437.48	451.12	781.82	505.42	433.78	2609.62
410	552.96	709.44	907.67	594.68	716.40	3481.15	218.95	206.60	311.36	181.79	140.97	1059.67
411	1045.05	1600.92	2690.44	2201.27	3568.72	11106.40	657.41	272.48	377.97	280.41	462.45	2050.72
412	133.68	210.23	363.35	253.98	256.41	1217.65	6.00	18.12	26.07	19.35	31.91	101.45
413	523.97	600.89	1172.92	1009.48	1504.61	4811.87	221.11	191.01	198.20	133.75	272.49	1016.56
414	681.96	700.38	1271.75	1161.17	2328.48	6143.74	556.25	495.17	638.69	438.92	645.76	2774.79

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
415	1025.92	1263.73	1712.15	1188.99	1603.44	6794.23	379.63	592.62	842.91	564.25	674.08	3053.49
416	1060.48	1187.74	1662.83	1365.90	3198.41	8475.36	1080.87	937.14	1222.51	803.04	1005.42	5048.98
417	583.63	701.02	828.18	521.69	622.77	3257.29	286.09	140.75	180.80	118.74	148.66	875.04
418	105.06	95.65	131.71	114.46	337.90	784.78	83.32	182.44	173.95	65.47	30.09	535.27
420	1186.54	1546.41	1269.22	530.06	340.41	4872.64	1873.54	1250.64	1387.07	891.94	1310.84	6714.03
421	1084.75	1518.63	1952.53	1159.32	1077.96	6793.19	776.01	772.40	876.04	443.93	328.97	3197.35
422	587.62	728.37	946.53	605.21	654.48	3522.21	599.26	165.90	179.57	90.95	67.39	1103.07
423	725.31	901.15	1252.82	956.10	1670.42	5505.80	627.41	643.19	651.94	322.65	253.76	2498.95
424	715.05	881.21	1193.42	876.18	1369.67	5035.53	58.61	185.35	454.54	293.32	179.64	1171.46
425	1205.39	1401.26	1898.50	1318.40	1717.69	7541.24	497.19	980.91	1070.54	536.00	404.83	3489.47
426	499.37	546.53	710.21	468.85	549.31	2774.27	563.34	902.56	962.40	531.79	529.05	3489.14
427	324.06	463.24	565.03	346.91	378.07	2077.31	205.81	534.47	661.69	427.30	555.66	2384.93
428	530.64	923.72	732.10	206.36	61.42	2454.24	400.76	666.58	586.06	225.30	115.68	1994.38
431	710.46	1109.01	1264.96	680.14	571.84	4336.41	724.56	380.40	654.52	289.39	109.43	2158.30
432	93.88	125.74	219.61	174.83	247.18	861.24	6.36	88.82	157.82	69.80	26.40	349.20
440	8.73	12.04	21.09	16.81	23.64	82.31	0.32	4.38	7.77	3.44	1.30	17.21
441	392.39	540.46	947.65	755.16	1062.41	3698.07	15.64	218.52	388.31	171.73	64.94	859.14
Sector 5												
500	1217.38	1792.86	2578.63	1992.07	3486.13	11067.07	441.72	472.17	447.53	256.55	327.29	1945.26
501	781.63	937.96	1563.26	1431.63	3513.24	8227.72	428.91	347.44	524.62	384.25	525.35	2210.57
502	1853.96	2575.55	2953.01	1776.25	1953.87	11112.64	4096.90	4102.22	4998.73	3125.67	3617.54	19941.06
503	1242.35	1878.21	2719.51	1839.09	2103.21	9782.37	926.17	468.62	540.94	337.17	390.12	2663.02
504	2052.68	3126.60	3806.31	2283.79	2338.16	13607.54	1102.38	1602.59	1852.74	1160.45	1483.60	7201.76
510	1060.20	1442.73	2546.64	2175.03	3705.20	10929.80	560.85	763.24	1005.05	653.08	775.84	3758.06
511	1975.63	2583.53	3647.34	2720.31	4255.23	15182.04	2648.65	1281.23	1458.31	1021.17	1773.35	8182.71
520	1346.30	1758.44	2106.47	1474.52	2454.50	9140.23	1825.97	1371.54	1687.75	1163.25	1769.90	7818.41
521	1193.74	1557.95	2336.92	1841.21	3186.71	10116.53	831.01	734.85	840.99	572.69	962.92	3942.46
522	324.63	525.73	764.15	542.95	715.31	2872.77	173.09	202.00	234.61	159.90	268.87	1038.47
530	994.20	1282.83	1836.06	1427.15	2477.47	8017.71	783.32	1175.84	1561.72	954.65	947.90	5423.43
531	1321.04	2192.92	2615.65	1444.34	1224.16	8798.11	1275.70	824.54	855.62	541.67	799.50	4297.03

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
532	903.51	1056.05	1378.75	991.52	1537.15	5866.98	1184.63	520.24	546.18	361.89	580.34	3193.28
533	893.61	1154.27	1615.96	1280.85	2509.58	7454.27	435.50	488.19	517.16	334.70	546.27	2321.82
540	579.72	711.07	955.63	751.82	1535.36	4533.60	181.87	192.74	210.79	144.39	277.63	1007.42
552	687.98	815.62	1517.77	1390.11	2673.83	7085.31	411.80	419.15	670.75	525.61	836.85	2864.16
560	114.25	142.81	273.11	289.18	963.93	1783.28	10.52	39.49	67.47	57.58	119.34	294.40
561	656.24	755.99	1123.47	923.98	1800.70	5260.38	391.56	316.95	513.79	437.51	906.64	2566.45
562	488.33	589.18	1003.20	934.20	2298.34	5313.25	421.87	178.51	271.27	230.34	477.21	1579.20
570	329.23	397.23	676.36	629.84	1549.56	3582.22	304.44	128.82	195.76	166.23	344.40	1139.65
581	251.61	303.57	516.89	481.34	1184.21	2737.62	146.41	61.95	94.13	79.92	165.57	547.98
Sector 6												
600	748.11	648.37	1147.10	1147.11	3441.32	7132.01	589.08	451.23	611.92	502.13	1251.75	3406.11
601	535.02	518.43	804.60	700.92	1592.61	4151.58	648.12	379.70	656.02	586.92	1170.33	3441.09
602	298.63	322.42	483.63	425.49	1109.98	2640.15	482.64	278.65	330.38	235.32	402.23	1729.22
603	250.42	306.51	486.81	380.63	580.97	2005.34	122.74	127.24	161.77	116.48	199.66	727.89
604	830.55	949.20	1495.00	1328.89	3306.42	7910.06	314.45	496.23	618.85	451.04	878.71	2759.28
610	191.38	328.09	677.20	483.71	426.93	2107.31	554.10	251.48	332.50	233.06	296.88	1668.02
611	463.61	682.52	1077.45	824.18	1240.57	4288.33	186.60	489.23	766.78	549.35	703.41	2695.37
612	528.61	841.38	1233.43	836.97	964.72	4405.11	281.53	398.27	706.36	440.44	329.18	2155.78
613	632.31	975.02	1332.21	873.66	1008.81	4822.01	1265.13	1052.57	1244.28	659.13	496.56	4717.67
614	478.95	646.13	1030.20	840.42	1518.18	4513.88	456.00	1145.11	2245.74	1425.88	1026.03	6298.76
615	224.49	291.65	493.16	357.05	399.47	1765.82	451.93	915.21	1155.82	625.85	485.46	3634.27
616	569.32	447.32	833.64	859.05	2373.84	5083.17	1004.23	1092.20	1939.55	1643.88	2845.85	8525.71
620	1010.34	1621.24	2271.31	1448.94	1480.26	7832.09	503.39	770.92	1086.87	744.98	943.72	4049.88
621	260.10	444.69	780.29	587.32	721.56	2793.96	1143.48	1519.90	2087.59	1470.29	2090.76	8312.02
622	334.27	555.25	787.29	516.58	569.07	2762.46	215.16	286.02	392.84	276.67	393.42	1564.11
623	499.17	702.14	1530.44	1267.14	1475.59	5474.48	340.86	381.74	551.07	409.53	634.97	2318.17
624	174.28	242.06	416.36	325.98	458.31	1616.99	109.24	98.29	131.54	97.00	162.58	598.65
625	323.73	361.31	560.76	488.49	1156.20	2890.49	157.58	106.50	137.81	101.13	169.29	672.31
626	781.10	972.96	1582.76	1294.99	2219.99	6851.80	298.12	318.41	432.86	319.90	536.40	1905.69
630	1271.11	1697.97	2409.42	1716.94	2361.98	9457.42	1621.73	2188.98	2663.67	1754.50	2419.40	10648.28

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
631	1165.86	1563.32	2349.39	1660.47	2075.59	8814.63	2050.82	1942.68	2443.64	1593.33	1965.36	9995.83
632	459.24	663.05	752.03	456.38	536.74	2867.44	544.12	354.75	445.65	322.63	538.68	2205.83
633	973.86	1841.18	2244.43	1301.01	1247.75	7608.23	413.79	629.61	1161.17	727.68	530.55	3462.80
634	430.37	662.36	1015.39	652.27	601.84	3362.23	130.69	291.59	547.92	343.96	250.86	1565.02
635	769.03	1331.56	2157.56	1445.49	1417.01	7120.65	153.26	834.68	1299.69	806.04	710.58	3804.25
636	1020.82	1131.18	1531.24	1165.67	2034.74	6883.65	441.78	709.51	824.12	518.73	669.82	3163.96
640	241.93	328.15	700.78	617.36	892.66	2780.88	80.08	251.40	335.51	220.39	272.76	1160.14
641	467.05	766.95	1342.17	1027.52	1312.67	4916.36	262.75	273.70	508.16	388.31	453.01	1885.93
652	182.08	248.29	398.93	316.17	513.16	1658.63	2.80	20.26	40.49	31.16	36.40	131.11
Sector 7												
700	1249.65	1345.78	1671.14	1183.11	1929.95	7379.63	455.02	600.07	874.55	586.40	668.05	3184.09
701	1802.02	2493.37	2969.37	1847.36	2221.35	11333.47	2228.32	1856.14	1865.83	1145.41	1650.02	8745.72
702	1761.53	2103.06	2291.80	1348.12	1482.93	8987.44	1845.64	943.28	887.49	516.85	656.39	4849.65
703	913.67	1190.54	1250.52	664.48	590.64	4609.85	1262.28	1304.68	1510.54	921.41	1066.19	6065.10
704	551.93	685.46	732.94	445.11	560.84	2976.28	253.82	766.13	1095.44	641.78	535.02	3292.19
705	1138.15	1593.41	2176.14	1602.51	2594.99	9105.20	953.21	1008.01	1360.47	931.39	1239.53	5492.61
710	964.79	1517.29	2341.89	1607.99	1805.90	8237.86	275.52	263.33	390.89	285.91	405.83	1621.48
711	801.84	878.21	1304.59	1081.86	2290.99	6357.49	98.93	132.65	219.74	170.66	255.21	877.19
712	1059.77	1633.82	2671.50	2141.62	3532.56	11039.27	827.47	609.51	1080.71	890.73	1397.22	4805.64
713	946.19	1101.31	1613.17	1326.21	2768.76	7755.64	501.47	447.03	733.88	428.90	296.98	2408.26
720	1349.09	1364.59	1581.71	1147.51	2302.77	7745.67	937.83	1206.67	1563.22	953.60	965.85	5627.17
721	988.83	1464.93	2353.04	1794.54	2554.47	9155.81	938.25	686.58	1108.39	901.30	1568.20	5202.72
722	846.80	1105.16	1865.84	1442.44	1916.08	7176.32	686.80	643.30	747.60	498.81	762.87	3339.38
723	1009.45	1367.96	2179.29	1764.19	3132.15	9453.04	481.71	381.85	449.29	314.06	550.43	2177.34
724	705.84	985.03	1432.77	979.76	1164.12	5267.52	334.16	435.24	489.04	305.31	401.34	1965.09
725	1461.01	1725.61	2404.34	1921.17	3991.89	11504.02	609.73	895.19	1284.00	921.77	1329.42	5040.11
730	2317.72	3750.18	4796.36	2768.37	2446.47	16079.10	1696.42	1699.49	2156.74	1215.15	1013.59	7781.39
731	974.61	1293.40	2249.79	1821.69	2768.97	9108.46	401.26	582.16	696.07	450.67	610.36	2740.52
732	78.20	82.28	139.46	112.04	170.97	582.95	11.38	16.48	19.70	12.76	17.29	77.61
733	935.09	1549.18	2107.45	1256.09	1130.48	6978.29	224.45	452.93	497.77	252.21	193.76	1621.12

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
734	1375.36	1840.55	2578.79	1820.32	2487.77	10102.79	1294.91	1590.02	1823.64	1053.88	1066.51	6828.96
740	371.56	418.84	672.17	584.35	1330.83	3377.75	107.95	177.78	173.91	98.78	119.13	677.55
743	45.40	67.57	110.81	96.76	221.08	541.62	39.44	103.01	130.96	87.49	122.10	483.00
746	430.14	654.84	972.61	606.68	542.48	3206.75	18.11	62.09	94.55	71.71	116.58	363.04
750	730.91	1067.77	1544.45	1163.10	1849.53	6355.76	469.62	458.61	577.00	420.71	782.20	2708.14
757	236.94	346.14	500.67	377.05	599.56	2060.36	100.71	98.34	123.75	90.23	167.76	580.79
758	129.43	189.09	273.51	205.97	327.53	1125.53	42.45	41.44	52.13	38.02	70.68	244.72
774	481.22	702.99	1016.85	765.77	1217.71	4184.54	285.44	278.76	350.73	255.72	475.45	1646.10
775	523.21	764.35	1105.57	832.59	1323.96	4549.68	592.04	578.14	727.41	530.37	986.10	3414.06
Sector 8												
800	573.23	953.84	1412.42	875.88	770.41	4585.78	272.48	393.57	467.39	258.52	223.16	1615.12
801	1611.51	2726.01	4442.94	3087.47	3207.96	15075.89	2962.18	2030.48	2252.05	1232.88	1061.20	9538.79
802	1641.60	2444.94	3364.71	2118.95	2060.74	11630.94	413.36	1074.36	1435.07	597.09	250.33	3770.21
803	320.61	458.45	785.05	614.26	818.00	2996.37	210.64	137.45	192.56	108.68	77.21	726.54
810	1034.45	1603.74	1909.21	1152.47	1235.79	6935.66	818.97	854.61	1270.50	816.73	783.53	4544.34
811	955.33	1258.36	1123.68	509.23	361.93	4208.53	701.83	287.15	359.11	163.48	76.10	1587.67
812	779.70	1319.92	1681.93	963.49	829.82	5574.86	579.39	558.72	803.45	371.62	173.51	2486.69
813	888.04	1520.60	1897.70	1015.76	760.30	6082.40	1730.90	1373.77	1278.03	525.19	282.61	5190.50
820	819.90	1481.56	2279.87	1416.83	1179.49	7177.65	1378.66	1131.53	1183.57	683.14	746.94	5123.84
821	774.76	1065.30	1765.57	1452.68	2398.79	7457.10	570.70	648.78	725.57	411.08	400.91	2757.04
822	916.63	1257.86	1880.10	1271.24	1351.53	6677.36	301.12	397.52	482.58	331.06	526.81	2039.09
823	884.36	1458.41	2257.43	1535.99	1636.84	7773.03	484.79	318.91	413.32	294.53	439.12	1950.67
824	791.06	1228.95	2027.07	1440.84	1582.10	7070.02	408.31	536.59	497.08	249.70	223.95	1915.63
830	305.45	360.42	443.91	325.81	602.75	2038.34	119.60	173.47	177.63	112.43	182.74	765.87
831	916.00	1248.57	1458.61	945.18	1277.74	5846.10	601.07	470.13	457.80	287.05	465.23	2281.28
832	575.78	799.69	1060.16	785.98	1352.62	4574.23	261.12	180.80	225.94	161.48	261.65	1090.99
833	1697.52	2384.87	2770.20	1687.11	1895.40	10435.10	1576.98	1556.65	1799.79	1016.33	933.44	6883.19
834	590.92	1016.38	1221.22	638.19	476.67	3943.38	1311.98	789.35	614.81	309.93	334.82	3360.89
835	1837.11	2755.67	3154.07	1759.64	1582.57	11089.06	1189.99	1221.82	1628.73	1028.21	1073.11	6141.86
840	35.63	27.07	37.09	34.16	110.55	244.50	28.05	25.82	25.15	12.56	10.24	101.82

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
841	258.71	304.25	389.09	314.59	805.10	2071.74	99.27	91.30	88.98	44.43	36.18	360.16
842	968.96	1253.93	1588.79	1175.56	2144.51	7131.75	581.51	577.23	566.19	283.09	230.57	2238.59
843	3.50	5.05	12.22	12.97	28.49	62.23	2.57	6.58	6.79	3.42	2.79	22.15
850	67.26	81.09	87.63	57.65	90.70	384.33	83.90	31.21	26.22	12.73	10.28	164.34
CORDON CROSSING												
6411	782.08	1057.03	1515.28	1093.69	1668.03	6116.11	106.24	130.05	160.39	106.44	148.16	651.28
6462	1667.32	2253.49	3230.44	2331.65	3556.09	13038.99	53.84	65.93	81.31	53.95	75.11	330.14
6463	440.97	595.99	854.38	616.67	940.50	3448.51	54.15	66.29	81.77	54.26	75.53	332.00
6474	2106.41	2846.94	4081.16	2945.67	4492.56	16472.74	111.45	136.41	168.25	111.67	155.43	683.21
6515	619.02	836.63	1199.34	865.65	1320.24	4840.88	31.50	38.56	47.54	31.56	43.92	193.08
6527	3136.67	4239.40	6077.29	4386.43	6689.91	24529.70	411.53	503.80	621.32	412.35	573.97	2522.97
6558	496.50	671.06	961.98	694.33	1058.96	3882.83	63.95	78.32	96.57	64.09	89.21	392.14
6579	150.13	202.93	290.91	209.97	320.23	1174.17	0.00	0.00	0.00	0.00	0.00	0.00
6590	3009.48	4067.49	5830.85	4208.56	6418.65	23535.03	305.95	374.54	461.92	306.56	426.71	1875.68
6601	32.65	44.12	63.26	45.66	69.63	255.32	2.12	2.60	3.21	2.13	2.96	13.02
6632	578.45	781.82	1120.74	808.93	1233.72	4523.66	116.35	142.42	175.65	116.57	162.27	713.26
6633	82.30	111.25	159.47	115.10	175.55	643.67	2.93	3.58	4.42	2.93	4.08	17.94
6654	1901.04	2569.39	3683.27	2658.49	4054.57	14866.76	319.13	390.69	481.83	319.77	445.10	1956.52
6685	600.71	811.90	1163.88	840.06	1281.20	4697.75	50.24	61.52	75.87	50.35	70.09	308.07
6706	1194.13	1613.95	2313.64	1669.92	2546.86	9338.50	142.74	174.76	215.52	143.04	199.10	875.16
6717	1091.05	1474.61	2113.90	1525.76	2326.99	8532.31	207.72	254.27	313.61	208.13	289.71	1273.44
6728	32.12	43.41	62.24	44.92	68.51	251.20	0.00	0.00	0.00	0.00	0.00	0.00
6749	1760.00	2378.75	3410.02	2461.26	3753.76	13763.79	406.95	498.18	614.39	407.74	567.55	2494.81
6760	2115.98	2859.87	4099.70	2959.06	4512.97	16547.58	266.29	325.97	402.04	266.81	371.39	1632.50
6771	284.93	385.10	552.05	398.45	607.70	2228.23	29.34	35.93	44.34	29.42	40.94	179.97
6782	558.47	754.81	1082.04	780.99	1191.11	4367.42	254.87	312.02	384.80	255.37	355.48	1562.54
6783	1207.13	1631.53	2338.83	1688.11	2574.60	9440.20	186.00	227.70	280.82	186.38	259.42	1140.32
6824	293.64	396.87	568.94	410.64	626.28	2296.37	0.00	0.00	0.00	0.00	0.00	0.00
6855	4520.34	6109.52	8758.15	6321.41	9641.03	35350.45	285.04	348.95	430.38	285.61	397.56	1747.54

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
6867	2209.33	2986.06	4280.58	3089.62	4712.09	17277.68	19.09	23.37	28.81	19.13	26.63	117.03
6878	83.08	112.29	160.96	116.18	177.19	649.70	74.74	91.48	112.85	74.89	104.24	458.20
6889	569.34	769.51	1103.10	796.19	1214.30	4452.44	100.84	123.45	152.24	101.04	140.63	618.20
Total	239224.11	294985.42	380213.55	255349.22	358716.25	1528488.55	239224.00	294985.42	380213.56	255349.14	358716.37	1528488.49

A.2.2.2. Trips by private transport

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
CENTRAL LONDON												
Sector 0												
0	89.64	165.12	208.59	159.78	265.38	888.51	157.08	278.43	432.15	368.40	615.42	1851.48
1	113.46	230.70	296.82	228.21	379.11	1248.30	109.83	489.72	807.81	650.97	859.47	2917.80
2	148.92	258.87	324.27	247.71	410.55	1390.32	326.34	811.32	1164.15	859.65	1026.42	4187.88
10	230.94	442.83	559.47	430.92	714.24	2378.40	282.72	967.20	1540.20	1232.46	1659.81	5682.39
20	10.32	13.08	15.15	11.37	18.63	68.55	54.12	103.56	123.60	94.02	174.54	549.84
21	117.87	214.92	269.22	207.99	344.34	1154.34	272.16	521.07	621.90	473.16	878.07	2766.36
30	502.95	917.19	1148.94	887.58	1469.46	4926.12	271.98	947.82	1845.75	1603.14	2062.83	6731.52
31	47.52	116.55	153.30	119.10	198.90	635.37	79.29	161.73	368.34	406.53	902.10	1917.99
32	466.23	974.34	1246.71	963.87	1597.71	5248.86	550.29	1518.06	2519.31	2350.17	5275.95	12213.78
33	444.36	860.94	1087.74	837.78	1388.58	4619.40	969.39	1829.91	2751.36	2217.12	3210.03	10977.81
34	442.89	576.36	676.47	509.64	831.18	3036.54	126.84	660.03	1345.77	1358.07	2857.20	6347.91
35	501.96	315.84	265.50	175.47	265.50	1524.27	259.98	670.44	1035.48	860.58	1372.20	4198.68
36	472.44	526.74	583.74	431.70	703.20	2717.82	599.10	1235.70	1658.55	1266.78	1873.65	6633.78
37	457.83	748.44	915.63	700.65	1158.48	3981.03	449.25	1234.32	1932.42	1692.15	3264.99	8573.13
38	297.45	400.86	472.59	356.52	584.37	2111.79	198.45	881.76	1524.30	1316.07	2042.97	5963.55
39	259.05	477.06	602.73	461.64	766.83	2567.31	146.79	589.47	878.04	644.82	734.67	2993.79
40	195.93	347.07	434.76	333.99	554.19	1865.94	429.12	792.93	997.59	776.40	1400.61	4396.65
41	205.95	330.96	404.91	309.84	508.77	1760.43	63.12	423.00	984.30	1054.98	2200.95	4726.35
42	154.29	258.96	319.59	243.81	402.21	1378.86	481.62	504.63	675.48	560.31	1032.36	3254.40
43	330.66	499.92	605.76	457.62	756.51	2650.47	507.81	895.56	1105.23	858.69	1598.52	4965.81
44	112.44	240.42	307.65	237.84	394.23	1292.58	309.39	523.95	692.88	553.80	987.99	3068.01
50	121.35	183.48	222.30	168.90	277.62	973.65	166.80	516.96	705.06	519.42	677.64	2585.88
51	253.26	425.10	524.61	400.23	660.24	2263.44	151.62	606.51	994.44	839.37	1310.58	3902.52
52	108.21	231.33	296.01	228.84	380.55	1244.94	106.74	447.06	733.59	605.64	874.11	2767.14
60	54.15	178.17	243.12	189.96	317.94	983.34	65.28	276.30	398.37	271.53	260.04	1271.52
70	139.02	211.92	256.74	195.09	320.67	1123.44	111.72	421.47	520.05	299.88	221.34	1574.46
71	29.19	44.52	53.97	41.01	67.41	236.10	40.08	151.29	186.63	107.64	79.44	565.08
80	128.01	421.23	574.86	449.19	751.71	2325.00	404.22	973.92	1387.11	1154.64	2177.16	6097.05

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
81	139.95	247.92	310.62	238.62	394.59	1331.70	78.72	524.85	1060.62	929.64	1197.87	3791.70
82	202.41	666.00	908.85	710.16	1188.51	3675.93	439.80	1016.64	1775.46	1614.96	2850.27	7697.13
83	164.34	291.09	364.62	280.11	464.76	1564.92	226.08	810.27	1273.80	1069.17	1756.14	5135.46
84	210.09	582.42	776.58	604.71	1008.93	3182.73	306.93	1035.45	1731.90	1630.95	3838.23	8543.46
INNER LONDON SECTORS 1,2 AND 3												
Sector 1												
100	366.00	403.08	336.12	173.76	145.26	1424.22	290.79	574.29	624.93	382.95	382.20	2255.16
101	606.57	1027.98	1118.58	649.89	535.65	3938.67	226.44	748.77	1125.99	830.82	942.51	3874.53
102	477.15	1013.40	1458.75	917.97	681.66	4548.93	614.19	1190.31	1995.60	1378.23	1111.53	6289.86
103	155.70	276.93	389.19	293.40	380.22	1495.44	127.53	272.49	493.29	440.43	690.63	2024.37
104	845.94	1405.80	1735.47	1132.11	1113.45	6232.77	615.54	921.63	1335.90	909.54	828.09	4610.70
105	469.50	859.32	1182.06	825.78	859.29	4195.95	525.33	923.16	1400.76	922.11	734.13	4505.49
106	899.52	1818.75	2649.06	2006.58	2510.70	9884.61	636.09	1326.69	1797.15	1301.40	1591.41	6652.74
110	698.22	1189.83	1235.34	623.85	384.21	4131.45	687.66	925.92	1110.33	849.81	1543.11	5116.83
111	910.11	1773.96	1573.41	622.17	262.23	5141.88	1258.98	1424.46	1470.06	884.16	865.35	5903.01
112	936.87	1705.38	1536.93	689.52	384.24	5252.94	847.86	1578.69	1950.39	1298.64	1387.71	7063.29
113	792.18	1553.19	1352.91	529.59	226.95	4454.82	353.85	821.58	1420.47	1064.61	1036.44	4696.95
114	440.88	759.69	932.67	617.25	641.01	3391.50	501.63	693.21	1087.41	861.84	1098.33	4242.42
115	737.46	1026.54	1474.95	1144.56	1516.26	5899.77	1389.72	1596.51	1657.20	1024.74	1083.84	6752.01
116	101.70	79.59	203.40	269.76	818.10	1472.55	125.67	144.21	266.16	259.77	521.76	1317.57
120	614.07	946.53	1048.23	653.19	653.19	3915.21	621.69	874.95	1016.58	764.01	1381.92	4659.15
121	670.95	918.69	994.95	613.74	609.93	3808.26	460.08	867.60	1071.81	746.34	920.64	4066.47
122	649.29	995.10	1045.05	610.89	537.93	3838.26	566.07	953.58	1390.20	997.08	1052.04	4958.97
123	560.67	969.57	1209.87	771.45	699.81	4211.37	409.20	1264.23	1840.20	1355.07	1596.93	6465.63
124	762.30	1254.33	1711.71	1323.63	1884.96	6936.93	406.26	669.66	850.98	682.83	1376.01	3985.74
125	993.57	1638.00	2363.07	1781.25	2175.09	8950.98	735.57	1692.24	2319.39	1722.18	2259.09	8728.47
130	869.43	1152.84	1172.07	744.54	869.43	4808.31	562.59	1141.53	1320.78	940.44	1416.51	5381.85
131	518.43	1010.40	1348.98	1015.71	1401.90	5295.42	865.83	766.86	998.46	763.08	1104.81	4499.04
132	541.20	1278.75	1754.55	1189.53	1171.71	5935.74	437.19	637.56	1285.26	1133.91	1409.61	4903.53

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
133	639.36	1212.39	1833.63	1254.60	1091.73	6031.71	585.12	1144.53	1954.86	1622.01	2161.89	7468.41
134	637.74	1451.82	1994.55	1356.84	1350.06	6791.01	547.62	813.36	1787.85	1720.08	2483.82	7352.73
135	383.37	664.47	900.87	619.74	629.34	3197.79	160.95	355.17	616.95	579.60	1204.26	2916.93
136	549.03	960.81	1462.11	1199.52	1790.31	5961.78	442.44	842.43	1196.31	1010.31	2015.91	5507.40
Sector 2												
200	333.33	615.06	638.52	382.62	373.26	2342.79	458.28	1179.45	1614.12	1097.61	1099.95	5449.41
201	959.61	1732.77	1891.56	1173.60	1159.77	6917.31	788.79	1725.81	2348.61	1562.76	1471.92	7897.89
202	658.77	1243.08	1471.53	956.22	977.49	5307.09	562.35	1217.40	2027.76	1693.62	2399.43	7900.56
203	373.47	603.30	726.87	517.14	652.14	2872.92	347.73	1139.88	1428.03	906.30	844.62	4666.56
204	501.87	772.47	973.20	772.44	1339.80	4359.78	228.00	770.25	1152.48	928.38	1425.78	4504.89
210	258.90	612.36	759.24	465.51	388.32	2484.33	392.55	575.13	686.73	492.96	703.44	2850.81
211	559.74	845.76	992.85	715.02	972.45	4085.82	479.28	948.96	1158.84	836.25	1196.28	4619.61
212	691.44	914.46	1115.22	920.04	1934.88	5576.04	1214.58	1593.57	2256.87	1899.66	3585.12	10549.80
213	479.82	529.59	742.35	719.70	2055.03	4526.49	448.08	982.08	1361.70	1139.79	2333.19	6264.84
214	412.32	697.35	1100.88	916.68	1267.56	4394.79	176.67	649.74	1001.58	807.30	1183.59	3818.88
220	1083.57	1639.44	1695.72	1118.76	1491.66	7029.15	853.23	1563.57	2041.74	1588.23	2657.52	8704.29
221	841.68	1085.43	1236.36	940.35	1689.12	5792.94	862.47	1135.29	1514.79	1222.41	2196.75	6931.71
230	910.92	1258.59	1495.02	1168.20	2120.85	6953.58	819.87	1183.71	1583.19	1219.89	1834.68	6641.34
231	510.21	726.03	961.53	829.08	1873.98	4900.83	515.49	745.35	1062.12	854.28	1341.00	4518.24
232	701.28	1054.80	1251.12	959.37	1643.85	5610.42	466.86	762.57	1267.68	1150.71	2180.34	5828.16
233	378.63	646.02	793.29	549.90	637.05	3004.89	319.08	730.80	942.87	739.29	1334.46	4066.50
Sector 3												
300	558.81	915.00	1651.92	1357.14	1658.07	6140.94	433.05	1161.78	1773.42	1324.41	1526.76	6219.42
301	442.74	584.40	825.24	658.77	1034.22	3545.37	477.09	656.19	792.66	515.43	530.16	2971.53
302	814.56	1595.88	2285.76	1670.70	1928.37	8295.27	1598.13	2433.42	2856.03	1787.22	1712.37	10387.17
303	689.85	1465.26	1574.70	699.33	328.26	4757.40	1025.07	1436.49	1664.67	1034.13	984.03	6144.39
304	548.04	996.90	1322.85	902.37	949.62	4719.78	1273.98	1610.10	1874.94	1081.32	834.69	6675.03
310	668.16	1191.39	1223.61	591.69	346.14	4020.99	1561.65	2060.58	1919.70	1130.10	1231.50	7903.53
311	1086.21	1909.98	2194.35	1217.46	882.12	7290.12	497.55	1392.12	1871.58	1085.82	739.86	5586.93
312	578.70	1203.18	1678.74	1140.18	1117.23	5718.03	1000.29	1702.38	2515.29	1856.79	2139.42	9214.17

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
313	1322.49	2749.92	3421.65	1847.28	1144.05	10485.39	894.63	1406.43	2365.95	1812.39	1953.15	8432.55
314	327.21	680.37	846.60	457.05	283.05	2594.28	298.02	1614.90	2760.00	2114.67	2278.89	9066.48
320	793.53	1402.11	1124.79	392.91	146.37	3859.71	456.09	795.78	926.13	523.95	388.68	3090.63
321	503.64	951.00	1010.61	516.90	334.65	3316.80	588.72	1404.75	1692.87	1116.09	1217.43	6019.86
322	640.77	956.40	868.02	416.64	277.77	3159.60	766.56	1052.40	1068.36	618.33	569.46	4075.11
323	628.71	1302.96	1439.64	733.50	451.02	4555.83	752.61	1077.15	1087.14	656.52	692.31	4265.73
324	1953.48	3188.31	2955.54	1315.83	698.40	10111.56	3389.49	6906.15	8908.92	4851.15	2957.97	27013.68
330	601.86	919.35	1208.43	876.72	1132.59	4738.95	450.42	879.99	1208.07	957.93	1595.19	5091.60
331	954.45	1297.77	1647.96	1215.36	1750.98	6866.52	963.15	1722.18	2007.33	1454.34	2301.78	8448.78
332	1115.43	1705.53	2150.10	1463.04	1648.95	8083.05	501.03	1769.85	2549.10	1902.96	2391.93	9114.87
340	543.45	925.50	961.77	507.24	359.01	3296.97	943.74	971.16	1360.86	953.10	990.18	5219.04
341	833.31	1672.35	1809.36	884.70	508.02	5707.74	756.33	1724.67	1782.60	981.51	780.60	6025.71
342	464.52	564.51	667.17	453.78	548.31	2698.29	403.35	477.42	445.29	275.49	353.07	1954.62
343	1224.09	1538.55	1504.83	786.12	561.51	5615.10	1322.10	1193.67	1179.69	744.21	914.19	5353.86
344	1178.25	2005.71	1932.87	933.33	569.25	6619.41	1349.55	1642.38	1812.90	1176.63	1359.21	7340.67
OUTER LONDON SECTORS 4,5,6,7 AND 8												
Sector 4												
400	1210.62	2966.10	4872.87	3389.82	2723.97	15163.38	306.90	1578.93	3898.92	3021.66	2150.10	10956.51
401	949.20	2074.29	5308.77	4781.40	4464.99	17578.65	1316.82	2889.81	4416.00	3101.76	2871.12	14595.51
402	647.22	1359.99	2228.43	1794.21	2154.72	8184.57	398.97	1332.72	2097.30	1679.91	2307.78	7816.68
403	658.53	1336.74	2860.20	2476.89	2506.38	9838.74	499.35	1566.93	2452.71	1864.23	2163.90	8547.12
410	738.93	1500.30	2097.42	1507.77	1612.26	7456.68	911.64	1390.65	1563.21	1061.07	1356.96	6283.53
411	913.02	2194.41	4052.46	3619.98	5221.74	16001.61	1730.85	2787.15	3135.90	2065.41	2393.49	12112.80
412	261.00	681.06	1280.58	978.78	880.92	4082.34	81.57	163.02	859.47	738.42	298.23	2140.71
413	701.34	1357.53	2907.33	2737.62	3608.67	11312.49	680.76	1419.15	2523.06	1986.18	2060.40	8669.55
414	696.72	1179.09	2336.70	2336.70	4169.58	10718.79	1473.45	1360.62	2767.71	2580.78	3102.81	11285.37
415	636.09	1251.60	1846.65	1408.92	1689.36	6832.62	740.49	1276.98	1622.13	1114.50	1226.58	5980.68
416	1166.70	2034.24	3096.24	2812.05	5848.44	14957.67	3040.59	4181.49	4970.16	3685.50	5795.49	21673.23
417	426.33	800.28	1032.12	714.27	759.15	3732.15	56.16	306.30	558.75	469.20	611.07	2001.48

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
418	89.73	130.20	195.84	187.08	491.22	1094.07	2.79	80.58	341.61	409.47	496.59	1331.04
420	925.41	1790.52	1604.37	733.74	421.65	5475.69	647.97	2163.75	3316.56	2373.81	2379.63	10881.72
421	804.96	1770.90	2503.38	1634.04	1344.27	8057.55	300.54	1604.88	2209.05	1236.84	761.43	6112.74
422	407.16	791.04	1128.39	791.04	763.89	3881.52	145.38	498.36	658.89	441.69	449.52	2193.84
423	561.75	1102.65	1685.19	1407.78	2177.55	6934.92	295.98	1068.54	1660.71	1256.13	1464.54	5745.90
424	534.87	1051.29	1555.38	1254.15	1746.00	6141.69	248.25	672.96	970.41	732.39	935.07	3559.08
425	686.76	1269.45	1886.85	1435.92	1671.78	6950.76	1186.35	1017.78	1174.59	928.89	1791.81	6099.42
426	267.30	469.56	674.28	486.45	508.14	2405.73	540.00	858.87	1153.92	727.86	575.85	3856.50
427	205.20	460.65	611.40	412.50	399.93	2089.68	227.04	595.35	938.64	686.85	694.80	3142.68
428	367.62	965.25	837.72	257.58	70.02	2498.19	205.53	1054.29	1482.84	877.29	601.05	4221.00
431	1407.99	3329.13	4131.84	2447.52	1829.07	13145.55	2666.58	4049.25	3988.89	2331.45	2267.64	15303.81
432	124.05	277.71	529.80	460.86	577.05	1969.47	82.08	300.27	395.31	254.76	233.28	1265.70
440	70.44	160.20	305.70	265.92	332.94	1135.20	54.18	198.18	260.88	168.12	153.90	835.26
441	350.58	797.28	1521.06	1323.15	1656.78	5648.85	246.33	900.72	1185.84	764.16	699.75	3796.80
Sector 5												
500	947.22	2172.96	3412.65	2883.36	4499.16	13915.35	784.26	1456.86	1971.54	1504.83	2123.13	7840.62
501	957.03	1846.89	3341.22	3341.22	7320.45	16806.81	981.57	1461.06	2739.93	2730.21	5340.24	13253.01
502	2059.53	4426.98	5543.37	3657.09	3580.08	19267.05	2520.03	6881.31	10747.23	8278.41	9902.79	38329.77
503	948.81	2274.72	3588.42	2663.94	2724.75	12200.64	526.17	1205.07	1709.10	1259.46	1493.94	6193.74
504	1665.30	3920.40	5204.07	3434.70	3105.12	17329.59	1701.33	3178.92	3989.01	2606.79	2512.59	13988.64
510	1107.75	2468.16	4742.01	4431.03	6685.41	19434.36	1247.22	2802.42	4474.50	3457.92	3956.10	15938.16
511	1954.02	4130.73	6307.38	5169.60	7173.09	24734.82	2527.14	5240.64	6831.90	4911.21	6098.97	25609.86
520	1300.65	2560.32	3381.78	2601.36	3847.26	13691.37	1847.79	3007.29	4037.13	3177.24	4990.50	17059.95
521	975.78	2019.30	3306.75	2859.51	4390.92	13552.26	1048.17	1931.64	3071.97	2530.71	3489.99	12072.48
522	362.97	931.11	1472.94	1146.78	1346.67	5260.47	456.72	903.27	1503.36	1134.33	1121.28	5118.96
530	657.30	1367.22	2129.67	1814.16	2795.70	8764.05	1029.39	1633.59	1971.54	1505.82	2645.25	8785.59
531	996.93	2544.21	3323.07	2014.62	1516.14	10394.97	455.64	1360.26	2192.31	1643.46	1739.31	7390.98
532	736.47	1394.64	1982.28	1559.19	2146.83	7819.41	850.50	1881.69	2527.41	1716.81	1713.24	8689.65
533	816.63	1666.83	2572.98	2226.18	3904.23	11186.85	384.81	1133.40	1696.02	1457.34	2883.54	7555.11
540	776.94	1494.90	2203.02	1898.13	3452.04	9825.03	792.24	1162.92	1661.55	1449.45	2983.26	8049.42

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
552	1196.49	2414.70	4872.96	4872.96	8375.37	21732.48	1437.72	2988.54	5054.94	4252.29	5778.12	19511.61
560	247.65	508.62	1064.07	1224.69	3647.28	6692.31	772.11	384.75	540.18	604.68	1809.24	4110.96
561	1097.97	2077.17	3368.04	3026.76	5252.34	14822.28	1373.94	2438.04	3480.09	2853.54	4722.03	14867.64
562	829.80	1628.82	3042.54	3088.65	6776.58	15366.39	450.15	1301.46	2547.69	2489.31	4696.38	11484.99
570	771.60	1514.67	2829.21	2872.11	6301.44	14289.03	452.25	1307.31	2559.09	2500.41	4717.32	11536.38
581	208.08	408.48	762.99	774.54	1699.38	3853.47	89.04	257.61	504.24	492.66	929.46	2273.01
Sector 6												
600	427.59	627.12	1204.38	1325.55	3541.92	7126.56	406.47	608.52	1089.39	1039.32	2039.16	5182.86
601	486.18	767.61	1324.14	1266.57	2545.95	6390.45	193.80	908.76	1711.59	1625.52	3108.96	7548.63
602	455.70	797.49	1300.11	1246.50	2901.81	6701.61	91.59	619.86	1388.07	1401.24	2485.74	5986.50
603	409.77	825.06	1423.08	1223.73	1655.64	5537.28	294.06	632.04	783.00	596.97	1038.21	3344.28
604	796.08	1489.32	2567.85	2490.81	5495.19	12839.25	765.00	1498.92	2322.93	2022.72	3791.10	10400.67
610	227.49	635.16	1429.11	1124.43	879.78	4295.97	8.43	305.61	1388.07	1624.11	1695.57	5021.79
611	634.56	1503.39	2567.52	2157.51	2899.44	9762.42	816.72	1718.58	3131.91	2715.99	3759.75	12142.95
612	639.30	1620.09	2592.15	1926.60	1970.43	8748.57	598.53	1568.04	2099.46	1444.11	1542.18	7252.32
613	801.96	1936.44	2865.54	2063.58	2112.48	9780.00	1583.49	2654.76	4015.26	3133.89	4032.48	15419.88
614	537.36	1167.06	2015.10	1805.19	2888.34	8413.05	1811.13	3358.83	3943.05	2780.49	3896.97	15790.47
615	247.77	528.60	977.88	776.37	773.07	3303.69	80.19	753.87	1744.62	1551.24	1739.25	5869.17
616	381.45	508.59	1059.60	1186.74	2918.43	6054.81	459.00	901.44	2579.55	2568.33	2836.68	9345.00
620	946.02	2406.96	3700.26	2574.63	2347.08	11974.95	507.21	1553.22	3295.71	2707.41	2634.42	10697.97
621	522.45	1453.32	2754.63	2270.22	2488.65	9489.27	1650.00	2808.60	4987.80	4452.63	6977.37	20876.40
622	524.10	1355.70	2103.42	1516.41	1488.45	6988.08	843.84	1692.42	2021.55	1456.38	2155.77	8169.96
623	778.38	1811.22	4355.94	3936.81	4056.57	14938.92	1275.78	2489.22	4601.58	3859.80	4671.42	16897.80
624	336.78	757.83	1420.92	1226.19	1520.91	5262.63	481.17	999.18	1488.93	1144.14	1457.34	5570.76
625	435.87	769.11	1313.91	1256.22	2634.24	6409.35	270.75	786.60	1317.93	1193.76	2320.59	5889.63
626	826.23	1677.12	3008.91	2700.63	4106.43	12319.32	1051.98	2018.43	3618.33	2789.37	2746.08	12224.19
630	845.79	1825.68	2805.54	2186.67	2671.47	10335.15	1187.91	2505.42	4153.38	3153.09	3316.02	14315.82
631	845.94	1873.89	3030.33	2355.72	2612.73	10718.61	1402.02	2748.84	3951.36	2870.73	3216.27	14189.22
632	419.01	922.62	1136.19	757.47	793.74	4029.03	231.51	941.49	1729.92	1248.87	1036.38	5188.17
633	749.64	2088.27	2793.30	1775.94	1517.13	8924.28	535.35	1285.38	1898.16	1423.68	1715.79	6858.36

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
634	332.37	839.67	1403.79	988.35	804.69	4368.87	98.91	703.08	969.90	461.13	199.38	2432.40
635	684.72	1896.24	3350.01	2465.10	2138.55	10534.62	912.72	1965.54	3090.48	2243.70	2229.96	10442.40
636	958.20	1714.08	2555.19	2118.69	3289.77	10635.93	826.71	905.85	1554.96	1397.34	2238.93	6923.79
640	616.86	1452.12	3354.12	3238.47	4176.57	12838.14	813.06	2303.82	3716.97	2720.10	2711.88	12265.83
641	1037.04	2777.79	5277.84	4425.99	5000.04	18518.70	1268.31	3138.33	5183.28	4199.10	5479.65	19268.67
652	829.47	1863.15	3228.57	2807.46	4032.51	12761.16	629.13	1004.88	1539.78	1245.99	1765.50	6185.28
Sector 7												
700	1127.88	1936.50	2617.50	2032.29	2936.73	10650.90	1249.11	1768.44	2322.12	1753.53	2448.18	9541.38
701	1347.99	2853.06	3690.66	2525.88	2682.93	13100.52	809.01	2472.27	3405.75	2562.78	3536.01	12785.82
702	932.64	1746.84	2079.93	1339.74	1310.16	7409.31	344.10	893.19	1316.16	1033.68	1456.50	5043.63
703	775.11	1550.28	1782.81	1043.46	828.81	5980.47	1059.90	2037.42	2470.71	1682.19	1964.70	9214.92
704	550.53	1046.43	1223.88	814.41	909.96	4545.21	295.74	1443.30	2326.98	1730.91	1845.57	7642.50
705	972.54	2105.16	3114.66	2511.42	3631.74	12335.52	898.35	2424.15	4203.66	3472.95	4454.40	15453.51
710	930.21	2332.14	3917.46	2961.03	2947.92	13088.76	747.45	1809.78	2262.57	1591.59	2014.77	8426.16
711	908.16	1601.19	2616.93	2365.98	4457.13	11949.39	634.05	1204.02	1755.06	1440.06	2353.56	7386.75
712	864.18	2100.93	3769.77	3307.86	4842.57	14885.31	500.13	2625.18	4561.11	3640.83	4335.66	15662.91
713	980.91	1829.25	2929.47	2624.58	4891.29	13255.50	1203.66	1790.94	2416.86	1947.78	3340.11	10699.35
720	840.75	1329.93	1704.42	1352.85	2415.27	7643.22	820.02	1428.42	1898.22	1498.77	2510.01	8155.44
721	988.86	2327.67	4107.63	3438.24	4351.02	15213.42	1818.54	3319.62	4550.91	3295.20	3841.29	16825.56
722	802.20	1707.54	3151.44	2670.15	3162.93	11494.26	928.20	1586.16	2805.84	2451.87	3488.04	11260.11
723	1241.37	2715.51	4693.95	4170.27	6594.84	19415.94	955.44	2112.18	3762.27	3266.91	4646.76	14743.56
724	653.85	1477.26	2332.89	1751.70	1848.57	8064.27	407.13	1303.56	2010.18	1471.86	1562.22	6754.95
725	1143.42	2140.23	3268.98	2858.52	5262.60	14673.75	1729.59	2974.71	3744.21	2719.59	3672.87	14840.97
730	2089.11	5234.28	7323.42	4660.38	3673.20	22980.39	2929.89	4305.33	4914.75	3327.60	4090.44	19568.01
731	878.34	1954.98	3669.15	3258.33	4419.99	14180.79	581.52	1566.42	2729.10	2264.79	2925.51	10067.34
732	43.38	76.74	141.21	125.10	169.02	555.45	162.21	68.46	73.71	56.13	70.77	431.28
733	932.49	2437.98	3606.36	2359.32	1887.45	11223.60	621.09	1648.59	2009.64	1243.56	1106.40	6629.28
734	1645.17	3508.41	5391.42	4182.33	5074.29	19801.62	2355.99	4434.30	5986.29	4196.22	4539.69	21512.49
740	408.66	772.62	1340.94	1277.07	2586.09	6385.38	254.70	796.47	1335.39	1078.95	1372.17	4837.68
743	60.51	137.19	247.65	237.15	481.29	1163.79	51.18	250.80	429.69	348.18	443.16	1523.01

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
746	394.11	977.97	1571.58	1070.43	856.35	4870.44	399.18	783.39	922.14	577.14	544.59	3226.44
750	573.51	1327.32	2097.45	1728.78	2449.80	8176.86	280.14	1213.11	2419.89	2174.01	3041.52	9128.67
757	690.06	1596.90	2523.51	2079.93	2947.38	9837.78	200.37	867.63	1730.79	1554.90	2175.33	6529.02
758	206.34	477.60	754.68	622.02	881.46	2942.10	65.43	283.38	565.26	507.84	710.46	2132.37
774	895.92	2073.45	3276.51	2700.54	3826.83	12773.25	311.64	1349.52	2692.08	2418.48	3383.55	10155.27
775	953.25	2206.08	3486.12	2873.34	4071.69	13590.48	553.53	2397.06	4781.70	4295.76	6010.05	18038.10
Sector 8												
800	492.33	1332.54	2146.53	1457.28	1135.59	6564.27	392.10	1189.14	1814.88	1197.21	963.57	5556.90
801	1433.46	3959.13	7030.86	5347.08	4960.26	22730.79	2376.36	4511.97	6505.71	4800.09	5534.73	23728.86
802	1475.88	3518.04	5302.80	3655.32	3209.13	17161.17	1170.12	2677.14	3933.06	2793.30	2839.65	13413.27
803	382.38	892.23	1669.17	1432.44	1705.56	6081.78	344.94	574.08	1309.95	1135.41	1108.41	4472.79
810	693.00	1638.66	2129.55	1414.89	1349.91	7226.01	1169.01	2853.78	3875.31	2457.27	2027.88	12383.25
811	608.22	1216.44	1188.63	592.32	377.67	3983.28	125.22	917.64	1263.69	588.36	244.17	3139.08
812	620.25	1628.19	2269.62	1430.85	1085.49	7034.40	481.35	1314.18	1813.47	1259.04	1322.13	6190.17
813	874.68	2364.54	3210.39	1893.54	1259.13	9602.28	1774.80	3467.76	4498.17	2638.47	1855.89	14235.09
820	550.08	1609.71	2709.81	1836.21	1367.07	8072.88	626.64	1751.64	3349.47	2744.88	3001.08	11473.71
821	522.72	1182.54	2125.20	1919.52	2819.28	8569.26	1090.17	1139.49	1728.21	1464.51	2260.08	7682.46
822	740.82	1662.30	2701.20	2005.59	1906.20	9016.11	341.85	842.19	1994.91	1915.83	2480.07	7574.85
823	841.11	2218.71	3718.14	2779.47	2633.19	12190.62	1309.86	1368.24	2201.64	1814.76	2306.49	9000.99
824	619.86	1568.46	2826.99	2207.13	2160.15	9382.59	593.97	983.76	1872.42	1597.38	1893.36	6940.89
830	353.94	655.14	884.82	707.85	1170.96	3772.71	533.55	618.00	651.12	428.01	525.12	2755.80
831	705.66	1467.24	1872.48	1334.49	1613.97	6993.84	934.47	1418.88	1369.14	844.98	1020.30	5587.77
832	482.76	1025.88	1484.55	1206.96	1846.65	6046.80	119.25	588.18	943.14	692.19	714.87	3057.63
833	1124.37	2443.41	3102.87	2075.79	2064.99	10811.43	1331.55	2568.48	3103.92	2041.41	2147.22	11192.58
834	265.62	712.98	931.05	534.03	352.29	2795.97	357.93	1227.06	1577.70	872.07	552.54	4587.30
835	821.82	1933.23	2418.45	1479.27	1174.02	7826.79	175.86	1410.90	2668.44	1915.98	1538.91	7710.09
840	149.40	191.58	288.24	290.01	836.64	1755.87	98.34	211.74	265.20	205.11	370.53	1150.92
841	247.02	449.73	630.24	560.58	1276.32	3163.89	284.76	311.88	496.38	452.25	851.34	2396.61
842	906.66	1802.70	2509.08	2034.66	3310.29	10563.39	1396.29	2092.62	2308.71	1623.84	2463.54	9885.00
843	21.39	53.73	137.76	161.19	314.82	688.89	236.79	155.76	150.18	104.10	157.68	804.51

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
850	260.91	480.27	574.98	413.31	577.26	2306.73	153.27	453.66	454.65	219.81	131.73	1413.12
CORDON CROSSING												
2411	207.99	444.96	692.43	547.62	742.44	2635.44	80.37	195.66	308.19	249.15	347.88	1181.25
2412	98.94	211.71	329.46	260.55	353.25	1253.91	54.51	132.87	209.25	169.17	236.19	801.99
2413	33.30	71.16	110.76	87.60	118.74	421.56	1.59	4.05	6.36	5.16	7.17	24.33
2424	188.37	403.05	627.21	496.02	672.51	2387.16	68.52	166.98	262.98	212.61	296.88	1007.97
2435	739.59	1582.14	2462.13	1947.24	2640.00	9371.10	445.38	1085.10	1708.92	1381.50	1928.94	6549.84
2446	148.50	317.64	494.34	390.96	530.07	1881.51	46.80	113.97	179.40	145.05	202.47	687.69
2457	170.37	364.50	567.27	448.65	608.22	2159.01	65.46	159.36	251.04	202.95	283.41	962.22
2468	312.81	669.12	1041.30	823.53	1116.54	3963.30	159.93	389.73	613.68	496.11	692.70	2352.15
2479	404.79	865.86	1347.51	1065.72	1444.89	5128.77	227.55	554.37	873.06	705.78	985.47	3346.23
2480	111.09	237.63	369.84	292.50	396.57	1407.63	45.48	110.91	174.60	141.18	197.16	669.33
2501	128.97	275.88	429.30	339.51	460.32	1633.98	28.47	69.39	109.29	88.38	123.36	418.89
2512	309.03	661.08	1028.79	813.63	1103.10	3915.63	168.30	409.89	645.57	521.88	728.67	2474.31
2523	469.95	1005.36	1564.56	1237.38	1677.57	5954.82	311.82	759.63	1196.31	967.08	1350.33	4585.17
2534	469.59	1004.64	1563.42	1236.45	1676.37	5950.47	290.70	708.27	1115.37	901.71	1259.01	4275.06
2545	140.85	301.29	468.90	370.83	502.77	1784.64	66.69	162.39	255.78	206.76	288.72	980.34
2556	44.85	95.97	149.31	118.11	160.11	568.35	5.49	13.38	21.12	17.07	23.82	80.88
2557	173.82	371.88	578.70	457.71	620.52	2202.63	123.90	301.77	475.20	384.18	536.43	1821.48
2558	38.82	83.01	129.18	102.18	138.54	491.73	59.19	144.18	227.10	183.57	256.32	870.36
2561	144.09	308.19	479.61	379.32	514.29	1825.50	104.43	254.43	400.74	323.97	452.31	1535.88
2562	69.09	147.87	230.13	181.98	246.75	875.82	71.28	173.58	273.33	220.95	308.49	1047.63
2571	142.05	303.90	472.95	374.04	507.12	1800.06	56.04	136.50	215.01	173.79	242.64	823.98
2572	103.23	220.89	343.71	271.86	368.55	1308.24	12.30	29.82	46.95	37.98	53.01	180.06
2583	698.43	1494.12	2325.18	1838.91	2493.12	8849.76	300.48	732.06	1152.90	932.01	1301.37	4418.82
2594	239.64	512.61	797.73	630.90	855.36	3036.24	145.95	355.50	559.86	452.61	631.92	2145.84
2605	118.62	253.77	394.92	312.33	423.45	1503.09	58.89	143.55	226.02	182.73	255.18	866.37
2606	113.31	242.34	377.16	298.26	404.37	1435.44	49.95	121.65	191.61	154.92	216.27	734.40
2607	149.85	320.52	498.81	394.50	534.84	1898.52	76.89	187.29	294.93	238.41	332.91	1130.43

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
2608	54.78	117.18	182.40	144.24	195.57	694.17	5.43	13.11	20.67	16.71	23.34	79.26
2609	160.71	343.92	535.17	423.27	573.84	2036.91	89.61	218.25	343.77	277.89	388.05	1317.57
2610	580.38	1241.61	1932.18	1528.14	2071.77	7354.08	275.76	671.79	1057.98	855.24	1194.18	4054.95
2621	130.08	278.31	433.11	342.54	464.40	1648.44	71.07	173.19	272.82	220.50	307.89	1045.47
2622	43.89	93.81	146.01	115.47	156.54	555.72	6.93	16.95	26.73	21.60	30.15	102.36
2623	51.81	110.76	172.41	136.35	184.86	656.19	34.20	83.34	131.22	106.11	148.14	503.01
2624	159.72	341.67	531.75	420.54	570.15	2023.83	92.64	225.63	355.38	287.31	401.16	1362.12
2625	72.66	155.40	241.86	191.28	259.32	920.52	21.30	51.90	81.63	66.00	92.16	312.99
2636	461.97	988.23	1537.89	1216.29	1648.98	5853.36	257.43	627.06	987.51	798.33	1114.68	3785.01
2641	29.49	63.09	98.13	77.61	105.21	373.53	30.93	75.39	118.71	95.97	134.01	455.01
2642	38.28	81.93	127.50	100.86	136.74	485.31	28.32	69.12	108.87	88.02	122.91	417.24
2643	74.49	159.33	247.98	196.14	265.92	943.86	42.75	104.25	164.13	132.69	185.28	629.10
2644	358.32	766.41	1192.71	943.29	1278.90	4539.63	199.29	485.52	764.64	618.15	863.16	2930.76
2651	1239.33	2651.16	4125.81	3262.98	4423.86	15703.14	511.29	1245.72	1961.85	1586.01	2214.51	7519.38
2662	76.74	164.10	255.36	201.96	273.81	971.97	34.11	83.19	131.01	105.93	147.90	502.14
2663	102.36	218.94	340.68	269.43	365.28	1296.69	38.16	93.00	146.46	118.41	165.33	561.36
2664	172.83	369.72	575.37	455.04	616.92	2189.88	48.54	118.20	186.15	150.48	210.15	713.52
2675	289.77	619.92	964.74	762.99	1034.43	3671.85	151.62	369.33	581.67	470.22	656.55	2229.39
2676	172.56	369.24	574.59	454.44	616.11	2186.94	22.89	55.80	87.81	71.01	99.15	336.66
2687	557.31	1192.29	1855.47	1467.45	1989.54	7062.06	321.72	783.69	1234.23	997.77	1393.23	4730.64
2698	147.12	314.73	489.78	387.36	525.21	1864.20	18.09	44.04	69.36	56.07	78.30	265.86
2699	92.49	197.85	307.92	243.51	330.15	1171.92	38.52	93.99	148.02	119.64	167.04	567.21
2700	120.39	257.49	400.71	316.92	429.69	1525.20	53.07	129.48	203.91	164.85	230.16	781.47
2701	232.89	498.18	775.29	613.17	831.30	2950.83	81.09	197.61	311.16	251.55	351.30	1192.71
2702	118.65	253.86	395.04	312.42	423.57	1503.54	8.34	20.34	32.04	25.89	36.15	122.76
2713	240.06	513.57	799.23	632.10	856.95	3041.91	75.36	183.57	289.08	233.73	326.31	1108.05
2714	60.69	129.84	202.05	159.78	216.63	768.99	3.51	8.55	13.53	10.92	15.24	51.75
2715	79.56	170.22	264.87	209.49	283.98	1008.12	4.77	11.67	18.30	14.76	20.64	70.14
2726	266.22	569.49	886.26	700.92	950.28	3373.17	176.10	429.00	675.57	546.15	762.54	2589.36
2727	113.94	243.81	379.44	300.09	406.83	1444.11	69.75	169.92	267.60	216.33	302.04	1025.64

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
2728	39.51	84.54	131.55	104.04	141.06	500.70	6.30	15.33	24.21	19.56	27.30	92.70
2739	892.05	1908.30	2969.79	2348.73	3184.35	11303.22	603.66	1470.57	2315.97	1872.21	2614.17	8876.58
2740	143.97	307.95	479.25	379.02	513.87	1824.06	48.84	118.95	187.35	151.47	211.47	718.08
2741	97.65	208.95	325.17	257.16	348.63	1237.56	41.22	100.41	158.10	127.83	178.44	606.00
2742	142.23	304.32	473.55	374.52	507.78	1802.40	38.37	93.42	147.09	118.92	166.08	563.88
2753	573.27	1226.37	1908.48	1509.36	2046.33	7263.81	314.34	765.81	1206.06	975.00	1361.40	4622.61
2754	175.38	375.18	583.80	461.73	626.01	2222.10	81.33	198.09	311.94	252.18	352.14	1195.68
2755	93.33	199.59	310.65	245.67	333.06	1182.30	10.14	24.57	38.76	31.32	43.77	148.56
2766	137.91	294.90	458.94	362.97	492.12	1746.84	72.33	176.16	277.44	224.31	313.17	1063.41
2767	207.60	444.09	691.14	546.60	741.06	2630.49	131.28	319.80	503.67	407.16	568.50	1930.41
2768	84.27	180.27	280.53	221.85	300.78	1067.70	55.59	135.36	213.12	172.29	240.57	816.93
2779	154.50	330.51	514.35	406.80	551.49	1957.65	6.21	15.09	23.79	19.23	26.88	91.20
2780	110.04	235.38	366.33	289.74	392.82	1394.31	125.07	304.68	479.85	387.90	541.62	1839.12
2781	603.72	1291.53	2009.88	1589.55	2155.08	7649.76	289.68	705.78	1111.44	898.50	1254.54	4259.94
2792	258.21	552.45	859.71	679.92	921.84	3272.13	173.97	423.75	667.35	539.52	753.33	2557.92
2813	204.30	437.10	680.19	537.96	729.33	2588.88	86.97	211.77	333.54	269.61	376.47	1278.36
2814	168.42	360.33	560.70	443.46	601.23	2134.14	130.59	318.06	500.94	404.94	565.41	1919.94
2825	269.40	576.33	896.88	709.32	961.68	3413.61	128.88	313.92	494.34	399.63	558.03	1894.80
2826	90.12	192.81	300.06	237.30	321.75	1142.04	9.36	22.77	35.91	29.01	40.50	137.55
2837	406.17	868.83	1352.10	1069.35	1449.78	5146.23	227.55	554.37	873.09	705.81	985.47	3346.29
2848	233.88	500.34	778.65	615.81	834.90	2963.58	73.68	179.58	282.72	228.57	319.11	1083.66
2849	60.84	130.08	202.47	160.11	217.08	770.58	5.73	14.04	22.14	17.91	25.02	84.84
2850	117.27	250.89	390.45	308.82	418.68	1486.11	12.09	29.43	46.38	37.50	52.38	177.78
2851	433.26	926.94	1442.49	1140.84	1546.71	5490.24	250.20	609.42	959.67	775.80	1083.24	3678.33
2852	134.91	288.54	449.04	355.14	481.47	1709.10	103.80	252.93	398.37	322.02	449.64	1526.76
2853	21.96	46.98	73.14	57.84	78.42	278.34	5.61	13.65	21.48	17.37	24.21	82.32
2854	72.15	154.38	240.24	189.99	257.58	914.34	31.71	77.43	121.83	98.49	137.49	466.95
2865	513.66	1098.87	1710.06	1352.43	1833.60	6508.62	339.09	825.99	1300.80	1051.62	1468.35	4985.85
2866	80.58	172.38	268.26	212.16	287.64	1021.02	42.12	102.57	161.58	130.65	182.43	619.35
2877	43.77	93.60	145.68	115.23	156.21	554.49	6.63	16.05	25.26	20.43	28.53	96.90

District	Trips produced						Trips attracted					
	Income Category					Total	Income Category					Total
	1	2	3	4	5		1	2	3	4	5	
2878	39.15	83.67	130.23	102.99	139.62	495.66	4.23	10.26	16.17	13.08	18.24	61.98
2879	111.84	239.13	372.18	294.33	399.06	1416.54	43.50	106.02	166.92	134.94	188.34	639.72
2880	29.22	62.52	97.29	76.95	104.31	370.29	17.82	43.35	68.28	55.20	77.10	261.75
2881	325.47	696.27	1083.51	856.95	1161.81	4124.01	299.19	728.76	1147.74	927.84	1295.55	4399.08
Total	165631.86	336170.61	496742.64	380636.49	496478.22	1875659.82	165631.74	336170.55	496742.82	380636.43	496478.37	1875659.91