# Cranfield University

Fathy El-Sayed Al-Tony

## The Marginal Social Cost of Road and Rail: Implications for Rail Investment and Pricing

Cranfield School of Management
Centre for Logistics and Transportation

PhD. Thesis

# Cranfield University

Cranfield School of Management
Centre For Logistics and Transportation

PhD. Thesis

Academic Years 1992-1995

Fathy El-Sayed Al-Tony

# The Marginal Social Cost of Road and Rail: Implications for Rail Investment and Pricing

Supervisor: Mr. Ian Black

August 1995

This thesis is submitted in partial fulfilment of the degree of Doctor of Philosophy

*To My Parents*

# Abstract

An important issue for transport policy is whether more investment should be devoted to rail schemes and less to road schemes and vice versa. This raises the problem of comparing the returns from investments in the two modes currently assessed on a different basis - road schemes are appraised on a Cost Benefit Analysis (CBA) basis, whereas rail schemes are assessed on a Financial Analysis (FA).

This study is a step in the direction of identifying the difference between the two techniques (CBA and FA) of appraisal in general and in case of rail investment in particular, and examining the implications of the use of the two different techniques in assessing the investment in road and rail. In addition, the study develops a methodology for assessing rail investment schemes that could be consistent with the cost benefit analysis being used in assessing road investment projects.

The differences between CBA and FA are identified. The current practice of assessing road and rail investment schemes is examined and the weaknesses are outlined. The potential implications of assessing road and rail investment on different criteria are explored. Previous rail investment studies where both CBA and FA were undertaken are reviewed and discussed to explore how the task of CBA were carried out to rail schemes and to show the difference with the current study approach.

The study framework of rail scheme appraisal is identified to include four elements of impacts. These are; financial impacts to the rail operator (producer surplus), rail user benefits (consumer surplus), non-user benefits, and other impacts on other bodies in the society (tax adjustments). Non-user benefits concerned by the study are road congestion time, noise, air pollution, accidents, and vehicle operating costs. Road congestion time, noise and air pollution are identified as externalities, while accidents and vehicle operating costs are dealt with as cases of cost misperception.

The five items of non-user benefits are measured at the margin in a process to identify the Marginal Social Cost (MSC) of travel as a function of the road type alternative. Eight types of road are identified for the study to represent the entire UK road network. The measurement process of non-user benefits incorporates the variation in traffic over time and place. This is carried out by incorporating four traffic distributions in the calculation process. The distributions of traffic reflect traffic variations from hour to another (24 hours) throughout the day, from day to another (7 days) throughout the week, from month to another (12 months) throughout the year and from location to another throughout the UK entire road network.

The implications of the study findings are explored. Three undesirable implications are identified. These are welfare losses to the society, lower share for rail travel, and investment bias towards roads. Three policy options are put as a solution. These are, pricing road and rail services according to the MSC, subsidising public transport, and applying a consistent appraisal method for road and rail investment. The contribution of these options towards achieving a sustainable balance between road and rail as well as their applicability in practice are examined. At the end some improvements and attached areas of further research are suggested.

# Acknowledgement

I would like to express my gratitude and sincere thanks to my supervisor Mr. Ian Black, for his patient guidance, valuable advice and helpful comments.

Also I would like to thank the friendly staff of the Center of Logistics and Transportation. Many thanks go to the co-operative staff of Cranfield University Library for their support.

I would like to take this opportunity to thank both the Overseas Development Administration (ODA) and the British Council for their financial support during the course of my studies. In addition, many thanks go to the Egyptian National Institute of Transportation (ENIT) for giving me the chance and support to finish my studies.

Great thanks go to my wife, Fatima, for her company, support, patience and help during the course of my studies.

Also I would like to thank the members of the School of Management research office for their support.

# Table of Contents

# List of Figures

# List of Tables

# Glossary

| | |
|---|---|
| COBA | Department of Transport's cost benefit analysis computer program for appraisal of trunk road schemes. |
| CBA | Cost benefit analysis |
| FA | Financial analysis |
| DTp | Department of Transport |
| MCTE | Marginal congestion time externality |
| MCTE | Marginal congestion time externality |
| pcu | Personal car unit |
| PCUKT | Personal car unit kilometre travelled |
| NTS | National traffic survey |
| OECD | Organisation for Economic Co-operation and Development |
| LAeq | Equivalent sound level in decibels |
| DOE | Department of the Environment |
| NPV | Net present value |

# Chapter 1

# Introduction

## 1.1 Introduction

Transport is a keystone of civilisation. The spread of production, trade and ideas and the economic ascendancy of mankind all depend upon movement. Personal mobility is one of democracy's most valued freedoms, and a surprisingly high proportion of our income is devoted to our movement and to the movement of the goods that we buy.

The transport sector is one of the largest in any advanced economy. In developing countries, transport has a vital role to play in achieving the targets of the development process. As incomes rise, for both developed and underdeveloping economies, an increasing share of consumers' expenditure is devoted to travel, a large amount of it is spent on private car purchase and operation. In consequence, governments spend large sums on the provision of the road infrastructure. At the same time , they spend large sums on the subsidisation of public transport services to maintain a proper balance between public and private provision of transport services.

In transport as in some other fields, the volume of public expenditure is only a partial guide to the importance of the decisions made by government. Direct public expenditure on road safety, for example, runs at only a few million pounds a year, but the total costs which safety measures impose on transport users and the benefits they bring, may be of the order of a hundred times as much. On a wider level, the nature of the transport system available has important implications for industrial and agriculture growth, urban development, the quality of environment and the enjoyment of leisure. Thus, in terms of both size and complexity the transport sector merits the attention it has attracted from analysts of various disciplines.

United Kingdom traffic forecasts indicate that by the year 2025 an increase in vehicle miles of between 83 and 142% is expected (Department of Transport, 1989). Average travel speeds in central London have altered very little since the turn of the century (Mogridge, 1990). Average peak traffic speeds in central London fell from 20.7 km/h in

1972 to 17.6 km/h in 1990 (Church, 1992). Americans spend about two billion man hours per year stuck in traffic jams and by the year 2000 there will probably be one car for every person aged 20 - 64 (Economist, 1992). The annual rate of growth in vehicle numbers in Germany exceeds the growth rate for world population (Holzapfel, 1992). The UK road construction and widening programme over the next ten years will cost £20 billion and add 5% to total road space. These trends draw everyone's intention to the necessity of finding a solution to the problem of increasing the use of private cars and congestion on the roads. The simple and first solution one can think of is to adapt the right balance between public and private transport, so that public means of transport can perform the relevant rule within the whole transport sector.

## 1.2 Transport Investment Analysis

The importance of investment analysis is obviously critical in transport economics, for the investments are usually long lived and commonly exercise a decisive influence on the way in which communities live and grow. The essence of such analysis is the comparison of a future stream of receipts from a project with the future pattern of costs, so that a decision can be made on which of several projects is financially most attractive or whether indeed society may prefer to reject all the projects in favour of expenditure elsewhere. Whether the investment is undertaken privately by an individual, company, firm or employs public funds, it involves the fundamental issue of choosing allocations for scarce funds.

## 1.3 Investment Appraisal

At the most general level, we may view the objective of any investment as being an increase in the real income of the community. The purpose of investment appraisal is to identify the ways in which and the extent to which alternative projects may contribute to increasing community welfare and to compare alternatives on this basis.

If the price mechanism could be relied upon as a good indicator of social values, both in product and factor markets, and perfect competition prevailed in these markets, we could be sure that the increase of ***profit*** accruing to the entrepreneur as the outcome of an investment was a reliable indicator of the real increase in welfare obtaining. For, in such circumstances, the individual firm would be a price taker. In the short run, any reduction in the real costs of production would accrue to the firm as increased profits. In the long run, other firms would copy cost reducing innovation and by price reductions compete with the original innovator. The benefits would then be predominantly passed on to the consumer with only enough "profit" remaining (the normal profit of classical economic theory), to justify the devotion of investment funds to this purpose. But, even with redistribution of benefits, the profit potential acts not only as a stimulant of investment but also as a proxy for the social welfare improvements which are its justification. Figure 1.1 presents this case.

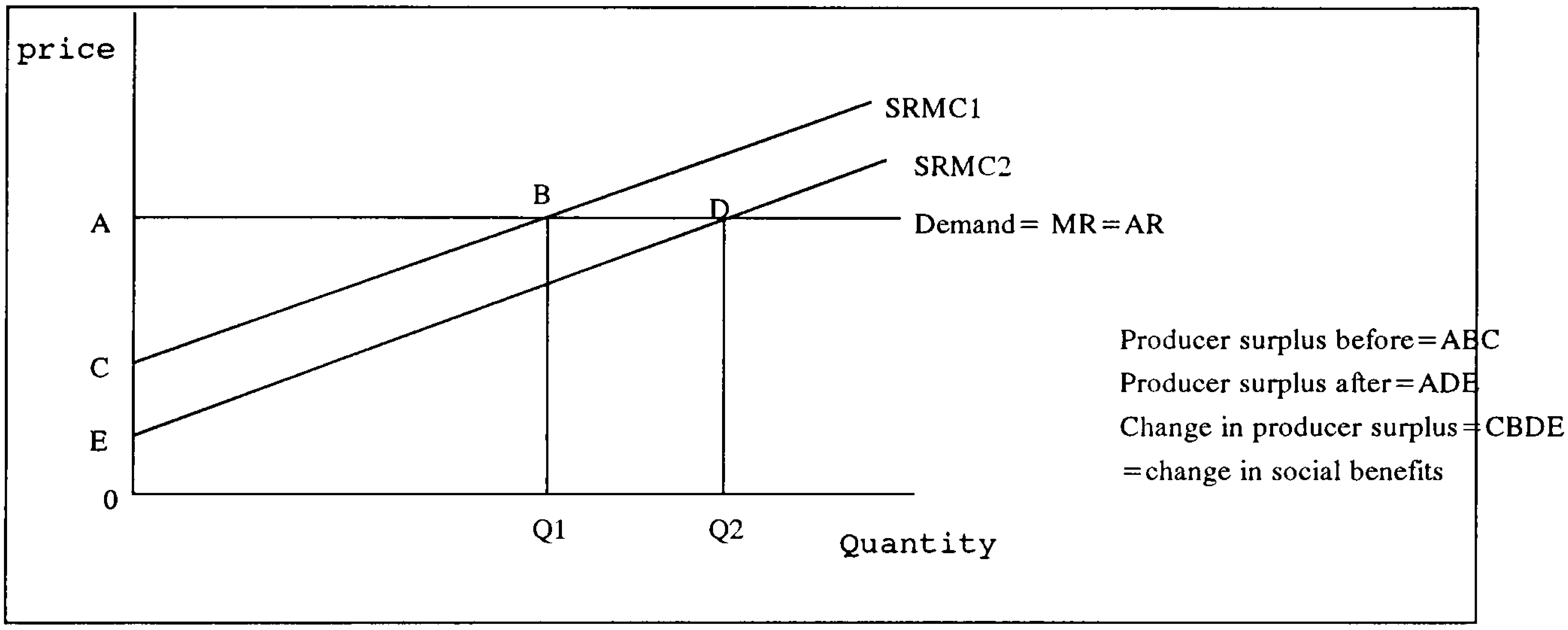



Figure 1.1 Short Run Equilibrium Under Pure Competitions

There are many areas within the transport sector where the preconditions broadly obtain, and where, therefore, a commercial criterion is a perfectly adequate proxy for the total social welfare improvement which is the ultimate community objective.

In other cases, however, the revenue accruing to a particular project will not adequately measure the benefits attributable to that project. Three important cases may be set out, these are:

### *1.3.1 Consumer Surplus*

Under conditions of imperfect competition or monopoly, benefits will accrue even in the short run to consumers, as well as to producers (unless a complete price discrimination is possible), and the consumer surplus needs to be taken into account in assessing the social benefits of the project. Figure 1.2 presents this case. MC1 and MC2 indicate to marginal cost before and after the investment assuming that the investment will shift marginal cost curve uniformly downward. And as it can be seen from figure 1.2, the absence of pure competition creates an area of consumer surplus which has to be considered in measuring investment benefits.

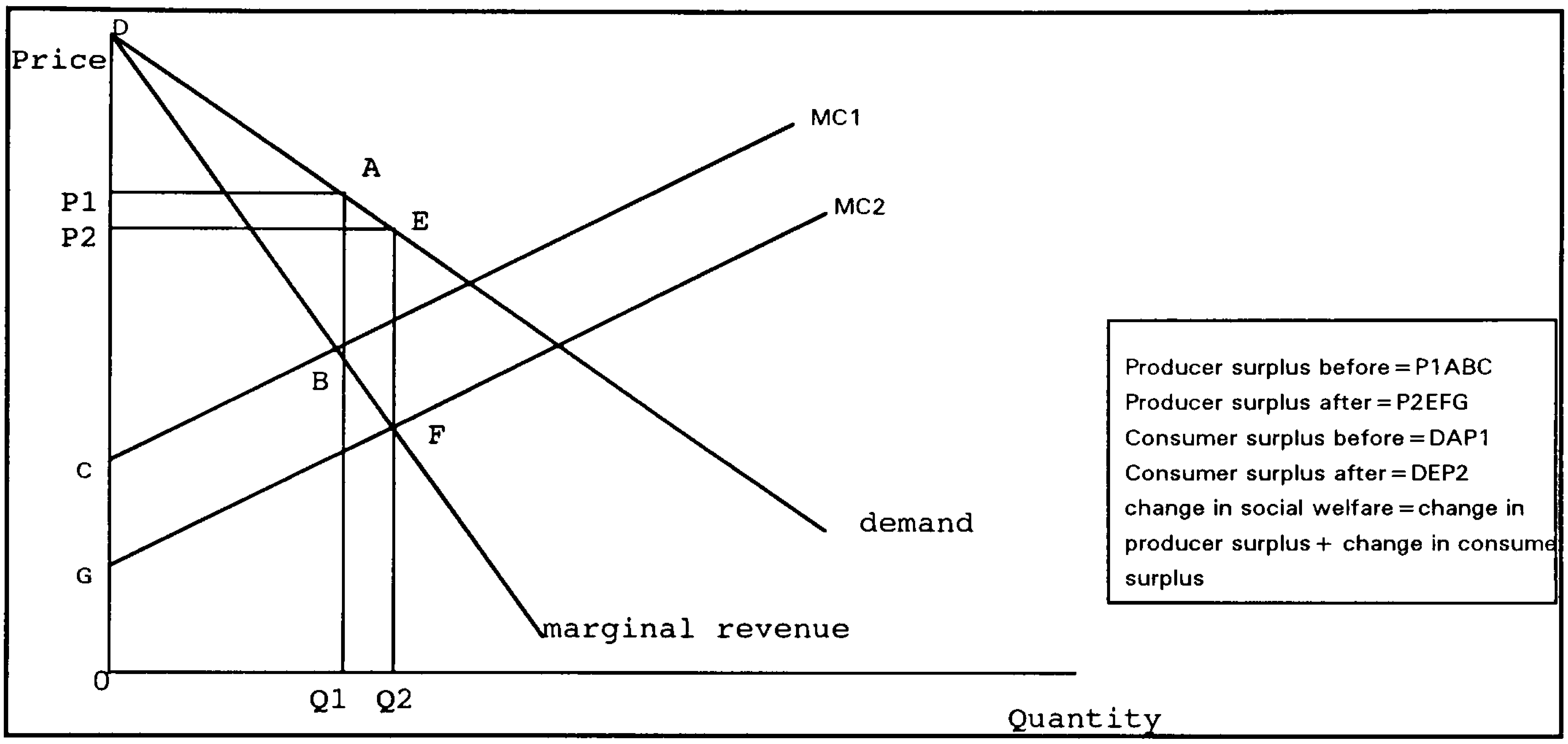



Figure 1.2 The existence of consumer surplus when pure competition is absent

### *1.3.2 Pricing Distortion*

Where no prices are charged for the use of facilities " e.g. roads", or where the prices charged bear scant relationship to the benefits deemed to be gained by users "e.g. public transport in rural areas", the revenue cannot stand as a proxy for the social benefits of the project.

### *1.3.3 Externalities*

#### 1.3.3.1 A definition of Externalities

Although the concept of external effects is widely used in economics, there is no consensus on its exact definition and interpretation. However, it is commonly recognised that externalities are an important source of market failure. Their existence leads to a deviation from the neo-classical world in which the price mechanism takes care of socially optimal resource allocation (Pareto efficiency). The following definition relies on those given by Mishan (1971, p. 2) and Baumol and Oates (1988, p. 17) :

*An external effect exists when an actor's (the receptor's) utility (or profit) function contains a real variable whose actual value depends on the behaviour of another actor (the supplier), who does not take these effects of his behaviour into account in his decision making process*

Figure 1.3 shows the optimal workings of the market mechanism in absence of external effects. Adam Smith's invisible hand secures social welfare maximisation at the market equilibrium $Q_0$ where marginal private cost (MPC) equals marginal private benefits (MPB). The existence of marginal external costs (MEC) (see figure 1.4) drives a wedge between marginal social cost (MSC) and marginal private cost. The market outcome $Q_0$, where private welfare is maximised is not optimal from a social point of view. Social welfare maximisation requires the activity to be restricted to a level of $Q^*$, where the marginal social cost is equal to the marginal benefits and the dead-weight welfare loss C is avoided. This optimum can for instance be accomplished by means of a quantitative restriction ($Q^*$) or tax (T).

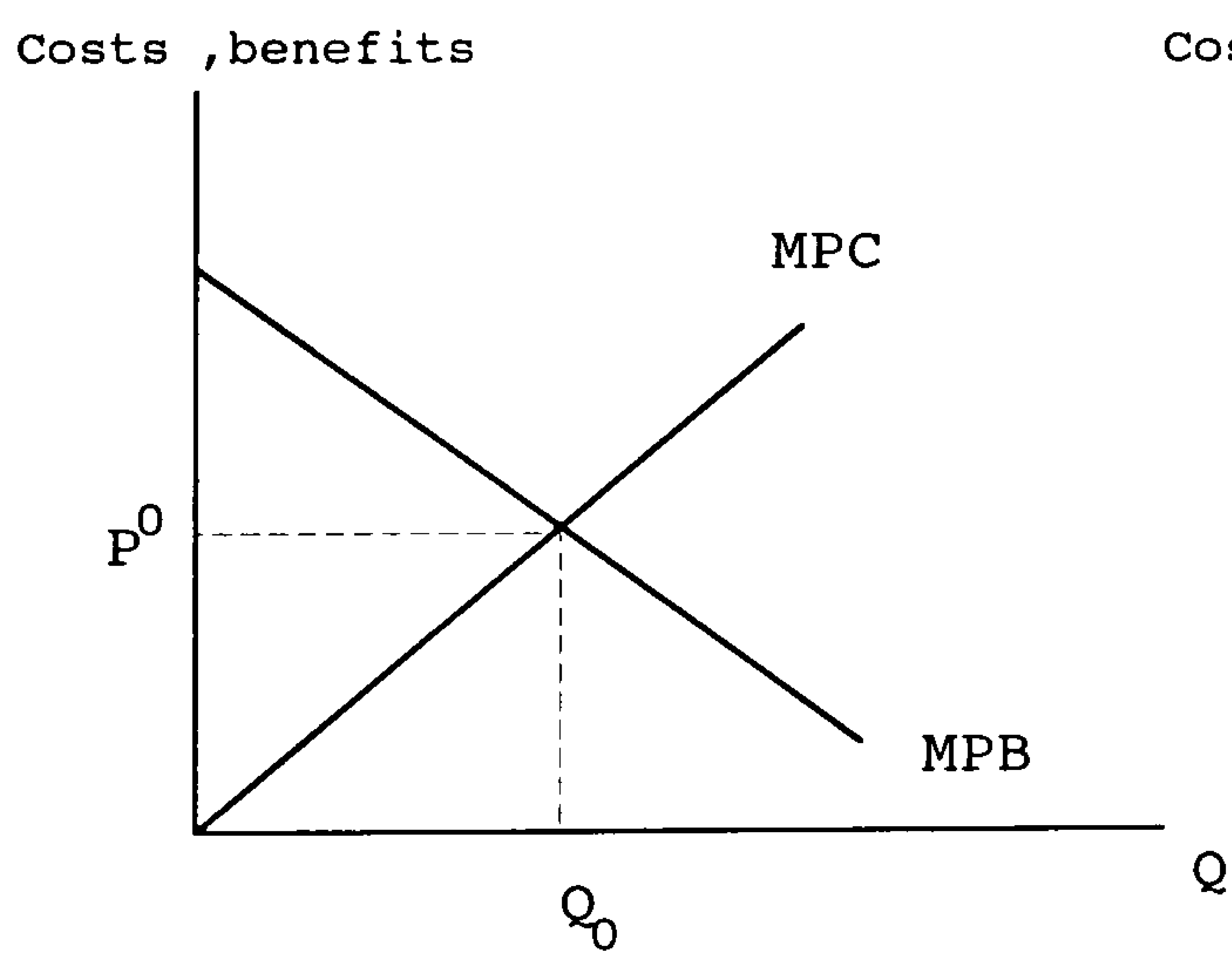



Figure 1.3: Normal case

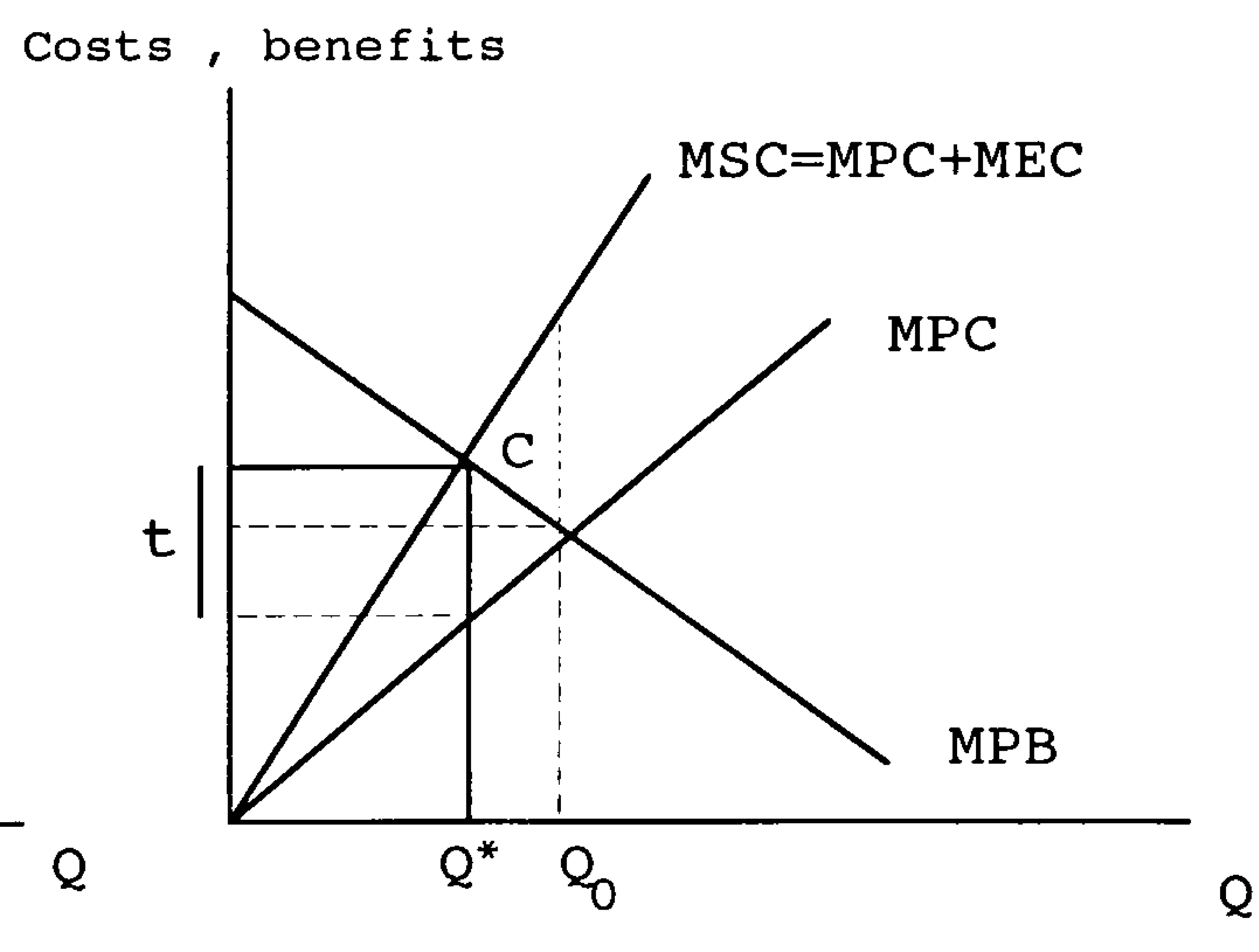



Figure 1.4: External cost

### 1.3.3.2 Transport Externalities

Where the project has external effects, benefits or costs are created in other sectors of the economy, or in other parts of the transport sector, and these need to be taken into account. One such case arises where the project has an impact on the production of goods for which no prices are charged. A clear example of this is the environmental impacts of a transport service. Although there is no market in environmental effects, the benefits of reductions in noise, smoke, etc. are real. A second case in where the project affects the demand for other goods, the production of which takes place under non-constant returns to scale. For example, the principal beneficiaries of the Victoria Line investment were the road users who benefited from reduction in congestion (Harrison and Mackie 1973).

It is quiet clear from our everyday experience, that there are external costs associated with transport that are not directly borne by those generating them. Air travellers impose noise costs on those living below aircraft flight paths, road travellers inflict dirt and vibration on those living adjacent to major trunk routes. Maritime transport frequently pollute bathing beaches with their oil discharges.

These are external costs generated by transport users and inflicted on the non - travelling public. Formally, externalities exist when the activities of one group (either consumers or producers) affect the welfare of another group without any payment or compensation being made. They may be thought of as a relationships other than those between a buyer and a seller, and do not normally fall within the measuring rod of money.

There are also external benefits as well as costs although these are generally thought less important in the transport sector. For example, wide streets may act as fire breaks, in addition to serving as transport arteries, this may be thought of as an external benefit associated with urban motorways.

The following table shows the range and the magnitude of the environmental impacts of transport modes.

Table 1.1 Range and magnitude of the environmental impacts of transport modes

| | Air pollution | Noise | Health and Safety | Water pollution |
|---|---|---|---|---|
| Road | very significant | very significant | very significant | insignificant |
| Rail | significant | significant | significant | - |
| Inland Waterways | - | - | - | significant |
| Sea | insignificant | - | - | - |
| Air | significant | very significant | significant | - |

Source: This table is adapted from Verhoef (1994) and Nijkamp (1994)

#### 1.3.3.3 External Costs of Road Transport

The existence of external costs of road transport is in fact beyond dispute. Road transport is responsible for a wide range of impacts on the users of the roads as well as non-users which in turn impose external costs on both categories. Figure 1.5 presents the range of the external costs of roads and table 1.2 shows the external costs of road transport in Britain for 1991 prices and estimates. These costs are not reflected in the pricing system of using roads, and then are not paid for by road users.

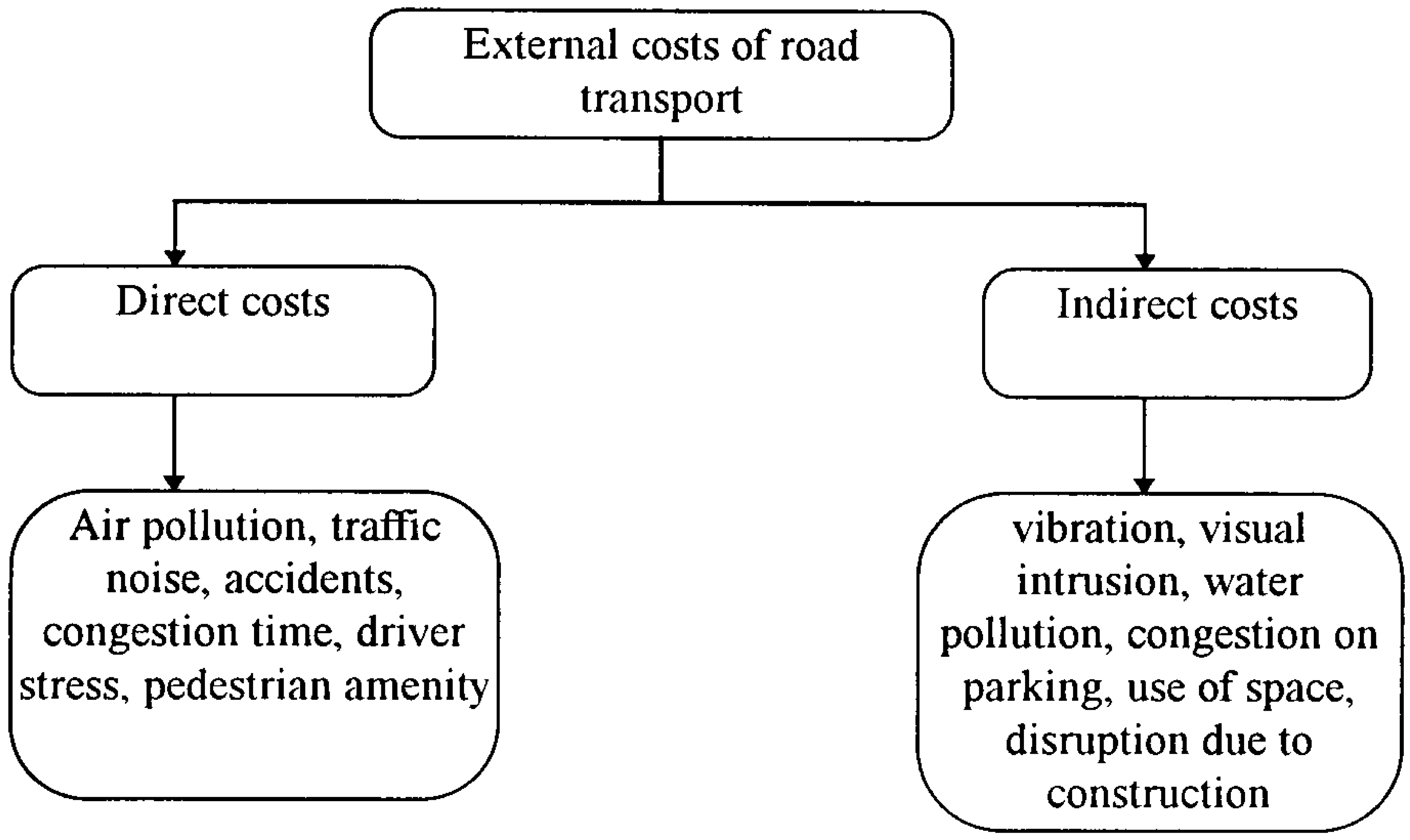



Figure 1.5 External costs of road transport

Table 1.2 The external costs of road transport (1991 estimates and prices)

| | Costs (£ billions) |
|---|---|
| • Congestion | 13.5 |
| • Damage | 1.3 |
| • Pollution | 2.8 |
| • Noise | 0.6 |
| • Accidents | 4.7 to 7.5 |
| • Total | 22.9 to 25.7 |

Source: Pearce 1993

## 1.4 Research Area

Since resources are always in a scarce, a case which imposes an obligation to maximise the use of what is available of it. In other words, to try the best to allocate it in a away such that to bring the maximum benefits to the community.

It is the concern of this research to look at and investigate the ways and methods of allocating investment funds within transport sector and between the modes. A matter which of great importance for the economy at large and for the transport sector to serve the rest of the economy in the best way possible. The main focus of the study will be on road and rail appraisal methods.

## 1.5 The Scope of the Problem

The simple economic rule for the allocation of resources between different competing uses is: invest until returns are equal at all margins. The problem at issue is simply stated: if different agencies - nationalised industries, government departments, or other bodies - invest and price their products according to different economic criteria, some financial, some non-financial, how shall this rule be applied ? Should the rates of return from each be regarded as directly comparable and the rule applied straightforward, or should some modification be introduced, to make them comparable, and if so what modification ?

Within the transport sector, in the UK, some investments are appraised on a financial basis, [railway schemes, buses, road haulage], while some are appraised on a cost benefit basis, [roads].

In the case of British Railway (BR), schemes are, at the time of writing, required to earn an 8% real rate of return in order to process (This was raised from 7% in 1989 as part of a general increase in public sector discount rates). Such an appraisal considers only savings in operating costs and increases in revenue as the two sources of benefit to the railway operator from the project.

On the other hand, road schemes are evaluated against costs and benefits using the Department of Transport's (DTp) computerised cost benefit analysis (COBA). COBA program compares the costs of road schemes with the benefits derived by road users, and express the results in terms of a monetary valuation e.g. Net Present Value, (NPV).

The fact raises the following questions:

a) How should a central authority faced with demands for money for projects appraised in the cost benefit sector and projects appraised financially decide how to allocate its funds ?

b) Can rates of return or net present values calculated financially be compared directly with the results of a cost benefit analysis ?

c) If they differ, is this:

- because of different coverage of implications of projects.
- or because they measure different things.
- or because they perform the same task but with varying degrees of reliability.

d) Can a rate of exchange between financial rate of return and cost benefit rate of return be found?

There has been a long debate on whether the use of social cost benefit analysis for the appraisal of trunk roads schemes and financial criteria for rail leads to a misallocation of resources. The Leitch Committee Report on Trunk Road Appraisal (Leitch, 1977) concludes that " in general social cost benefit rates of return exceed financial returns, and that there was, therefore, potential for resource misallocation in the use of different criteria in the two sectors". It recommended that: "Where direct alternatives arise between road and rail schemes the competing solutions should be compared using cost benefit analysis" and also "Strategic or policy studies conducted to compare the rates of return from investment in road and rail should be conducted on the basis of cost benefit analysis, rather than financial analysis.

The number of schemes which have been appraised using both cost benefit and financial appraisal techniques is small, but the Department of Transport has produced evidence from a study on the provision of a public transport link to Heathrow Airport and the Railway Board has produced assessments for two signalling schemes in the southern region and has additionally drawn our attention to two French comparisons. This evidence is set out in the following table:

Table 1.3 Comparison of cost benefit and financial returns

| Case | Financial return | Cost Benefit return | Ratio of cost benefit to financial returns |
|---|---|---|---|
| 1. Heathrow Airport Piccadilly Line extension [1] | 1 | 3.65 | 3.56:1 |
| 2. BR Feltham resignalling [2] | 13 | 18 | 1.39:1 |
| 3. BR London Bridge resignalling [2] | 14 | 23 | 1.65:1 |
| 4. SNCF new route (Paris-North)[2] | 11.1 | 34.75 | 3.13:1 |
| 5. SNCF improvements Paris-Clermont)[2] | 1.5 | 28 | 18.7:1 |

Source: (Leitch 1977)

[1] = returns are calculated as a net present value over cost [2] = internal rate of return is calculated

More recent studies have been carried out using both cost benefit and financial techniques, and the conclusions were supporting the earlier results (see Department of Transport 1984 and Midland Main Line Consortium 1992).

## 1.6 Purpose of the Research

The aim of the research is to develop a methodology for appraising rail schemes which could be consistent with the cost benefit techniques used to appraise road schemes. The methodology to be developed is not meant to be for a certain rail scheme. It is rather a general one, that deals with and has the answer to, different circumstances of rail investments. The circumstances considered here are the type of the road that can be a direct alternative to the railway line to be improved or invested in. The types of roads considered are:

1. Motorways
2. Major urban central roads
3. Major urban non-central roads

4. Major rural single carriageways
5. Major rural dual carriageways
6. Minor urban central roads
7. Minor urban non-central roads
8. Minor rural roads

## 1.7 Research Objectives

Having stated the research problem, and the purpose of the study, it is the turn now to set the objectives of the research. These are as follows:

### *1.7.1 Main Objectives*

The main objectives are:

1. To identify different appraisal techniques used for assessing the investment in transport sector, in particular cost benefit analysis and financial analysis. In addition a detailed comparison between the two techniques and implications of resource allocation.
2. To identify the difference between cost benefit analysis and financial analysis in the case of rail investment.
3. To identify the factors that influence the divergence between the returns on the investment of the two techniques.
4. To identify the means by which the difference may be incorporated into the framework of investment appraisal.

### *1.7.2 Sub-objectives*

In addition to the main objectives outlined above, the following sub-objectives are targeted and meant to serve in achieving some of the main objectives.

a) To identify user benefits of rail investment (consumer surplus), and investigate to what extent it does exist and define how pricing policy and cost and demand elasticity may affect the magnitude of the consumer surplus..

b) To identify and quantify non-user benefits of rail investment at the margin as a function of the road alternative, these are:

- Congestion benefits on road
- Accident benefits on roads (Misperception)

- Road vehicle operating cost benefits (Misperception)
- Environmental benefits (noise and air pollution)

## 1.8 Structure of the Thesis

Figure 1.6 shows the structure of the thesis.

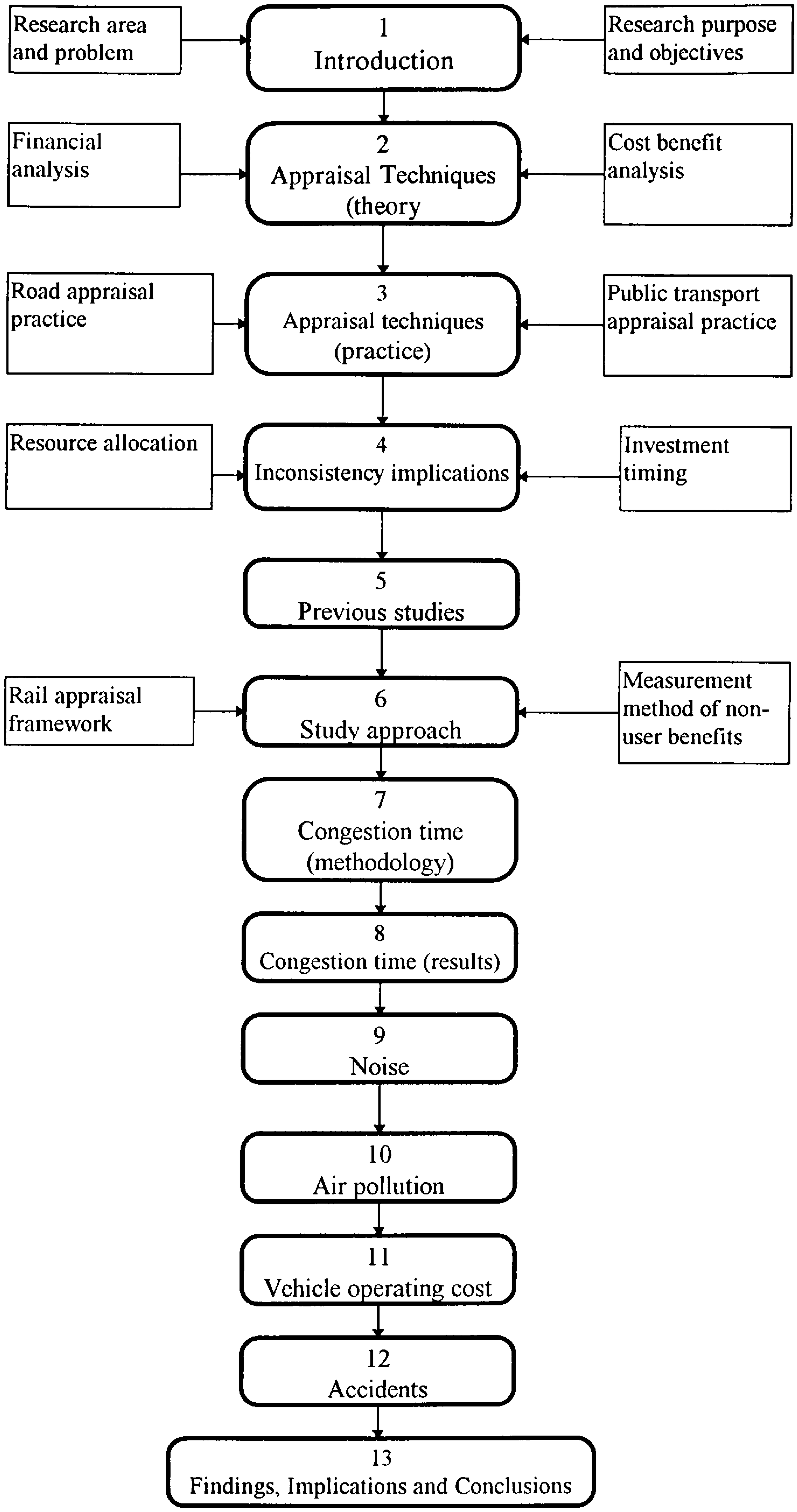



Figure 1.6 The structure of the thesis

## 1.9 Chapter Summary

The above sections showed the importance of investment analysis in the transport sector. The problem of allocating funds between projects assessed on a different basis has been outlined. The purpose of the study has been formulated as a development of an appraisal framework for rail investments to be consistent with road appraisal method. In achieving that aim a set of objectives have been defined in details. The chapter ends by demonstrating the structure of the whole study and a brief outline of the contents of each chapter.

### References


1. **Harrison A. J.** (1974), *The Economics of Transport Appraisal.* Croom Helm, London.
2. **Harrison A. J. and P. J. Mackie** (1973), *The Comparability of Cost Benefit and Financial Rates of Return*, Government Economic Service Occasional Paper no. 5, HMSO, London.
3. **Pearce D. et al** (1993), *Blueprint measuring sustainable development 3.* Centre for Social and Economic Research in the Global Environment, Earthcan Publication Ltd, London.
4. **Button K. J.** (1993), *Transport Economics.* 2nd Edition. Edward Elgar, England.
5. **Leitch, Sir George (Chairman)**, (1977), *Report of the Advisory Committee on Trunk Road Assessment.* HMSO, London.
6. **Department of Transport**, (1984), *Economic Evaluation Comparability Study, Final Report.* Department of Transport, London.
7. **Midland Main Line Consortium**, (1992), *The Role of Investment Appraisal in Road and Rail Transport: A response to the Department of Transport.* Public Transport Unit, Derbyshire County Council.
8. **Church, A.** (1992) *London's transport system.* Geography, 334(77), part 1, PP. 84-7.
9. **Department of Transport** (1989), *National Traffic Forecast.* HMSO, London.
10. **Economist** (1992), *Planes, trains and automobiles.* 12 September 1992, pp. 91-2.

11. **Holzapfel, H.** (1992) *Violence and the car.* Unpublished manuscript, University of Kassel.

12. **Mogridge, M.** (1990) *Travel in Towns.* Macmillan, London.

13. **Misham, E. J.** (1971) *The Post-war Literature on Externalities: An interpretative essay.* Journal of Literature, 9: pp. 1-28.

14. **Baumol, W. J. and W. E. Oates** (1988). *The Theory on Environmental Policy* (2nd ed.). Cambridge University Press, Cambridge.

15. **Nijkamp, P** (1994), *Roads Toward Environmentally Sustainable Transport.* Transport Research A. Vol. 28A no. 4 pp. 261-271.

16. **Verhoef E.** (1994), *External effects and social Costs of Road Transport.* Transportation Research A. Vol. 28A, no. 4 pp. 273-287.

# Chapter 2

## Appraisal Techniques (Theory)

### 2.1 Introduction

This chapter formulates the first section of the theoretical part of the study, it also serves in achieving the first objective of the research outlined in the first chapter above. It is devoted to examining and investigating theoretically the evaluation methods of transport investment. In particular cost benefit and financial analysis. How the two techniques differ in the coverage of investment benefits, and how and why they might lead to a different returns on the investment.

The chapter starts by reviewing the appraisal techniques in general. Then a detailed comparison between Cost Benefit Analysis (CBA) and Financial analysis (FA) is made. After that it turns to investigate the possibility and magnitude of a divergence between CBA returns and FA returns. Finally it highlights the fact that CBA returns are most likely to be higher than the FA returns and a chance of resource missallocation might occur when the two techniques are used to allocate funds. The chapter ends by a summary of its different sections.

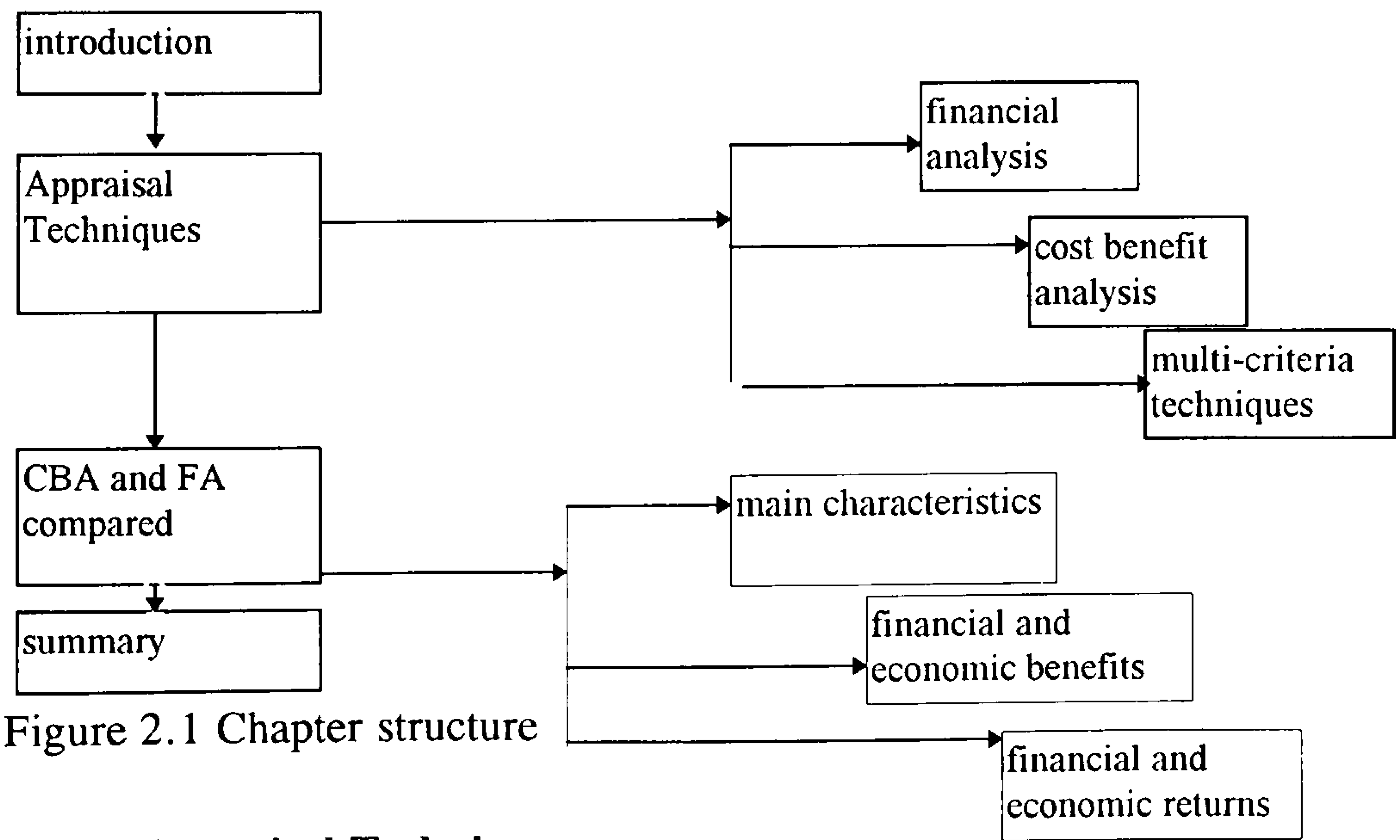



Figure 2.1 Chapter structure

### 2.2 Appraisal Techniques

At the most general level, the methods of assessing projects in the transport sector may be identified as follows:

1. Financial Analysis (FA)
2. Cost Benefit Analysis (CBA)
3. Multi-criteria decision-making techniques, such as:

- Planning Balance Sheet Analysis (PBSA)
- Goals Achievement Analysis (GAA)

On one hand, these methods are not completely different, and in fact some of them have their roots from the other, especially the multi-criteria methods. On the other hand, one may define some other tools of project evaluation, such as Cost - Revenue Analysis (CRA), and Cost - Effectiveness Analysis (CEA). But again these methods are all related and find their original roots from each other.

In the following paragraphs, a general definition of these methods outlined above will be highlighted.

### *2.2.1 Financial Analysis (FA)*

Financial analysis, (sometimes called cash flow analysis), is a method by which the effects of an investment on a particular industry or a firm can be measured. It is frequently used in the private sector as a method for estimating the money rate of return on any investment.

FA considers only the direct impacts of the project on the entrepreneur in a cash basis. Any other direct or indirect impacts on other parties in the society are not included.

This is one facet of FA, the second facet is regard to the valuation of revenue and costs. FA accepts prices in the market as it is. Cash flows are determined by market conditions, whether competitive or imperfect. So FA may be summarised as follows:

A method by which only the effects of a project on the entrepreneur are measured on cash basis and using the prices it finds in the market at the time of evaluation, while the questions of external impacts of the project on the rest of the society or direct impacts on the consumers and adjustments for resource costs (shadow pricing), are all irrelevant in financial analysis framework.

In the transport sector however, many investments have the characteristics that those who use them do not pay directly for their use. This is particularly so of the road system. This is a sort of price distortion as mentioned in chapter 1, and is not relevant or allowed for on FA framework. In addition, many investments have impacts other than that on the undertaking such as benefits to users (consumer surplus) and benefits or costs to the rest of the society (externalities) . These impacts are not included in the FA framework.

Financial criteria are, therefore, of limited use in the appraisal of transport policy since the change in profit of a transport undertaking neither reflects the net movements benefits to people or goods nor considers the externalities that might exist.

### *2.2.2 Cost Benefit Analysis (CBA)*

Cost benefit analysis is one of a family of evaluation techniques used for assessing alternative investment projects by technique based on economic efficiency (social surplus maximisation) and is defined as " a practical way of assessing the desirability of projects, where it is important to take a long view (in the sense of looking at repercussions in the further as well as the nearer future) and a wide view (in the sense of allowing for side effects of many kinds on many persons, industries, regions, etc.), that is, it implies the enumeration and evaluation of all the relevant costs and benefits" (Prest and Turvey 1965). Ideally, items that enter a CBA calculation are to include all those that affect the welfare of any individual in that particular society.

In other words, CBA is a particular kind of economic appraisal, and briefly it is the usual method for testing the "soundness" of proposed activities. It involves a calculation of the value of the resources to be employed in them " the costs" which are compared with the value of the goods or services to be produced " the benefits". In the contrast with financial analysis, CBA is a method by which the effects of an investment to the society as a whole are measured.

CBA then is a *comprehensive framework* *measures* the actual or expected real impacts of a project on a society. These real impacts may be direct (i.e. revenue or profit to the undertaking) or indirect (i.e. benefits or costs to users or non-users, e.g. consumer surplus and externalities), tangible (i.e. measurable) or intangible. Social costs and benefits in CBA are measured at the real economic prices where possible (resource costs). Shadow pricing may be required for adjusting the market prices.

So not only the cost benefit type of analysis *more comprehensive* in terms of the items considered, but also redefines many of the items retained from commercial criteria

(FA). For example, the costs of imported raw materials used in a potential road construction project in a third world country would be valued at market prices if a commercial undertaking were responsible for road investment decisions. If a public body undertakes road investment using wider social criteria (CBA), then it would look beyond the immediate financial indicators and at the *shadow prices* of imports so that the scarcity of foreign exchange and the limitations of adequate finance for imports is reflected in the decision making.

In some investments use is made of formerly unemployed factor services, for instance, unemployed labour where the opportunity cost for employment in a transport scheme is zero. A commercial concern would cost such imputes at the wages that have to be paid, but in a CBA study they may not be considered a cost at all or, more probably, would be costed so that genuine resource costs are incorporated in the calculations.

Another example of resource cost adjustments incorporated in the CBA framework is the sales and other indirect taxes. The tax on gasoline, for example, is a financial cost to those who pay the tax, but it does not necessarily reflect economic costs to the country as a whole, for an increase in the tax does not mean that more economic resources are required to produce a given volume of gasoline. Similarly, licence fees and import duties will be excluded from the calculation of economic costs in a CBA framework.

A further very important distinction between social efficiency approach (CBA) and the commercial approach (FA) is that the former takes cognisance of *distributional effect* of the investment. This is often difficult to do in reality although various schemes for weighting costs and benefits have been advanced by theoreticians (for example, McGuire and Gain 1969). In practice there is a tendency to employ rather crude methods, often, as in the case of planning balance sheet approach used in several urban infrastructure investment appraisals (Lichfield and Chapman, 1968), involving the simple setting out in tabular form the impacts of a scheme on the different user and non-user groups affected or, as with inter-urban road appraisal in the United Kingdom (Department of Transport, 1978), carrying out a partial CBA with no allowance for distributional effects and subjecting the results of this to further debate at public enquiry.

Another area of distinction between the social and commercial approaches is the issue of *transfer payments*. A financial analyst will include any cash receipts regardless of their sources or origin. A scheme which brings a £1m revenue to a transport operator and reduces the tax revenue by the same amount will appear in the positive side of the operator balance sheet, but if a CBA approach is carried out this revenue will be considered as a transfer payments and does not mean a real benefit to the society and then will not be included at all.

Last but not least is the subject of *perception* . In the transport sector as in other sectors there is a possibility of individuals misperceive the actual benefits of an improvement to the service or fail to take account of the full costs. There are many reasons of misperception, examples of which are: limited information available to them, the change in the transport service is extremely small, the costs may be so small that it is not worthwhile to take account of, some costs which are, in fact, variables may be regarded as fixed costs. e. g. vehicle depreciation, the individual may be genuinely unaware of the existence of a connection between what he does and the costs involved.

A financial analysis approach will not allow any corrections to be made for the misperceived costs or benefits, while a comprehensive social approach will make an allowance for the potential misperception of any cost and benefit elements.

### *2.2.3 Multi-criteria Decision-making Techniques*

Multi-criteria decision-making techniques move away from the idea of utility maximising which underlies CBA, and are more akin to the management theories of satisfying. Rather than attempt to seek optimum solutions which, for practical reasons, are likely to be unobtainable, the decision maker selects actions complying with a range of criteria which describe minimally satisfactory alternatives.

The Planning Balance Sheet Analysis (PBSA) initially developed by Lichfield (Lichfield, 1956) for town planning purposes is similar to CBA in that all costs and benefits are included and that distributional considerations are not neglected, but *it represents a movement in the direction of multi-criteria analysis* in that not all the effects of the various schemes are translated into monetary terms. It has subsequently been developed and employed in the evaluation of urban transport and airport investment proposals. Where evaluation is difficult, the PBSA approach employs physical values and when quantification is impossible, ordinal indices or scales may be used. A socio-economic account is drawn up setting out the full effects of each course of action and indicating the extent to which various groups in the community will be affected. A modified version of this type of approach, *the project impact matrix*, has recently gained the favour of the Leitch Committee (Department of Transport, 1978).

Critics of the PBSA methodology point to the need to develop ordinal ranking criteria to permit the various items of the PBSA account to be set against various planning goals instead to reflect community preferences. The ranking process has to reflect social preferences which are themselves difficult to ascertain and, even if a consensus is possible, the ordinal nature of the ranking suggests a loss of efficiency in the techniques (Button and Pearman, 1983). Peters (1968), for instance, argues that PBSA only offers

> *a bombardment of monetary measures, quantitative measures and qualitative judgements in confusing array, without a single indicator, with a danger of double counting and an embarrassing degree of circularity.*

The critics, although partially valid, tend to contrast PBSA with an idealised conventional CBA framework rather than the pragmatic CBA approach adopted in practice.

The PBSA attempt to extend CBA into a multidimensional framework, however, requires substantial data imputes and only offers a partial solution to the problem of making interpersonal comparisons. Despite this and although PBSA does not avoid the problem of making value judgements, the technique has the merit that, unlike the pure CBA model, these normative judgements are made explicit rather than hidden in a final, single net present social value calculation.

The PBSA method falls somewhere between the traditional CBA approach and true multi-criteria decision making techniques. It contains elements of the maximisation principles which underlie CBA, but without the exclusive reliance on monetary evaluation of all the investment's impacts.

Multi-criteria decision making techniques, which have been extensively developed at the theoretical level in the context of regional impact analysis generally involve introducing weights to reflect the relative priorities attached to the various outcomes associated with different courses of action (Pearman, 1978). They have not yet been applied in the transport field but are attracting the attention of many concerned with the inherent limitations of the CBA approach. A number of multi-criteria approaches have been devised, each attempting to achieve a multidimensional compromise between the wide diversity of goals and costs which are embodied in public sector choice. The approaches differ in their method of presentation, the level of mathematical sophistication involved and the amount of data impute required. In general, however, these particular techniques tend to be rather specialised in their nature and are only of practical use in certain specific circumstances. Of more practical value in the transport field are some of the simpler weighting techniques which already enjoy a degree of acceptance and for which the theory is comparatively well advanced (Button and Pearman, 1983).

The introduction of weightings permits the effects of a projected action to be reduced to a single, summary figure. The Goals Achievement Matrix approach, which has been used in urban transport planning (Hill, 1968), for example, offers an explicit treatment of various goals and applies a set of predetermined weights to them so that each option can be assessed in terms of goal achievement. To facilitate this, the goals are related to physical measures to reflect the extent to which they have been achieved. The final goal achievement account employs the weighted index of goal achievement to determine the preferred course of action.

### *2.2.4 Summary*

At the most general level, one may define the appraisal techniques theoretically as financial analysis (commercial approach) and cost benefit analysis (social approach).

Multi-criteria decision making techniques are an extended versions of cost benefit analysis CBA. They represent a movement in the direction of multi-criteria analysis in that not all the effects of the various schemes are translated into monetary terms. They contain elements of the maximisation principles which underlie CBA, but without the exclusive reliance on monetary evaluation of all an investment's impacts.

## 2.3 Cost Benefit Analysis and Financial Analysis Compared

After defining the general appraisal methods, this section will go one step further. It summarises the main dimensions of comparison between the two main methods, CBA and FA, in order to present a picture of the similarities and differences between them. In addition, it shows how the outcome of each of them, in terms of returns on the investment, may differ and how pricing policy operated may affect that difference. It also shows the factors that determine the divergence between CBA return and FA return and how it might be difficult to obtain a single relationship between the two returns.

### *2.3.1 Main Characteristics*

Table 2.1 summarises the main dimensions of comparison for the CBA and FA perspectives..

Table 2.1 Main dimensions of comparison between CBA and FA

| | Financial Analysis | Cost Benefit Analysis |
|---|---|---|
| 1. Goal | Determination of financial net present value (FNPV) | Determination of social net present value (SNPV) |
| 2. Financial statement | Accounting entity's income statement(cash receipts-cash disbursements) on a cash basis | Community's social balance sheet (social benefits-social costs) on a social valuation basis |
| 3. Inclusion rule for gains and losses | 100 percent of cash flows | 100 percent of social impacts (direct and indirect tangible and intangible) |
| 4. Positive sign variables | Annual cash receipts of the project | Social benefits of the project defined as the sum of consumers willingness to pay for enjoying the expected benefits of the scheme |
| 5. Negative sign variables | Annual cash disbursements and initial investment | Social opportunity cost of resources used up annually for carrying out the project and initial investment |
| 6. Valuations of gains and losses | Current prices under existing market conditions (accepts prices it finds in the market) | Competitive shadow prices estimated for ideal market conditions (shadow prices are required) |

Table 2.1 Continued

| | | |
|---|---|---|
| 7. Discounting procedure | Calculated cost of invested funds (usually the value of interest rate of borrowing and lending in the capital market) | A variety of theoretically defensible options including the government bond rate, private return on investment, private rate of time preference, social rate of time preference, and weighted average of applicable rates |
| 8. Distributive equity | Irrelevant to a private firm but often considered in public pricing | Politically determined weights or constraints are widely used |
| 9. Transfer payments | All payments are included regardless of their origin and destination | Adjustments are made to correct for transfer payments |
| 10. Perception | Irrelevant to a private operator (no allowance is given to cases of misperception) | Corrections are made for the misperceived items (costs or benefits) |

Source: adapted from Harlow and Windsor (1988).

As we can notice from the table, CBA measures social net present value (SNPV) as equation 2.1 illustrates,

$$SNPV = SB - SOC = WTP - SOC \qquad (2.1)$$

While FA tends to measure financial net present value (FNPV) as equation 2.2 presents.

$$FNPV = ACR - ACD - IN \qquad (2.2)$$

Where:

SB= discounted social benefits expected from the project

SOC= discounted social opportunity costs for carrying out the project (understood in terms of the sum of such benefits foregone by not selecting the next best use of the resources employed)

WTP= consumers willingness to pay for enjoying the expected benefits form the entire life of the project

ACR = discounted annual cash receipts from the project

ACD = discounted annual cash disbursements for the project

IN = original capital investment cost

One might identify the main theoretical and methodological difference between CBA and FA as that, the first, CBA, is conducted from Net Social Welfare (NSW) orientation while the latter, FA, is conducted from a business type Return On Investment (ROI) orientation. To clarify this point more, the following explains how projects are looked at commercially and socially.

#### 2.3.1.1 Commercial Approach

The commercial firm will, in the absence of a budget constraints, accept investments when the financial net present value is positive, this is:

$$NPV_f = \sum_{n=1}^{k} \frac{P_n - C_n}{(1+r)^n} \qquad (2.3)$$

Where:

$NPV_f$= financial net present value

$P_n$= revenue that would be earned in year n from the investment

$C_n$= financial cost of the investment in year n

r= rate of interest reflecting the cost of capital to the undertaking

k= the anticipated life of the investment

The private sector will usually obtain the value of (r) as the value of interest rate of borrowing and lending in the capital market. A positive $NPV_f$, therefore, tells the businessman that it is worthwhile undertaking an initial investment. This is when he only has one alternative to invest in. But when he has more than one option, the comparison will be between NPVs for all options. The alternative that has the highest $NPV_f$ will be preferred.

#### 2.3.1.2 Social Approach

In contrast, economic efficiency is assessed using some form of cost benefit analysis, which again in the absence of a budget constraint, suggested schemes with a positive social net present value should be chosen, and if there are more than one option, the option that achieves the highest NPV socially will be processed. The following shows the calculation of social net present value.

$$NPV_s = \sum_{n=1}^{k} \frac{B_n - RC_n}{(1+i)^n} \quad (2.4)$$

Where:

$NPV_S$ = social net present value

$B_n$ = the probable social benefits to be enjoyed by the society in year n as a result of the investment's completion

$RC_n$ = the probable social costs to be sacrificed by the society in year n as a result of the investment's completion

i = is the relevant social discount rate, reflecting the relative social weight attached to a cost or benefit accruing in a given year.

k = is the anticipated life of the investment

It is worth mentioning that Net Present Value (NPV) is only one method of looking at investment benefits and comparing projects together. There are other methods, these are:

1. The Benefit Cost Ratio (B/C), where the measured benefits of the project are compared with the costs of carrying out the project. On financial basis the ratio will be R/C, where R is the revenue that would be earned from the scheme and C is the financial cost of the scheme. On CBA basis, the ratio would be B/RC, where B and RC are the probable social benefits and costs of the investment.
2. Internal Rate of Return (IRR), the internal rate of return is defined as the rate of discount which will bring the net benefits of the scheme to zero. The following expression shows how it is estimated.

$$C = \sum_{n=1}^{k} \frac{B_n}{(1+s)^n} \quad (2.5)$$

Where:

C = capital cost of the scheme

$B_n$ = net scheme benefits in year n

k = anticipated scheme life period

s = discount rate that brings benefits $B_n$ into equality with capital costs of the scheme C (internal rate of return)

3. Pay back period, the pay back period is defined as that period of time in which the commulative sum of the expected net benefits from a project equals the initial capital expenditure. In general the shorter the pay back period the more favourably the project will be regarded.

Each of these methods has some advantages and disadvantages as they arise in their practical application within the transport sector, and then each of them will have a certain circumstances within which it is appropriate to be used as a measure.

### *2.3.2 Economic and Financial Benefits of Investment*

As illustrated in the earlier paragraphs, CBA is a comprehensive assessment of the investment effects into the economy as a whole, while FA only considers the effects of the investment into the firm or the industry on question. Having known that, the benefits of an investment measured in a cost benefit basis will probably differ from that measured on a financial basis.

Consider a simple case, figure (2.2) shows the demand curve DD, marginal revenue curve MR, and marginal cost curves before and after the investment MC1, MC2 for a firm. Assuming that the objective of the firm is profit maximisation, the level of production and price will be OQ1, OP1 before any improvement to the service. After the investment, the level of production and price would be OQ2, OP2. The producer surplus would be the area P1ACF and area P2BED for before and after situations. In addition to this producer surplus, however there is an area of consumer surplus DAP1 and DBP2 for before and after situations respectively. This area represents the fact that some consumers would have been prepared to pay more than OP1 and OP2 for before and after situations to use the facility produced, and may therefore be said to derive benefits in excess of OP1 and OP2.

A cost benefit appraisal, attempting as it does to measure benefit wherever they accrue, would seek to include both the producer surplus and the consumer surplus elements in the benefits of the project. On the other hand, a financial appraisal, attempting to measure benefits accrue only to the firm or industry in question, would include only the producer surplus as the benefits of the project.

For this case, the financial analysis approach will consider only the change in producer surplus (area P2BED-area P1ACF), as the investment benefits. On the other hand a CBA approach will include both the change in producer and consumer surplus in measuring the investment benefits, (area P2BED-area P1ACF + area P1ABP2).

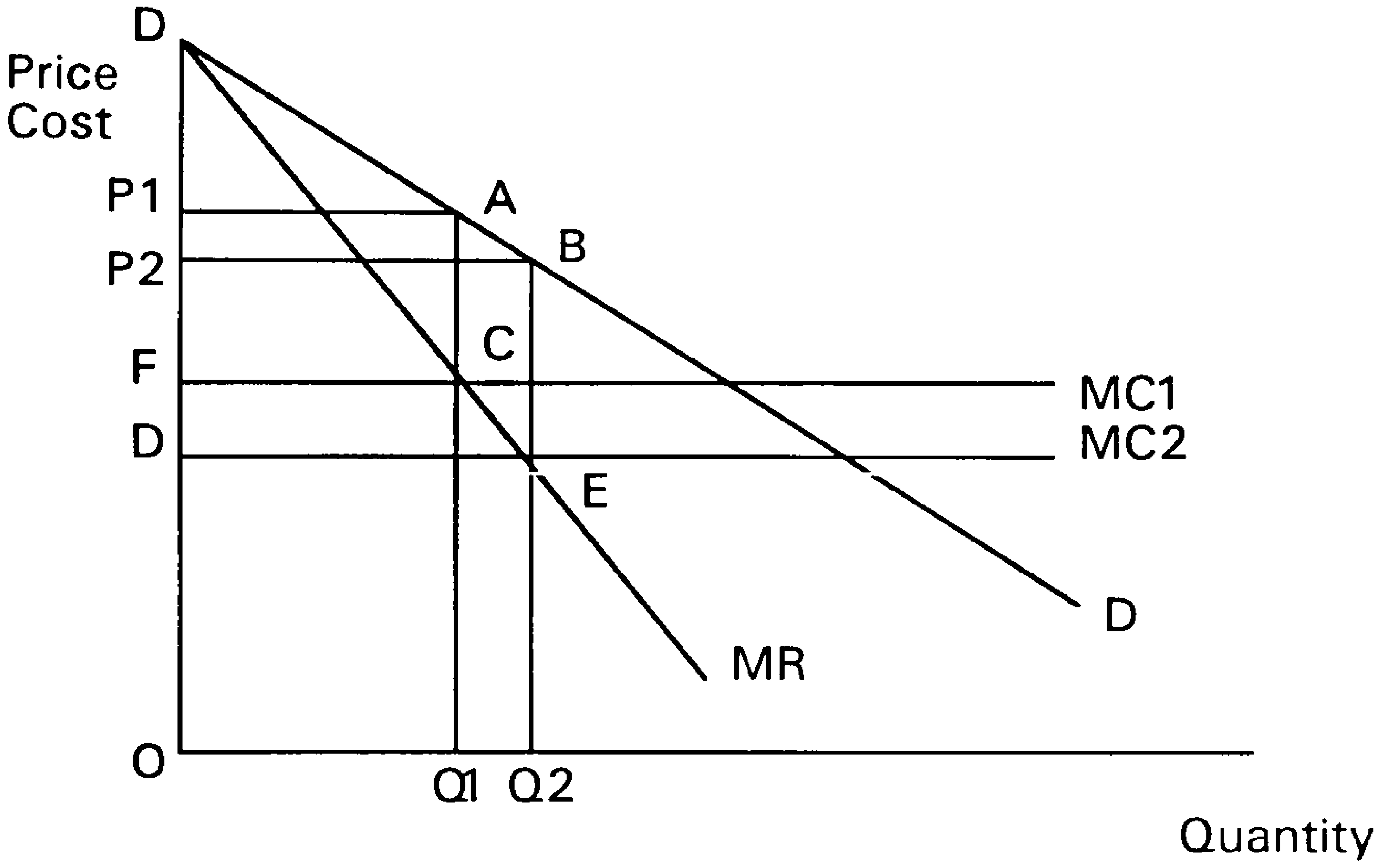



Figure 2.2 Financial and cost benefit measures of benefits

In the above case with a linear demand curve and a single profit maximising producer, the benefits measured on CBA basis would be greater than that measured on FA basis by a very considerable margin.

The question that may be raised here is : can a ratio of consumer surplus to producer surplus be found. In other words can a rate of exchange between the measured benefits under CBA and that under FA be found. The answer to that question does not seem to be simple. In the above example, the only fact that can be confirmed is the existence of consumer surplus. The factors that have been found to influence the ratio of the financial benefit to the CBA benefits include (Harrison and Mackie, 1973):

1. The shape of the cost curves with and without the investment. Here a variety of shapes can be identified: linear, non-linear, etc. Also whether the cost is an increasing, decreasing or constant as production increases. The cost elasticity will be playing an important rule in the magnitude of consumer surplus, and the elasticity will be very much related to the shape of the cost curves.
2. The shape of the demand schedule. As with cost, there are different possibilities for the shape of demand curve, which will have its implications on the elasticity of demand and in turn on the consumer surplus.

3. The pricing policy operated and the consistency with which it is persuaded. The three known possibilities of pricing theoretically are:

- Profit maximisation pricing
- Welfare maximisation pricing (marginal cost pricing)
- Output maximisation pricing (average cost pricing)

Each of these will have a different implications on the existence and the magnitude of the consumer surplus. Practically, there might be a variety of pricing policies, which may also add to the difficulty of having a relationship between consumer and producer surplus. In addition, it may be argued that the undertaking might consider different pricing policy before and after the investment. This will have its own implications in the determination of consumer surplus.

4. The magnitude of any external effects to the project
5. The extent of price discrimination

In summary, if one is to pursue the issue of finding or formulating a relationship between financial and cost benefit returns, one probably has to consider so many combinations of demand, cost, pricing and elasticity. Each of these combination will end up with a relationship different from the others.

This section will illustrate how it is possible to have a variety of relationships between economic and financial benefits.

#### 2.3.2.1 Assumptions

**1. Demand Function**

Demand function is assumed to be linear and specifically as follows:

$$Q = a - bp \qquad (2.6)$$

Where:

Q= travel demand (no. of trips, no. of passengers per period of time, day, week, year)

a= constant

b= slope of demand curve

p= price of travel (£/tripe, or £/passenger km)

From equation (2.6), the price and elasticity functions can be derived as follows:

$$p = \frac{a - Q}{b} \quad (2.7)$$

and

$$E = \frac{-bp}{Q} \quad (2.8)$$

Where :

E= elasticity of travel demand

**2. Total Revenue**

Total revenue is the total amount of money obtained by selling a certain level of output. It is the quantity produced times the selling price. In here it is the number of trips multiplied by the price of the trip, specifically,

$$TR = pQ = \frac{a - Q}{b}Q = \frac{aQ - Q^2}{b} \quad (2.9)$$

Marginal revenue is the increase in total revenue by selling one more unit of production and calculated by taking the first derivative of total revenue function.

$$MR = \frac{\partial TR}{\partial Q} = \frac{b(a - 2Q)}{b^2} = \frac{a - 2Q}{b} \quad (2.10)$$

Where:

TR= total revenue

MR= marginal revenue

**3. Cost Functions**

Marginal cost function (firm supply function)

Marginal cost function is assumed to be an increasing function of output. In other words, it is assumed a decreasing returns to scale production function. Equations 2.11 and 2.12 show marginal cost functions before and after the investment assuming that the investment will shift cost function uniformly downward indicating cost savings.

$$MC_1 = C_1 + dQ \quad (2.11)$$
$$MC_2 = C_2 + dQ \quad (2.12)$$

Where:

| | |
|---|---|
| $MC_1 =$ | marginal cost before the investment |
| $MC_2 =$ | marginal cost after the investment |
| $d =$ | slope of marginal cost curves |
| $C_1, C_2 =$ | are constants ($C_2 < C_1$) |

**Total Cost**

Total cost function shows the total cost of producing different levels of output. It is found by integrating the marginal cost function.

$$TC_1 = \int MC_1 \partial Q = C_1 Q + \frac{1}{2} dQ^2 \qquad (2.13)$$

$$TC_2 = \int MC_2 \partial Q = C_2 Q + \frac{1}{2} dQ^2 \qquad (2.14)$$

Where:

$TC_1, TC_2 =$ total cost before and after the investment respectively

**4. Profit (producer surplus)**

Producer surplus is the net profit, and estimated by subtracting total cost from total revenue.

$$PS_1 = TR_1 - TC_1 \qquad (2.15)$$

$$PS_2 = TR_2 - TC_2 \qquad (2.16)$$

Where:

| | |
|---|---|
| $PS_1 =$ | producer surplus before the investment |
| $PS_2 =$ | producer surplus after the investment |
| $TR_1, TR_2 =$ | total revenue before and after investment |

**5. Consumer Surplus**

Consumer surplus is defined as the amount that a person would be willing to pay for any given quantity of an item purchased minus the amount the market requires him to pay. It is ordinarily measured as the total area under the demand curve up to the designated quantity minus what the consumer must actually pay for that quantity. Specifically,

$$CS = \int_0^{Q^*} p(Q)\partial Q - p^* Q^*$$

$$= \int_0^{Q^*} \frac{a-Q}{b} \partial Q - p^* Q^*$$

$$= \frac{1}{b}\left[aQ - \frac{1}{2}Q^2\right] - p^* Q^* \quad (2.17)$$

Where:

CS = consumer surplus

$p^*$, $Q^*$= the equilibrium price and volume of travel

**6. Economic Benefits**

Is the total benefits of an activity accrues to whatever gains the benefits and measured as the sum of consumer and producer surplus. Specifically,

$$SW = CS + PS \quad (2.18)$$

Where:

SW= economic benefits (measured on CBA basis)

### 2.3.2.2 Results:

Using the assumptions of demand and cost curves outlined above and assuming a profit maximisation pricing policy, the following table summarises the results:

Table 2.2 Financial and economic benefits of investment in case of profit maximisation

| | Before investment | After investment | Change |
|---|---|---|---|
| Consumer surplus | $\frac{(a-c_1 b)^2}{2b(bd+2)^2}$ | $\frac{(a-c_2 b)^2}{2b(bd+2)^2}$ | $\frac{(c_1-c_2)[2a-b(c_1+c_2)]}{2(bd+2)^2}$ |
| Producer surplus (financial benefits) | $\frac{(a-c_1 b)^2}{2b(bd+2)}$ | $\frac{(a-c_2 b)^2}{2b(bd+2)}$ | $\frac{(c_1-c_2)[2a-b(c_1+c_2)]}{2(bd+2)}$ |
| Economic benefits = consumer surplus + producer surplus | $\frac{(a-c_1 b)^2(bd+3)}{2b(bd+2)^2}$ | $\frac{(a-c_2 b)^2(bd+3)}{2b(bd+2)^2}$ | $\frac{(bd+3)[(a-c_2 b)^2-(a-c_1 b)^2]}{2b(bd+2)^2}$ |

Using the results in table 2.2, it is possible to formulate a factor linking the economic benefits to financial benefits as follows:

$$R = \frac{\Delta SW}{\Delta PS} = \frac{bd+3}{bd+2} > 1 \qquad (2.19)$$
$$b, d > 0$$

Where:

$\Delta$SW = economic benefits of investment

$\Delta$PS = financial benefits of investment

Equation 2.19 shows that the ratio of economic to financial benefits R is more than one (subject to b, d$>$0) . That means the economic benefits will always be more than the financial benefits. The deviation of the value of R form 1 will be a function of the value of demand and cost slopes, b and d. In other words, will be very much related to demand and cost elasticity.

### *2.3.3 Economic and Financial Rates of Return*

Having demonstrated that CBA yields more benefits than FA , it can be possible to demonstrate that financial returns on the investment will be always lower than the CBA returns. In other words, for a certain project with capital cost C, the economic benefits are more than the financial benefits. Consequently, the benefit cost ratio or internal rate of return will be higher on CBA basis. Specifically,

$$C = \sum_{n=1}^{k} \frac{\Delta SW_n}{(1+R_E)^n} \qquad (2.20)$$

$$C = \sum_{n=1}^{k} \frac{\Delta PS_n}{(1+R_f)^n} \qquad (2.21)$$

Where:

$\Delta SW_n =$ economic benefits of investment in year n (consumer and producer surplus)

$\Delta PS_n =$ financial benefits of investment in year n (producer surplus)

$C =$ capital cost of scheme

$R_E =$ cost benefit internal rate of return (%), discount rate that brings the economic benefits to be equal the scheme capital cost assuming no scrap value of the project at the end

$R_f =$ financial rate of return (%), discount rate that brings the economic benefits to be equal the scheme capital cost assuming no scrap value for the project at the end

Since $\Delta SW$ will always be more than $\Delta PS$ at any period of investment life, the value of $R_E$ that brings the sum of the right hand side and the lift hand side in equation 2.20 to equality will be higher than the value of $R_f$ that does the same thing for equation 2.21. The conclusion is that the existence of consumer surplus will make a divergence between CBA return and FA return and the latter will be lower than the former. One should notice that, in the above example it is assumed the investment has no externalities, and that the capital cost C is the same on both CBA and FA basis.

### *2.3.4 Interaction Between Appraisal Techniques and Pricing Policy*

As sections 2.3.2 and 2.3.3 demonstrated, there is a chance of divergence between CBA and FA rates of return. The largeness of that divergence will vary from case to another according to the assumptions, such as pricing policy, demand and cost functions, etc. The example presented above assumed a profit maximisation firm and linear demand and cost schedules, beside a consistency of pricing policy operated before and after. A relaxation of any of these assumptions will lead to a different relationship between CBA and FA rates of return. The following section considers the impact of pricing policy as well as the interaction between appraisal techniques and pricing policy on the measured benefits of the investment.

Using the assumptions of section 2.3.2.1 and pursuing two pricing polices, profit maximisation and marginal cost pricing, six cases can be identified:

$$\frac{\Delta PS(PM)}{\Delta PS(WM)} = \frac{b^2d^2 + 2bd + 1}{b^2d^2 + 2bd} \neq 1 \qquad (2.22)$$

$$\frac{\Delta SW(PM)}{\Delta PS(PM)} = \frac{bd + 3}{bd + 2} \neq 1 \qquad (2.23)$$

$$\frac{\Delta SW(WM)}{\Delta PS(PM)} = \frac{bd + 2}{bd + 1} \neq 1 \qquad (2.24)$$

$$\frac{\Delta SW(PM)}{\Delta PS(WM)} = \frac{b^3d^3 + 5b^2d^2 + 7bd + 3}{b^3d^3 + 4b^2d^2 + 4bd} \neq 1 \qquad (2.25)$$

$$\frac{\Delta SW(WM)}{\Delta PS(WM)} = \frac{bd + 1}{bd} \neq 1 \qquad (2.26)$$

$$\frac{\Delta SW(WM)}{\Delta SW(PM)} = \frac{b^2d^2 + 4bd + 4}{b^2d^2 + 4bd + 3} \neq 1 \qquad (2.27)$$

Where :

ΔPS(PM), ΔSW(PM)= financial and economic benefits of an investment assuming profit maximisation pricing policy

ΔPS(WM), ΔSW(WM)= financial and economic benefits of an investment assuming marginal cost pricing

Looking at the six equations above, 2.22-2.27, the following can be concluded:

1. For the same pricing policy, there will be always a divergence between financial and cost benefit returns, unless demand elasticity is infinity. The type of pricing

policy operated will have a significant impact on the magnitude of that divergence as equations 2.23 and 2.26 illustrate.

2. There will be a divergence between financial rates of return measured under different assumptions of pricing policy. Similarly, different pricing policies will bring different CBA returns as equations 2.22 and 2.27 show.
3. Equations 2.24 and 2.25 present two cases of interaction between evaluation and pricing. Each illustrate the ratio between cost benefit and financial returns under inconsistent pricing policy.

## 2.4 Chapter Summary

This chapter identifies the evaluation methodologies of transport investment under three headings, financial analysis, cost benefit analysis and multi-criteria decision making techniques. It demonstrates a detailed comparison between the two main techniques, CBA and FA. It shows that FA by definition is concerned only with the financial effects in terms of extra net revenue accruing to the agency carrying out the scheme concerned. CBA measure is concerned with a larger framework; all transport users or society at large. This has three important consequences: first, as far as the FA is concerned, the discussion of resource cost adjustments is irrelevant, FA accepts the prices it finds. Second, there are elements of consumer benefit which a CBA would measure but which a FA would not, e.g. those areas of consumer surplus which, because of the relative crudity of most pricing policies, the financially based organisation cannot tap. Third, if there are effects external to the transport sector, these will in principle enter into the CBA but not into the FA, unless arrangements exists for internalising them, e.g. through compensation mechanism.

The chapter then turn to illustrate how the two techniques may result in different returns on the investment and ends by exploring the factors affecting the divergence between the outcome of the two measures in particular pricing policy operated.

## References


1. **Prest A. R. and R. Turvey** (1965), *Cost Benefit Analysis: A survey.* Economic Journal, Vol. LXXV, no. 300, December 1965.

2. **Lichfield N.** (1956), *Cost Benefit Analysis in Town Planning: A case study of Cambridge.*
3. **Harlow K. C. and D. Windsor** (1988), *Integration of Cost Benefit and Financial Analysis in Project Evaluation.* Public Administration Review, Vol. 48, no. 5, Sept./Oct. 1988.
4. **Button K. J.** (1993), *Transport Economics.* 2nd Edition. Edward Elgar, London.
5. **Harrison A. J.** (1974), *The Economics of Transport Appraisal.* Croom Helm, London.
6. **Harrison A. J. and P. J. Mackie** (1973), *The Comparability of Cost Benefit and Financial Rates of Return*, Government Economic Service Occasional Paper no. 5. HMSO, London.
7. **Leftwich R. H. and R. D. Eckert** (1985), *The Price System and Resource Allocation.* Ninth Edition, The Dryden Press, New York.
8. **Department of Transport**, (1978), *Report of the Advisory Committee on Trunk Road Assessment* . Leitch Committee, London HMSO.
9. **Lichfield, N. and Chapman, W.** (1968), *Cost benefit analysis and road proposals for a shopping centre- a case study.* Edgware, Journal of Transport Economics and Policy, 2, pp. 280-320.
10. **McGuire, M. and Gain, H.** (1969), *The integration of equity and efficiency criteria in public project selection.* Economic Journal, 79, pp. 882-93
11. **Adler, H. A.** (1987), *Economic Appraisal of Transport Projects*, Washington, World Bank.
12. **Button, K. J. and A. D. Pearman** (1983), *The Practice of Transport Investment Appraisal.* Gower, England.
13. **Peters, G. H.** (1968), *Cost benefit analysis and public expenditure.* Eaton Paper 8, Institute of Economic Affairs, London.
14. **Pearman, A. D.** (1978), *An assessment of Multiple Criteria Decision Making Methods and their Potential use in Comparability Studies between Trunk Road and rail investment.* Report prepared for the British Railway Board.
15. **Hill, M.** (1968), *A goals Achievement Matrix for Evaluating Alternative Plans*, in Journal of the American Institute for Planners, vol. 34, pp. 19-29.

16. **Foster, C. D.** (1969) *Investment and finance theory and pricing: investment policy and pricing in transport*. Paper presented at the International Symposium on Transportation Pricing held at the American University, Washington, D. C. between June 16 and 20, 1969.

# Chapter 3

## Transport Project Appraisal Techniques (Practice)

### 3.1 Introduction

There has been a long-running debate among British transport planners about what appraisal techniques are appropriate for road and rail investment schemes. A particular feature of the argument relates to whether the procedures currently adopted unduly favour investment in highway schemes relative to rail schemes. This issue has become even more central since the Department of Transport (DTp) issued revised guidelines in 1989 on the eligibility of public transport investment schemes, in England and Wales, for grant under Section 56 of the 1968 Transport Act. This chapter briefly summarising current British practice for assessing transport investment schemes. Then it presents a summary of the weaknesses in current appraisal techniques. The following diagram shows the structure of the chapter.

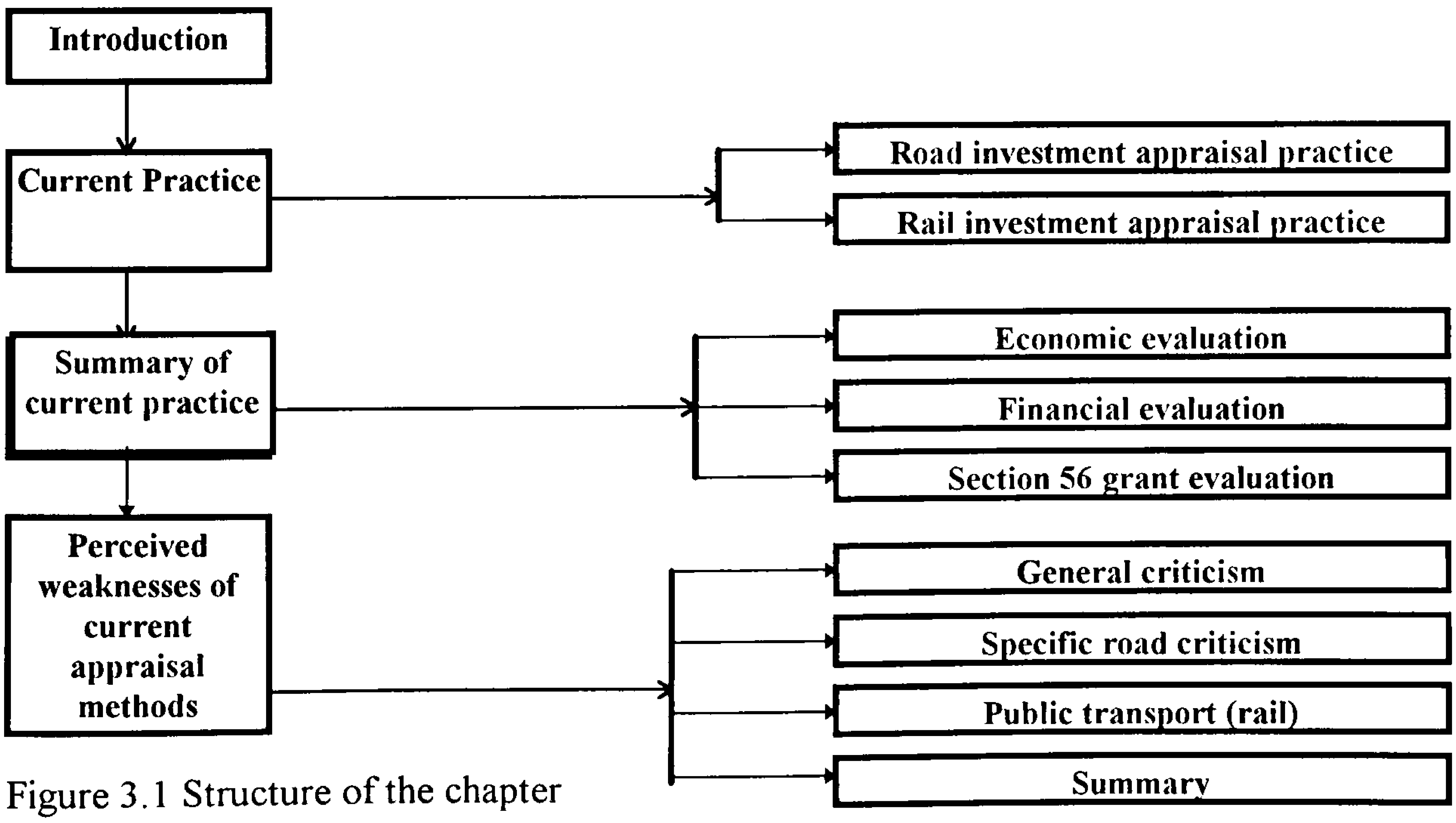



Figure 3.1 Structure of the chapter

## 3.2 Current Practice of Transport Investment Appraisal

### *3.2.1 Road Investment Appraisal*

#### 3.2.1.1 Introduction

The method used to appraise new trunk road schemes in the UK is the Leitch Framework (DTp 1979), which is explained in detail in COBA manual (DTp, 1981). The objectives of the framework appraisal are to ensure that all the relevant impacts of a scheme or proposal on people and the environment are considered; to provide the DTp with a balanced presentation of a set of comparative data; to show that the DTp has considered the effects of the available options prior to reaching a decision and to enable the public to give their view in the knowledge of the implications of the various alternatives. The various alternative options put forward are assessed against a do-nothing situation in which congestion worsens as traffic grows, or a do-minimum situation in which account is taken of proposed small scale improvements to the network.

The appraisal of new road schemes using the Leitch Framework is based on a social cost benefit analysis and an environmental impact assessment. The effects included under these separate evaluations are assessed in relation to the following appraisal groups: travellers, occupiers of property, users of facilities, policies for conserving and enhancing the area, policies for development and transport and financial effects.

#### 3.2.1.2 Social Cost Benefit Analysis (CBA)

The basic comparison involved in the economic appraisal of road investment is the trade-off of capital and maintenance expenditure against benefits to existing and potential users of the new road in the form of time savings, accident savings and changes in vehicle operating costs each valued in monetary terms. On average around 80% of the benefits of a scheme evaluated by COBA (the DTp's programme for calculating the user benefits of a project option) take the form of time and operating cost savings (split equally between business and private users) 20% are reduced accident costs (Nash et al 1991a).

Time savings are divided into working time savings, which are based on the hourly wage rate of the workers in question, plus a margin for overhead costs, and leisure

time savings, which are valued at rates based primarily on stated preference studies of what users are willing to pay to save time. Accident cost savings reflect the loss of output of those injured, which is valued at the wage rate, together with damage to property, medical expenses etc. In addition a value is placed upon the pain, grief and suffering associated with the loss of life. These values have recently been revised, in accordance with stated preference results on the willingness to pay to reduce the risk of death so that now a life is valued at £744057 in 1991 prices (DTp 1993).
The net present value of a scheme is calculated by taking the costs and benefits of a scheme expressed in monetary terms discounted over 30 years at a discount rate, currently set by the Treasury at 8% (Nash et al 1991b).

#### 3.2.1.3 Environmental Impacts

The environmental impact assessment of new road transport schemes is based upon the DTp's Manual of Environmental Appraisal (MEA) (Department of Transport 1983). This composes both the environmental effects resulting from traffic as well as land loss and damage to sites as a result of new construction. The MEA includes the impact of a project upon a list of attributes as well as policies for enhancing and conserving the area. The attributes are traffic noise, visual impact, air pollution, severance, effects on agriculture, heritage and conservation areas (including demolition of property), ecology, construction disruption and pedestrians and cyclists. No consideration is given to the cumulative effects of individual projects upon environmental systems, for example global warming. Each impact category is measured in different ways and valued in non-monetary terms, although by including such effects in the Leitch Framework alongside time savings, accident savings and changes in vehicle operating costs, they receive an implicit monetary valuation in the final decision.

### *3.2.2 British Rail Investment Procedure*

#### 3.2.2.1 Financial Appraisal

In the case of British Rail schemes are generally submitted solely to a financial appraisal, as opposed to social cost benefit analysis. Schemes are currently required to earn an 8% real rate of return in order to proceed (Nash et al 1991b). Schemes are always sponsored by one of the British Rail sectors, which does the outline appraisal; they are then fully appraised by the British Rail corporate investment analysts before going to British Rail Investment Committee for approval. Finally, major schemes (over £10 m require DTp approval before going ahead and may be "called in" by DTp for a full examination of the appraisal. A summary of British Rail investment proposals is produced annually in the British Rail Corporate Plan.

Such an appraisal obviously considers savings in operating cost and increases in revenue as the only two sources of benefit to the railway from the project. No considerations are given to the benefits that users of rail service may obtain from the scheme on the assumption that these benefits are all recouped from the fare box. Of these, it appears that savings in operating cost are generally regarded as the safest basis on which to put forward proposals (Nash et al 1991a).

A full range of options must always be considered to ensure that the project selected is not just a good one but is the best for the route in question. This should include a "do nothing " base where feasible, a "do minimum" investment option and two or more major alternatives. In the case of grant aided services, bus substitution is usually one of the options. Benefits and costs are discounted over 30 years (scheme period) at 8% discount rate. The option with the highest NPV will normally be selected.

#### 3.2.2.2 Government Grant

Grants under Section 56 of the 1968 Transport Act may be paid by Central Government to local authorities for the support of rail investment projects where there are adequate external benefits. Such grants are for projects of regional significance, normally costing at least £5m, and generally cover 50% of the net cost of the scheme. The remaining 50% is normally expected to be found by the local authority.

The grant is assessed as 50% of capital expenditure after deducting contributions from other sources. These might include borrowings, where the project will yield a surplus that can serve part of the capital cost, private or developer contributions or European Regional Development Fund Grants.

Where schemes are eligible for Section 56 grants, a social cost benefit analysis is called for. During 1988 DTp issued new guidance on Applications for Section 56 grants for rail and light rail schemes. This made it clear that only external benefits (i.e. reduced congestion, environmental and where these could not be recovered as developer contributions, developmental benefits) were seen as a justification for grant aid. Benefits to public transport users were to be excluded from the analysis; on the grounds that these should be recovered by the operator in the form of increased fares revenue. Private contributions from developers are also to be sought wherever possible. By contrast, Transport Supplementary Grant, which is paid to local authorities for highway schemes is much more generous, is paid for schemes above £1 m and justified largely on this basis of user benefits (May et al 1991).

The paradox of the new regime regarding Section 56 grants is that the most readily measured item, user benefits, are disallowed. As a result enormous effort has to be put in to measuring smaller, more obscure effects, as well as investigating the possibilities for private finance. As a result, developing a Section 56 grant application is much more expensive and time consuming than applying for Transport Supplementary Grant, and there can be a time lag of many years between initial application and receiving the grant.

#### 3.2.2.3 Environmental Impacts

There are no formal procedures for valuing the environmental impacts or benefits which arise from railway project investment. In the past various ad-hoc approaches have been used where major projects have been appraised e.g. East Coast Main Line electrification. More recently the introduction of new legislation on Environmental Impact Assessment (EIA) requires that major new rail projects require an EIA e.g. Manchester Light Rapid Transit. In many respects this requirement covers many of the same issues where relevant as are laid out in the MEA for roads. Such an appraisal would generally be concerned with assessing the negative impacts of rail transport on the environment rather than comparing the relative impact of rail vs. road investment or including the environmental benefits from modal switching, as the current study suggests.

## 3.3 Summary of the Current Practice

This section summarises the current practice of transport investment appraisal in the UK.

### *3.3.1 Economic Evaluation*

Economic evaluation is used by the DTp and the Scottish Office for the assessment of trunk roads and this is normally undertaken using the COBA program except in Scotland where the, broadly similar, NESA package is used. The main benefits included in the evaluation are time savings for car users, car operating cost savings and reductions in road accidents. Major local authority highway schemes are also normally subject to economic evaluation and this is expected for schemes submitted to the DTp for Transport Supplementary Grant (Vaughan et al 1992).

### *3.3.2 Financial Evaluation*

British rail projects are usually assessed using financial evaluation but the DTp has indicated that it is prepared, under certain circumstances, to consider wider economic benefits in the case of Regional Railways and Network South East projects. A recent example where economic evaluation was used during evaluation of the Cross-rail scheme in London (Vaughan et al 1992).

### *3.3.3 Section 56 Grant*

Section 56 Grant is available for major public transport schemes, promoted by local authorities and private sector bodies. Under current DTp guidelines (DTp 1989), applications for this grant are assessed using a hybrid evaluation. The main assessment is financial, but economic evaluation is used to include non-user benefits that cannot be captured financially.

## 3.4 Perceived Weaknesses of Current Appraisal Practice

### *3.4.1 Introduction*

This part presents a summary of the weaknesses in the current appraisal techniques. In section 3.4.2 the general criticism of the current appraisal methodology is presented whilst sections 3.4.3 and 3.4.4 detail weaknesses specific to highway and public transport appraisal respectively. Lastly section 3.4.5 summarises this part.

### *3.4.2 General*

The main general criticism of current urban transport appraisal one can think of is its failure to provide a consistent framework in which all possible transport responses to urban policy objectives may be judged. Social CBA is considered to be acceptable as a methodology for this purpose but must be applied to all transport improvements consistently with amendments and corrections as suggested in this study. In short the appraisal method should present all the relevant costs and benefits clearly and concisely. It should also enable testing of alternative transport policies involving parking control, public transport subsidy, and company car measures. The end aim is to allow policy makers to take informed decisions and for those affected to see the rationale behind and consequences of these choices (May et al 1991)

### *3.4.3 Specific Road Weaknesses*

#### 3.4.3.1 Road Funding

For public funding purposes roads may be divided into three groups: trunk roads which are the responsibility of the DTp and centrally funded, non-trunk roads which are eligible for the centrally funded Transport Supplementary Grant (TSG) , and those roads which are wholly financed from local funds. There are identifiable biases in the present system of grant allocation which favour larger scale, capital intensive highway schemes which are eligible for central funds regardless of the benefit to cost ratios (B/C). The allocation of the transport supplementary grant for local road building concentrates on projects with a high total Net Present Value rather than those with high benefit/cost ratios. In addition local government might be persuaded to undertake TSG funded road building rather than smaller schemes involving road building or, for example, traffic calming which are funded from local budgets. These observations imply that the present methodology does not apply a consistent or common appraisal technique to the different highway based measures which may be used to address a potential transport problem (May et al 1991).

#### 3.4.3.2 Treatment of Externalities

The appraisal of trunk road investment normally has two components: the running of the COBA programme and an environmental assessment using the Manual of

Environmental Appraisal (MEA). The COBA programme estimates the scheme benefits in the form of accident reductions and the time and operating costs savings to all road users. It discounts these benefits and costs to give a measure in current monetary terms of the project's value (NPV). The MEA is a non-monetary assessment of the environmental effects of the highway scheme.

It is often argued that the externalities resulting from highway schemes are either under-weighted, as with the environmental effects, or simply not measured, as with the effects on the economic development of an area.

As regards the environmental effects, it appears that these are mainly taken into account at the stage of selecting which option to pursue for a particular scheme. More strategic decisions are based almost entirely on the relative NPV's of different schemes, and these of course take no account of environmental factors (Nash et al, 1991b).

The treatment of development effects has been a matter of much controversy. To the extent which they can be predicted, it is correct, of course, to base the traffic forecasts on such predictions, and therefore some attempt needs to be made to consider the impact of new infrastructure on the development of the immediate and wider areas. Annex B submissions for TSG may " if appropriate" include information on "new industrial and commercial development or redevelopment which is associated directly with the scheme" (DTp 1991a). However, there is no indication of the weight to be placed on such information the assessment process.

### 3.4.3.3 The Impacts on Pedestrian and Cyclist

The effects of highway schemes on the journey times of Pedestrian and Cyclist are not currently estimated. In the urban context the value of these costs and benefits may be significant to the extent of altering the acceptability of a scheme if they were incorporated.

### 3.4.3.4 Distribution Effects

These are largely ignored under the present system of appraisal. Cost Benefit Analysis assumes that £1 of cost or benefit is worth the same whoever gains or losses it. Just like a commercial appraisal. The marginal utility of money is assumed to be equal and constant between individuals. This introduces a bias in favour of the wealthier members of a society who have a lower marginal utility of money and can afford to pay more for a given level of benefit. A scheme which gave £5 of benefit to a rich man and extracted a cost of £4 from a poor person would yield a positive net benefit under the current practice. This is not to say that CBA is an inappropriate appraisal technique, merely, that to be used to best advantage the underlying assumptions must be made clear.

COBA contains a standard value of leisure time, regardless of the incomes of those affected. A value based on willingness to pay would bias investment in favour of wealthier areas. However, there is also a problem with the equity value which gives a greater value to poorer individuals than they actually possess, relative to, say, money savings. The danger is this could result in investments taking place justified on these figures which the true value is negative to those affected by it.

#### 3.4.3.5 Scope of the Appraisal

The definition of a study area to capture the full effects of a highway investment is an important step in the appraisal process. The Traffic Appraisal Manual for trunk road assessment section 3.3.1 defines the study area as being the area "within which the construction of the scheme or rout improvement would significantly affect the traffic flows" (DTp 1981b). The provision of new highway infrastructure may have consequences for the road network beyond the immediate confines of the planned improvement. To the extent that this happens a scheme cannot be viewed in isolation and the wider impacts of the scheme need to be appraised.

The same argument may be advanced for the environmental and development effects described above. It is likely that the scheme will have impact beyond the immediate area and may indeed have city wide implications.

#### 3.4.3.6 Fixed Trip Matrix Assumptions

Because COBA programme was originally developed to appraise inter-urban highway investments, it is argued that in this context highway investments do not give rise to changes in trip distribution, modal split, and generation (DTp 1981a). Therefore the programme operates under the assumption of a fixed trip matrix which simplifies the calculation of benefits. This assumption becomes more questionable when COBA is used in the appraisal of urban highway investments, where congestion normally prevails. Consider the situation typical of urban areas where the before investment and after investment highway conditions are congested . Under a fixed matrix assumption the investment secures time savings for present road users and reduced congestion. However when the assumption is relaxed trips will be attracted to highway mode - as a result of improving travel conditions- raising congestion levels, link times, and eroding the benefits to existing users calculated using a fixed matrix. Under such circumstances the fixed matrix assumption cases an overestimate of the time savings from the investment.

The previous paragraph covered three facets of the fixed trip matrix assumption-distribution, modal split and the generation of new trips. A fourth facet concerns the effect of a scheme on peak spreading. A change in the cost of highway travel in one time period will cause some movement of trips between time periods. For example the reduction of congestion in the peak will persuade some highway travellers in the off-peak to change their travel time. The fixed matrix assumption in a situation of highway congestion will, as explained above, lead to the overestimation of benefits.

While there is provision within COBA for departure from the fixed matrix where a scheme impacts on a heavily congested urban area, this provision is rarely used in practice. The vast majority of COBA assessments are run on the fixed matrix assumption (May et al 1991).

Goodwin (1994) questioned the COBA assumption of a fixed trip matrix. He stated that, although whether the road improvement generates extra traffic or not is ultimately an empirical question. Goodwin carried on to conclude that:

> *The amount of extra traffic must of course be dependent on the specific circumstances, but an appropriate average rule of thumb is that each 10% improvement in traffic speed would cause about 5% more traffic in the short term and up to 10% more traffic in the longer term.*
>
> *What is more important is, as congestion prevails, there is a high chance of extra traffic as road gets improved, and the fixed trip matrix assumption, should always relaxed in such situations, otherwise, the probability of miss-estimation of benefits will highly exist and a distortion is likely to occur.*

### 3.4.3.7 Monitoring Projected Benefits

The DTp has recently invested resources in comparing the forecast and actual benefits of highway schemes attempting to judge the accuracy of highway appraisals. This is a welcome development because of the existing emphasis placed on the provision of convincing forecasts rather than assessing the achievement of specific results. For most highway schemes there is no systematic monitoring of the project performance and this is seen as a weakness.

### 3.4.3.8 The Treatment of Risk and Uncertainty

Benefits based on forecast traffic volumes, costs and benefits over a 30 year time scale are subject to uncertainty and risk. Current DTp practice is to take high and low growth assumptions and weight the outcomes in order to allow for uncertainty. Doubts were raised as to the adequacy of this procedure.

### 3.4.3.9 Further Weaknesses

Highway appraisal does not consider the energy implications of a scheme. Although energy conservation awareness varies with oil prices there is a greater concern over the use of non-renewable resources which has its expression in the desire for more energy efficient transportation. This should be a component of the appraisal.

Concern was also given to the current treatment of freight movements, the effects on public transport, and the influence of different pricing and subsidy regimes. Highway appraisal gives insufficient attention to the effects of a scheme on the costs and environmental effects of freight movement. Highway schemes will possibly change public transport trip levels and costs (bus). The existence and magnitude of such consequences needs to be measured. Finally the appraisal does not adequately deal with pricing and subsidy issues such as company car and parking subsidies (Nash et al 1991a).

### 3.4.3.10 Annex B and Highway Appraisal

In the assessment of local roads for TSG support under the Annex B guidelines (DTp 1991a) a COBA assessment of the economic benefits may be supplemented by evidence on road safety, the environment, the local community and local industry and commerce. The latest guidelines have been revised in the light of a report by

Transport Planing Associates for the Department of Transport on local scheme appraisal (Transport Planning Associates , 1991). The type of information required in these areas is clarified, for example the Manual of Environmental Appraisal should be used to examine impacts on the environment and on the community, while road safety benefits may be expressed in terms of reduced accident rates and changes in the number of expected personnel injury accident per year. However, coverage of these issues remains largely descriptive with no clear indication of how such impacts should be weighted against those with a monetary value.

### *3.4.4 Public Transport*

#### 3.4.4.1 Current Appraisal Methods of Public Transport Investment

As stated before (section 3.2.2.2), Section 56 grants may be given for certain public transport projects of regional import and of significant cost; generally only projects with a cost in excess of £5 million are considered (DTp 1989). Under the current practice potential benefits of rail schemes come in the form of increased revenue or reduced operating costs. May (1991) argues that it is usually easier to justify investment on the basis of the latter because revenue is more difficult to forecast.

Under Section 56 guidelines grants may be given for certain public transport projects of regional significance such as the Manchester LRT system. An authority must conduct a form of CBA and also appraise the environmental effects of a scheme. However section 56 rules prevent the inclusion of benefits accruing to the users (new and existing) of the affected mode when doing the CBA. In effect the application for grant must be justified on the basis of its external benefits in the form of road de-congestion and development impetus. The DTp assumes that any user benefits will contribute to the cost of the scheme through increased fares. In addition where there is a possibility of gain to commercial organisations - e.g. developers - they should be made to contribute as far as is practicable. Added complexity is given to the appraisal by the need to study in detail the prospects for private funding.

Investment by bus operators is solely based on commercial criteria with a consequent failure to consider externalities or consumer surplus (user benefits) except where it may be converted into revenue by fares increases. Public funding may be obtained through the tendering process for uncommercial routes. It has been argued that investment in bus services has been depressed by the uncertainties created by this procedure. At the same time, the inability to fund improvements in services or reductions in fares on commercially viable routes is a major constraint on transport policy (May et al 1991).

#### 3.4.4.2 The Potential Implications of Public Transport Appraisal Methods

Several of the weaknesses detailed and discussed under road appraisal method are applicable also to public transport. External impacts are not usually considered in British Rail appraisals at all, although the recent Central London Rail Study (DTp, 1990) includes both benefits to passengers and congestion relief on the roads in the CBA. An environmental impact study was also carried out, and there is some discussion of wider impacts such as regeneration.

Under Section 56 grant external effects are assessed and there is an emphasis on estimating any benefit to developers. However, there is no established procedure for valuing either environmental effects or development benefits in money terms, which makes assessment of value for money from section 56 grants difficult.

Similar weaknesses about the scope of the appraisal in assessing all the effects of the scheme, and the effects of rail congestion on peak spreading also apply. These represent minor problems in comparison with the basic methodological inconsistency between appraisal techniques.

In the case of bus companies, it is argued that effects other than any change in the cost of tendered services should be ignored, as these form part of the commercial sector of the industry. However, changes in bus service profitability lead to changes in fares and service levels, with consequent costs or benefits for their users. In a full cost-benefit analysis these user costs or benefits should be assessed together with any second-round effects on third parties such as other road users.

The treatment of accidents under section 56 is very curious and not completely clear, indeed grant applicants are not required to consider accidents at all. If accidents are assessed :

"average net output loss plus medical cost should be assumed at 7.5% of the overall value given there for a fatal accident. The results may then be applied to fatalities avoided by those projected to switch to the new mode" (DTp 1991b).

The section 56 guidelines require that new public transport investments should be funded as far as possible through user contributions, fares. Revenue maximisation will have adverse implications for distribution. No public transport operator can price discriminate perfectly; therefore there will be a loss of scheme benefits as some potential users are priced off. Those priced off will be those who value their trips least in money terms. Low income users are likely to be those most affected as they are least able to pay. These low income users are also unlikely to have access to private transport. Thus, a perverse result emerges whereby an improvement to public transport may result in a loss of mobility for low income users.

#### 3.4.4.3 A Misallocation of Funds in Favour of Road Solutions

In cases where given objectives may be achieved through alternative combinations of private and public transport this inconsistency between road and public transport in methods of appraisal and allocating investment funds is likely to lead to a misallocation of resources in favour of highway schemes. For British Rail the use of financial criteria tends to give a lower benefit to cost ratio than would have resulted using CBA. Benefits resulting from external effects such as road de-congestion are omitted and benefits to users are only included to the extent to which they may be recouped by fare increases.

For the Section 56 grant the most measurable form of societal gain (user benefit) is disallowed and instead benefits to road users and developers must be estimated. These effects are much more difficult and expensive to measure resulting in very long and expensive applications. Bates and Lowe (1989) demonstrate how the different criteria of highway and public transport appraisal undermine the net returns of public transport schemes. In an example they show how the external de-congestion benefits of a rail scheme are eroded when fare increases are used to capture all user benefits (Bates and Lowe, 1989). Indeed the ability of most fare systems to do this is questionable given their coarse nature. In short the inconsistencies in evaluation techniques between modes is the major weakness in current appraisal methodology leading as it does to resource misallocation in the light of all the relevant costs and benefits.

### *3.4.5 Summary*

This part has examined the weaknesses of the current methodology for transport investment appraisal in the UK. The major points may be summarised as follows:

#### 3.4.5.1 Road Appraisal

A) The reliance on Net Present Value (NPV) as a measure to the scheme benefits, combined with grant eligibility rules, leads to bias in favour of large scale, capital intensive schemes.

B) External impacts such as those on the environment are treated descriptively, with no clear weight placed on these impacts. There is thus a danger that they will be undervalued relative to those factors included in the NPV.

C) Some factors are excluded from appraisal framework include impacts of energy consumption, public transport trip levels and costs (bus)

D) Some other factors are inadequately dealt with include pricing and subsidy issues relating to public transport, company cars and parking.

E) The reliance on a fixed trip matrix for traffic forecasts may lead to distortions (in terms of under or over estimation of benefits), particularly in congested networks.

F) Results are presented in aggregate form, making distributional impacts difficult to assess.

#### 3.4.5.2 Railways

The emphasis is on financial rate of return, without considering the wider social costs and benefits of schemes.

#### 3.4.5.3 Buses

Bus operators assess services on commercial criteria, omitting any consideration of user benefits or externalities except where they may be converted to revenue through far changes.

#### 3.4.5.4 Section 56 Grant

A) Revenue extraction of user benefits may reduce total benefits by limiting patronage. Also those priced off are likely to be low income users, who are least likely to have access to private transport. There may be a loss of mobility for low income users.

B) Accidents avoided by users are valued at a fraction of the normal values applied in COBA.

C) The appraisal omits any valuation of benefits to users aside from that extracted in fares revenue.

#### 3.4.5.5 Conclusion

The lack of a consistent appraisal framework and funding method across all modes in general ***and between road and rail in particular*** is seen as a major weakness of the current appraisal approach in evaluating transport schemes in urban areas. This fact together with the main conclusions of chapter 2, that cost benefit returns are likely to be higher than the financial returns, as a result, a systematic bias towards highway investment is likely to occur.

### 3.5 Chapter Summary

This chapter outlines the current British practice of transport investment appraisal. It shows that road investments are currently appraised on a pragmatic cost benefit basis using the DTp's COBA program. The appraisal framework does not value the environmental impacts in monetary terms. On the other hand, rail schemes are assessed on financial basis. Grants are given for rail projects of regional importance, that have enough non-user benefits to justify grants, while the main benefits of rail schemes (user benefits) are not included.

The weaknesses of the current appraisal practice are detailed and the major wakens is the lack of a consistent comprehensive appraisal framework for all modes. This inconsistency allows for potential undesirable implications concern the allocation of resources and distortions to the decision of investment. These implications are to be discussed in the following chapter.

## References


1. **Bates J. and Lowe S.** (1989) *Criteria for Public Support in Urban Public Transport.* Presented at Summer Meeting of PTRC.
2. **Department of Transport, British Rail, London Regional Transport and London Underground Ltd** (1990). *Central Rail Study - a report on further work 1990.* Working Paper.
3. **Department of Transport** (1991a) *"Transport Policies and Programme Submissions for 1992/93 - Information Required on Individual Major Highway Schemes"* . Highway Policy and Local Roads Division.
4. **Department of Transport** (1991b) *3/89 Annex A to Department of Transport Circular.*
5. **Department of Transport** (1983), *Manual of Environmental Appraisal.* HMSO, London.
6. **Department of Transport** (1979) *Report of the Leitch Committee, ACTRA*
7. **Department of Transport** (1981a) *COBA 9.* HMSO London
8. **Department of Transport** (1989) *Section 56 Grant for Public Transport, circular 3/89.*
9. **Department of Transport** (1993) *Road Accidents Great Britain.* HMSO, London.
10. **Department of Transport** (1981b) *Traffic Appraisal Manual.* HMSO, London.
11. **May. A. D. et al** (1991) *The Development of a Common Investment Appraisal for Urban Transport Projects.* The Institute for Transport Studies, the University of Leeds and the MVA Consultancy, ITS Working Paper 348. December 1991.
12. **Nash C. A. et al** (1991a) *Evaluation of Road and Rail Projects: Issues and New Developments.* ITS, Leeds University.
13. **Nash C. A et al** (1991b). *The Future of Railways and Roads.* Institute for Public Policy Research. London.
14. **Nash C. A. and J. Preston** (1991) *Appraisal of Rail Investment Projects: recent British Experience.* Transport Reviews vol. 11 no. 4 pp. 295-309
15. **Transportation Planning Associates** (1991) *" A Review of Traffic and Economic Appraisals of Local Authority Highway Schemes"* Final Report to the Department of Transport.

16. **Vaughan B. C. et al** (1992) *"Comparability in Road and Rail Investment Appraisal: The Trans-Pennine Rail Study Example".* PTRC Summer Annual Meeting ,Siminar C, Manchester, September 1992.
17. **Goodwin P. (1994)** *Traffic growth and the dynamics of sustainable transport policies.* Transport Studies Unit, University of Oxford.

# Chapter 4

## Implications of the Inconsistency of Appraisal Techniques Between Road and Rail

### 4.1 Introduction

Chapter 2 identified the main methodologies of assessing the investment projects in the transport sector. It demonstrated the differences between cost benefit and financial analysis, and concluded the possible existence of a divergence between cost benefit and financial returns, and that the divergence is a function of both demand and cost elasticity as well as the pricing policy operated.

Chapter 3, explored the practice of investment appraisal in transport modes in the United Kingdom. It showed that road investment is being assessed on a pragmatic cost benefit analysis basis, while rail investment projects are evaluated on financial basis. The main weakness of the current practice is the lack of a consistent framework for assessing the investment and allocating funds between all modes of transport in general and between road and rail in particular.

This chapter illustrates how the findings of chapter 2 and the situation presented in chapter 3 may lead to misallocation of investment funds between road and rail and then result in welfare losses to the society at large. It also considers different alternative solution to the inconsistency of appraisal methods and the possible contribution each alternative may provide and the applicability of them in practice.

### 4.2 The Decision to Invest

Whether or not to invest in new physical capital, such as machinery, equipment factories, stores, railway line and roads, depends in part upon whether the expected rate of profit or rate of surplus on the new investment is greater or less than the interest rate that must be paid on funds that need to be borrowed to acquire these assets. Even if the funds were readily at hand, a decision would have to be made between the alternative of using the funds to purchase the new physical asset or of lending the funds to someone else at the existing market rate of interest. A moment's reflection confirms the fact that these two decisions are one and are the same.

Whether the funds are available or must be borrowed makes no difference; the asset should be bought if its expected rate of return exceeds the market rate of interest.

The rate of return on new investment is generally known as the Marginal Efficiency of Capital (MEC) and sometimes as the expected rate of return over cost on the new investment (Dernburg and McDougall 1976). Economic theory suggests that the profitability of new investments decreases as the investment level rise. This would be because of some or all of the following reasons:

1. as the investment level grows, the demand and then the price of the factor services increase and then the cost of carrying out the project increases.
2. as the investment level rises the supply of goods produced rises and a fall in sale prices are inevitable, which reduces the expected revenues or people willingness to pay for the goods or services.

## 4.3 Cost Benefit and Financial Marginal Efficiency of Capital

Chapter 2 showed that the cost benefit rate of return is most likely to be higher than the financial rate of return, in other words, the cost benefit MEC is most likely to be higher than the financial MEC. This fact, if it is translated into investment decisions, will have some implications in determining the investment levels for both road and rail and in consequence will have some undesirable welfare implications.

### *4.3.1 Investment Level*

Figure 4.1 depicts a situation for a hypothetical firm. The horizontal line shows different levels of investment, while the vertical axis presents the levels of profitability (MEC) for each level of investment. As can be seen the social profitability curve (CBA) is above the commercial profitability curve (FA) reflecting the fact that CBA returns are higher than financial returns.

If this firm were a railway organisation, assessing the profitability of new investments on commercial basis, and if the market rate of interest is (X), the level of investment that is worth undertaking will be $OI_f$ , where the MEC is equal to the interest rate. But if the railway organisation were to use a wider cost benefit analysis in assessing the investment profitability, the level of investment to be worth carrying out would have been $OI_E$. The difference between the investment level justified financially and that justified on cost benefit grounds will depend upon the divergence between the commercial and social rate of returns and the shape of MEC curves. The main fact that can be captured here is that the difference between $I_E$ and $I_f$ will present a missing opportunity for the society and then will imply a general welfare losses.

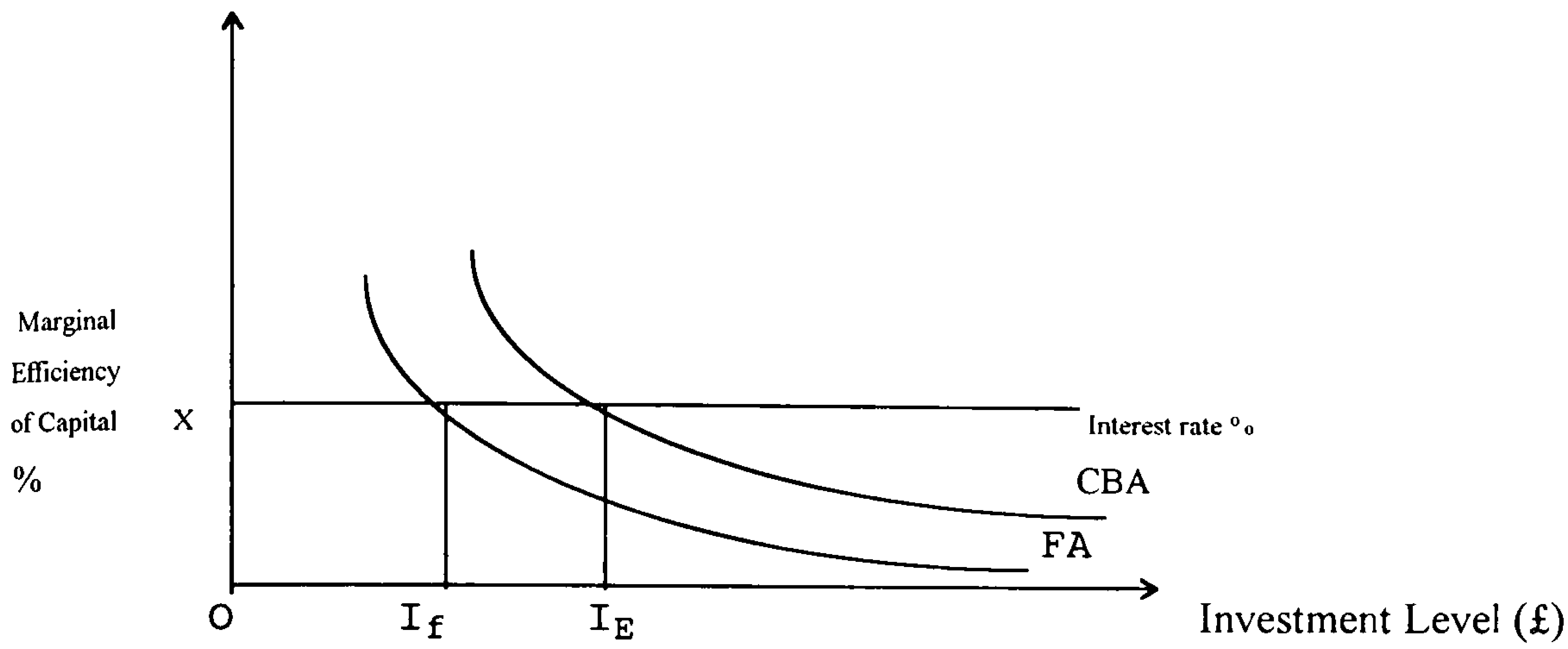



Figure 4.1 Cost Benefit and Financial Marginal Efficiency of Capital

### *4.3.2 Implications on Investment Timings*

If one agrees that cost benefit returns are higher than financial returns, and the two measures are used for assessing investment in road and rail respectively, one might argue that the case will cause a delay in rail investments or speed up investments in roads.

The argument was first raised by Foster who concluded:

> *If the rate of interest which equilibrates the demand and supply of loanable funds is X %, then if one makes the classical assumption of diminishing returns to capital, one would expect investment funds to go only into marginal projects. Thus in a classical economy, it would at first appear that projects would always be invested in earlier if a social criterion rather than a financial criterion were used, which is another way of saying that the social return for any given investment would seem higher (Foster 1973).*

In reality the profitability of rail investments will rise from one year to another, this is because of two reasons:

1. increasing traffic on roads over time worsens the road condition and leads to a potential increase in public transport patronage.

2. the general growth in the economy will lead to higher demands for both road and public transport services.

In fact when discussing the impact of time on the profitability of rail investments, one has to distinguish between different types of investments. For example, rail schemes may be categorized as follows:

1. Pure expansion schemes (e.g. new railway line)
2. Replacement schemes (e.g. rolling stock replacement)
3. Improving service quality schemes (electrification)

The categorization of rail schemes can vary according to the purpose of classification. In addition, for a given classification, such as the above one, some schemes may fall in more than one category.

The change in scheme profitability over time may depend in part on the type of the scheme. For a pure expansion investments (e.g. new rail line), one might assume to a degree that the scheme profitability will rise from one year to another. This is because of the growth in road traffic, which will worsen road travel conditions and then more demand for rail will be expected. In addition, the general growth in the economy may mean more travel demand for the new rail line.

What is said about the pure expansion schemes might be true to some extent for the schemes that improve the quality of rail service. For example, if an electrification proposal or a rolling stock replacement is going to improve travel conditions, faster trains, more comfortable trains, less noise while on board, one might assume to a reasonable degree of confidence that the profitability of such schemes is increasing from one year to another (unless some improvements are carried out on road at the same time).

On the other side, when talking about a rail scheme that only lead to savings to the operator cost (cost reducing schemes), the argument of changing profitability over time is not clear.

Further more, the issue of changing rail investment profitability over time may vary according to the method of which the investment profitability is measured. For example, a new rail line links two main cities might not have an increasing returns to the rail operator from year to another one. However, the social profitability of the line may rise from one year to another. This may lead to conclude that not only financial and social returns are different for a given scheme, but also their behaviour over time may be different.

So if the expected returns on some rail projects are increasing function of time, that is to say the returns on the investment are increasing from year to another. In consequence, this will have some implications in determining the timing of an investment. For example, a rail project that was rejected last year because it was not financially viable, and proved to be viable financially this year, if a wider CBA were used to assess the social benefits of that project , it might have been selected last year. So financially assessed projects might always have to wait for sometime to be viable, while on CBA grounds, they might have been selected earlier. The flowing section illustrates how a delay might occur.

Assuming that cost benefit return is higher than the financial return, that is to say:

$$ER_n = FR_n \times X \qquad (4.1)$$

Where:

$ER_n$= cost benefit rate of return for a given project in year n (%)

$FR_n$= financial rate of return for a given project in year n (%)

X= rate of exchange between cost benefit and financial rate of return

If as mentioned above, rates of return, (social and financial), are increasing function of time, that is to say:

$$ER_{n+1} = ER_n \times T \qquad (4.2)$$

Where:

$ER_{n+1}$= cost benefit rerun on year n+1

T= factor determines the change of investment returns over time

Solving equations 4.1 and 4.2 in $ER_n$, the following relationship can be obtained:

$$ER_n = FR_{n+1} \times \frac{X}{T} \qquad (4.3)$$

Equation 4.3 indicates that the cost benefit return this year (year n) is equal to the financial return in the next year (year n+1), times the ratio of X over T. The following can be concluded:

1. if X = T, the socially appraised investments have to wait one year to achieve a financial return equal to their cost benefit return now.

2. if X>T, that means the socially appraised investments will wait more than one year to achieve a financial return equal to their cost benefit return now.
3. if X<T, that means the socially appraised projects will wait less than a year to achieve a financial return equal to its cost benefit return now.

In conclusion, as far as the ratio of cost benefit to financial returns X, is more than one, which is probably the case, as chapter 2 concluded, and the returns on the investment rise over time, there will be an opportunity of good schemes failing to go ahead not for any reason, but because they are subject to a commercial assessment.

#### *4.3.3 Implications on the Allocation of Resources Between Road And Rail*

What are the allocation conditions that have to be met if units of any given resource are to make their maximum contribution to welfare?. In general terms the requirement is that the value of marginal product (MP) of the resource in any one of its uses be the same as its value of marginal product in all of its other uses.

Suppose, for example, that a machine used on agriculture purpose contributes at the margin £1000 worth of agriculture products annually to the output of the economy, and that machine can be used for construction purposes and can contribute a yearly £2000 worth of products. If the machine were switched from the agriculture sector to the construction sector, there would be a net gain to consumers of £1000 worth of product. In this case some consumers will be made better off without making anyone worse off. So, transfers of resources from lower value of marginal product uses to higher value of marginal product uses always yield a welfare increase to the society as a whole. The maximum welfare will be achieved when these transfers have been carried to the point at which the value of marginal product for each resource is the same in all its alternative uses.

The above example can be generalised, whether the resource is a machine, labour force, money, and even a piece of land, or any combination of two or all of them together. The Marginal Product (MP), can be estimated in any case, and resources have to be allocated accordingly till all the MPs are equal at all margins.

Investing in a new railway line or in building a road is a clear example of allocating resources to improve the transport sector. Whether the investment is worth undertaking will be determined by valuing the costs and benefits of the proposed schemes in order to rank them in terms of their net present value or internal rates of return. The measured NPVs or internal rates of return is the reflection of the marginal product of the resources employed in the proposed schemes. So the choice of these schemes in fact will be determined by their marginal products. Given an amount of resources, and if the maximum social welfare is to be achieved, resources have to be used between the alternatives up to the point where the returns or NPVs are all equal at all margins.

The problem at issue is how can this rule be applied in the transport sector and especially, how can the funds of investment be allocated between road and rail investments, the first being assessed on cost benefit basis, and the latter is assessed on commercial criterion.

If both road and rail investment were assessed on a social basis (comprehensive CBA), funds would have been allocated between them such that the social welfare would have been maximized. But the situation in hand might imply welfare losses to the economy.

Figure 4.2 presents the case. The horizontal axes presents the total investment funds available to be allocated for road and rail investments in one period of time (year for example). Moving from left to right on the axes means more investments allocated for rail and less funds for road. In the contrast, moving from right to left means more funds to be given to road and less for rail. The left and right horizontal axes, present the expected rates of return (MEC) from different levels of investment for both road and rail. As can be seen, the figure presents the financial and cost benefit marginal efficiency of capital schedules for road and rail.

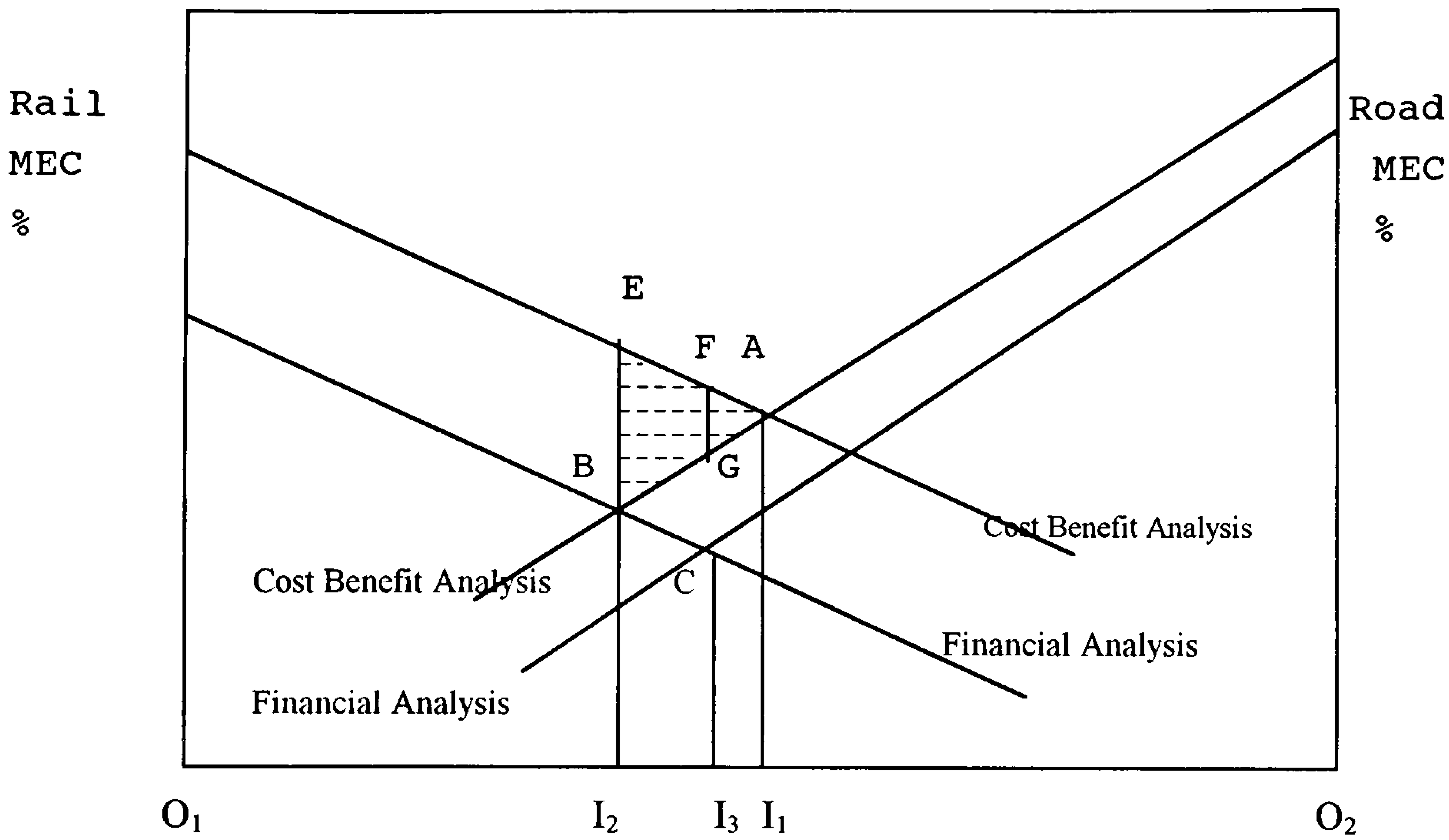


Figure 4.2 Welfare losses of appraisal inconsistency between road and rail

Point A on the figure presents the optimum position for resource allocation, where the social return on the investment for rail and road are equal, which achieves the economic rule for resource allocation. The optimum level of investment would be $O_1I_1$ and $O_2I_1$ for rail and road respectively. This point will achieve the maximum social welfare can be obtained from road and rail investments.

The situation in hand, where road investment is appraised on social basis and rail investment assessed on financial grounds, would suggest that point B is the allocation of funds between the two modes. The level $O_1I_2$ will be allocated to rail and $O_2I_2$ will be allocated to road. Comparing the positions A and B, rail would loss an amount of funds equal to $I_1I_2$, which will be allocated to road instead. In other words, there will be over investment in road and under investment in rail sector.

Since social welfare of the investment is defined as the total area under the social marginal efficiency curves, choosing point B instead of the optimum point A, will imply a welfare losses measured by the area BEA, and this undesirable welfare impacts are mainly caused by the inconsistency of the evaluation methodologies between road and rail.

## 4.4 Downs-Thomson Paradox and the Equilibrium between Rail and Private Transport

If the inconsistency of appraisal methods between road and rail leads to favour road investments on the account of rail investments, this might have a reverse reaction for the two modes given that they are operating in congested condition. In other words, allowing for more roads to be built or more widening will worsen the congestion on roads and can lead to a deterioration to public transport in general and rail in particular. These consequences are based on the assumption that public transport in general and rail in particular are services produced with a downward-sloping cost curve, while roads have an upward-sloping cost curve. The following paragraphs show how this reverse reaction may happen.

Lardner was the first to recognise that railways have such a downward-sloping cost curve, or the existence of economies of scale in railway operation (Lardner, 1850). The argument was also raised by Joy in 1973 and 1989, who admits that a very high proportion of railway costs were fixed and the marginal cost of the extra flow or volume will be lower than the average cost. He used this argument as a justification for a subsidisation to railways (Joy, 1973 and 1989). Lang and Soberman in 1966 give an analysis of urban rail transit systems in the USA. This analysis suggests that there are indeed economies of scale in such operations, and therefore that marginal costs are below average costs (Lang and Soberman, 1966). Mohring in 1972 gave a detailed analysis of the average and marginal costs of operating the Minneapolis-St Pauls (Twin Cities) bus system. His analysis and conclusions supported the assumption that public transport services are produced with a downward-sloping cost curve (Mohring, 1972).

Downs in 1962 seems to have been the first to argue through the consequences for the allocation of the space of the city between car users and public transport users. He argues, that where roads had an upward-sloping cost curve, and public transport had a downward-sloping cost curve, an equilibrium between car and public transport costs would be established. At this point, there would be travellers who would have the same costs by road as by public transport, and who would be indifferent as to which of the two methods of travel they should use. Then he went on to speculate on what must happen if there is such an equilibrium between public and private transport costs. He then admits that if road capacity is increased, by the construction of a radial expressway, when the alternative is a segregated-track rail service, and a very large number of persons shift from segregated track transit to automobiles, the cost of such transit per passenger may rise so that its attractiveness is drastically reduced. In such a case, congestion on the highways may have to become slightly worse than it was before the expressway was opened before automobile travel becomes just as undesirable as segregated track transit travel. Then he stated the paradoxical conclusion that :

> *the opening of an expressway could conceivably cause traffic congestion to become worse instead of better, and automobile commuting times to rise instead of fall (Downs, 1962).*

Thomson is conjoined to the paradox because he also recognised the phenomenon. In his book Great Cities and their Traffic (Thomson, 1977), defined his paradox as the following:

> *Unhappily, attempts to improve traffic conditions by providing more capacity (on the roads) can lead to a deterioration in public transport, if by drawing paying customers away from the latter, they force an increase in fares and a reduction in service. In this case, the balance of traffic may shift from public to private transport until a new equilibrium is reached where each system is of lower quality than before.*

If we retrieve the impact of allocating funds to road and railways on different basis, to be building, widening, and improving more roads on the account of rail improvement schemes, we might argue, bearing the reverse reaction of transport system operating on congestion condition discussed above in mind, that the consequences will probably be higher costs for rail users and more congestion on the road network. In fact, Downs and Thomson argument were basically for a case of cities, but there is still a possibility that the reverse reaction could also happen for the case of building a new motorway or widening an existing one that has a railway line on barrel, or even a single bypass while a railway line is a direct alternative. Globally, this might lead to a situation where road building and widening continue, and the result is more congestion on the roads and higher costs or fares for using railways, because more and more people will be shifting from public transport to the door to door most favourable private transport. The main conclusions of this argument may be summarised as follows:

1. The existence mix of appraisal methods between road and public transport (especially railway) - given that public transport is a downward-sloping cost curve will depress the relative competitiveness of public transport compared to private transport.
2. The wakens of public transport relative competitiveness, may probably in turn make it less attractive for more investments (unless it receives subsidisation). This is because, given that public transport is running commercially, the financial profitability of the investments will probably be wakened.

### 4.5 Alternative Solutions

The general conclusion to be drawn from the theoretical discussion in chapter 2, is that the notation of a single rate of exchange between the cost benefit and financial returns is a chimera. A large number of relationships may exist between returns calculated by the two main sets of criteria and there cannot even be a general presumption that the financial criteria always understates the true benefits of investment. Given that difficulty and considering the undesirable implications mentioned above as a result of having two different methods for assessing road and rail schemes, it is worthwhile considering other approaches or solutions to the problem. The following sections will highlight some of these solutions proposed as a contribution towards the problem of comparability between returns assessed on different basis.

1. Appraise each project submitted in the financial sector according to the most comprehensive CBA criteria available and accept or reject accordingly. This solution was put forward by Harrison and Mackie (Harrison and Mackie, 1973). They stated that this solution has two-fold difficulties. The first is, even where the right institutional framework exists, it would be very time-consuming and expensive to re-appraise on quite different criteria, all the projects submitted by the financially based sector. The second, is there would be potential conflict over those schemes which lay below the financial minimum but which could be justified by reference to other benefits. For obvious reasons the enterprise concerned would be reluctant to submit

such projects, and it would blur management objectives, they stated. However, Harrison and Mackie concluded that this solution may be suitable in some areas, e.g. conurbations, where comprehensive transportation studies are in any case carried out.

2. Modify the cost benefit criterion by omitting some benefits. This solution has been proposed by Wohl and Hendrickson (Wohl and Hendrickson, 1984), this is, to omit from the cost benefit criterion certain sources of benefit. They stated, "because of the non-comparability that would result between public and private sectors of the economy, the latter of which does not include consumer surplus in the assessment of alternative investments, and because of the indeterminate nature of consumer surplus measurement, it is our view that consumer surplus should not be included in any users trip-making benefit calculations to be used on assessing the economy of public projects.

In fact this does not seem to be the best method by which to proceed. This for two reasons, first is it is based on the assumption that the benefits omitted by the financial criterion can be approximated by omission of certain sources of benefits from the cost benefit framework. There is no guarantee that this omission will compensate correctly for the unestimated benefits of the financially assessed schemes. Second, it would seem attractive to use a social cost benefit approach as a base for all schemes, since it serves to achieve the maximum social welfare, which is probably an ultimate goal to be achieved from the available resources.

3. As a solution to the dilemma, an argument might be raised as follows:, since expected cost benefit returns are likely to be above the financial returns, this can be corrected for by raising the required cost benefit returns for road schemes and lower the required financial returns for rail investment, or in other words, raise the discount rates used for calculating the social net present value in case of road schemes and lower it when calculating the financial net present value for rail projects. This will give railways more chance to have more projects go ahead and might correct for the distortion of the inconsistency of appraisal methods. In fact this argument might be correct theoretically, but there will be a difficulty when it comes to practice. The difficulties will arise from the need to answer the following question: on what basis the required rates of return on (or the discount rate to be used for) road and rail scheme will be determined?, and if they are determined, will this correct the full

distortion caused by the use of two different appraisal methods?. In other words will the use of different required rates of returns (or different discount rates) on road and rail schemes lead to point A on figure 4.2?

In fact this solution, although it has a theoretical background to support, its practical use does not seem to be supportive. Partly because of the questions raised above, and partly from the fact that the ratio of cost benefit to financial returns is not a straightforward one as illustrated in chapter 2. The only fact one may be sure of is the existence of a divergence between the two measures. How much is the divergence is a matter of empirical evidence. In addition one might expect different ratio between cost benefit and financial return for different rail schemes. This will add to the difficulty of applying the above solution. This because, for each case the required rates of returns on the investment or the discount rates to be used, will have to be different to suit and correct for the ratio of cost benefit and financial returns for the scheme concerned, which seem to be impracticable.

4. The second argument that probably be brought, as a solution of the inconsistency of appraisal methods between the two modes is the application of financial criteria for both modes. Although, theoretically this solution might be appealing, practically it has two shortcomings, these are:

A) applying financial analysis for both road and rail will mean being at point C in figure 4.2. This point is not necessary the optimum one from resource allocation point of view and will imply a losses in social welfare measured by the area AFG. Comparing point C with point B, point C implies less welfare losses, but it still does not achieve the maximum social welfare. In fact, whether point C achieves welfare maximization or not will depend upon the relationship between cost benefit and financial returns for both modes. In other words, if the area between CBA marginal efficiency of capital curve and its financial counterpart is the same for road and rail, point C will be exactly as point A, and will achieve the maximum welfare, otherwise, point C will still not the optimum point from the welfare point of view. On the other side, it is to difficult to predict whether these areas will be the same for both modes, and there is no reason they should be the same.

B) the second shortcoming comes from the practical difficulty of applying a financial criteria for road investments, two main points may be raised here. The first is that pricing distortion that might occur in measuring the financial streams of a road investment. This is because of the fact that road users do not normally pay the full cost - if they pay at all- of using the road. So on either cases, there will not be a guarantee that the revenue collected reflects the actual cost and then the actual benefit of using the road. The second is that roads have long been understood as being a public good, that is accessible for all member of society without paying for it. And even if road pricing is applicable, it will not be easy to apply it for each single stretch of road in the country, in addition to the issue of the cost of applying the road pricing policy itself, which deemed to be not insignificant.

5. Having discussed the possibility and difficulties of other solutions to the problem at issue, probably the most appealing way of correction for the distortion and avoiding the undesirable welfare implication of the inconsistency of appraisal methods between road and rail is to make these methods consistent in a way such that they can easily be applied for both modes without practical difficulties. This will only happen. if a comprehensive social cost benefit approach - as suggested in this study-is used for both road and rail. In this case, it follows:

A) more railway schemes will probably be justified on the social grounds and then more investment will be directed to railways such that a potential right balance between private and public transport will have a chance to exist and congestion on roads will probably be improved gradually.

B) having realised that railways are more environmentally friendly compared with roads (TEST, 1991), achieving the right balance between private and public transport will definitely benefit the environment and improve the quality of life accordingly.

Achieving this desirable consistency between road and rail will require two main tasks, these are:

A) finding the comprehensive social appraisal framework that measures all the relevant costs and benefits of schemes accurately and precisely as developed in this study.

B) applying that framework to rail schemes. Here, a straight-forward application of social CBA to rail investments-given the current organizational structure of railways- might not be possible. As a result some administration instruments may be required in order to bring the consistency between the two modes. These administration tolls have to be designed to make over and match exactly the difference between the cost benefit and the financial returns. In this case the results of the current study may be used as a basis for designing these tolls.

## 4.6 Chapter Summary

This chapter illustrates the implications of the inconsistency of appraisal methods between road and rail. It showed how this inconsistency might lead to a chance of resource misallocation and welfare losses to the society. The chapter also draws attention to the possibility that the current appraisal practice of road and rail projects might help in setting the right climate so that a reverse reaction to the two modes might occur (Downs-Thomson Paradox). If this happens, then a deterioration to railway services will follow and road congestion will be worsened. The chapter ends by demonstrating some alternative options and their suitability for the problem of inconsistency.

## References


1. **Harrisson, A. J. and P. J. Mackie** (1973*) The Comparability of Cost Benefit and Financial Rates of Return.* Government Economic Service Occasional Paper no. 5, HMSO, London.
2. **Dernburg, T. F. and D. McDougall** (1976) *Macroeconomics: the measurement, analysis and control of aggregate economic activity.* Fifth Edition.
3. **TEST**, (1991) *Wrong Side of the Tracks?, impacts of road and rail on the environment: a basis for discussion.* London
4. **Joy, S.** (1973) *The train that ran away: a business history of British railways 1948-1968.* London, Ian Allan.
5. **Joy, S.** (1989) *Railway costs and planning.* Journal of Transport Economics and Policy: 23 pp. 45-54.

6. **Lang A. S. and R. M. Soberman** (1966) *Urban Rail Transit, its Economics and Technology*. Cambridge, Massachusetts, M.I.T. and Harvard University.

7. **Lardner, D**. (1850) *Railway economy, a Treatise on the New Art of Transport, its Management, Prospects and Relations, Commercial, Financial and Social.* London.

8. **Mohring, H**. (1972) *Optimization and Scale Economies in Urban Bus Transportation*. American Economic Review: Vol. 62 pp. 591-604.

9. **Foster, C. D.** (1973) *Investment and finance theory and policy in transportation pricing: investment policy and pricing in transport*. Paper presented at the International Symposium on Transport Pricing held at the American University, Washington, D. C.

10. **Downs A**. (1962) *The law of peak-hour expressway congestion*. Traffic Quarterly, 16, 393-409.

11. **Thomson J. M.** (1977) *Great cities and their traffic*. Gollancz Peregrine Edition, London.

12. **Wohl M. and C. Hendrickson** (1984) *Transportation investment and pricing policy principles*. John Wiley & Sons. New York.

# Chapter 5

## Literature Review and Previous Studies

### 5.1 Introduction

This chapter is devoted to show how the problem of comparability between cost benefit and financial rates of return and the allocation of funds between projects assessed by different criteria have been examined before. In addition, it reviews the previous rail investment studies, where both financial and cost benefit methods were used and reveals and examines how the sources of benefits and costs that are not included in the financial framework have been incorporated within the cost benefit framework. The chapter ends by showing the main features of this study and the main differences with the previous studies.

### 5.2 Comparability of Returns Measured on Different Basis

1. The problem of comparability between rate of return on an investment of a private firm with the rate of return on an investment on a nationalised industry or public corporation has been considered by Foster 1960 (Foster, 1960), who concluded that:

A) It would make sense to compare rates of return in private and nationalised industries only if nationalised industries had the same policy as private enterprise, that is generally profit maximisation.

B) It makes no sense, for example, to compare the rate of return in the electricity industry with that in British Railways, since the former, being in surplus, has a policy of passing on some of its profits in lower prices while the latter is not.

C) For example, suppose that the British Rail makes profit after it has paid its capital charges. If this were the case, many would argue that prosperity should be passed on to the consumer rather than go as a dividend to the Treasury. Let use suppose that this advice prevails and that the average rate per passenger mile is reduced from 3 to 2. By intention this is less than the railways could get from their services. In other words they are paying a subsidy of a penny a mile. In this situation it would be ridiculous to compare the rate of return on the railways capital with that earned by private firm which did try to maximise its profits.

2. In an essay about financing transport investment , Sadove and Fromm, in 1965 concluded the following (Sadove and Fromm 1965):

*"The conclusions of economic and financial analysis of projects can conflict and conclusions based solely on either economic rates of return or financial analysis should not determine investment priorities. A combined approach should be utilized."*

3. Analytic discussion of the comparability problem appears to have considered with an unpublished paper by J. L. Carr of the Treasury Economic Section, the gist of which was published in 1967, (Carr, 1967), which used a simple model of a tolled and un-tolled road. This is shown in the following diagram:

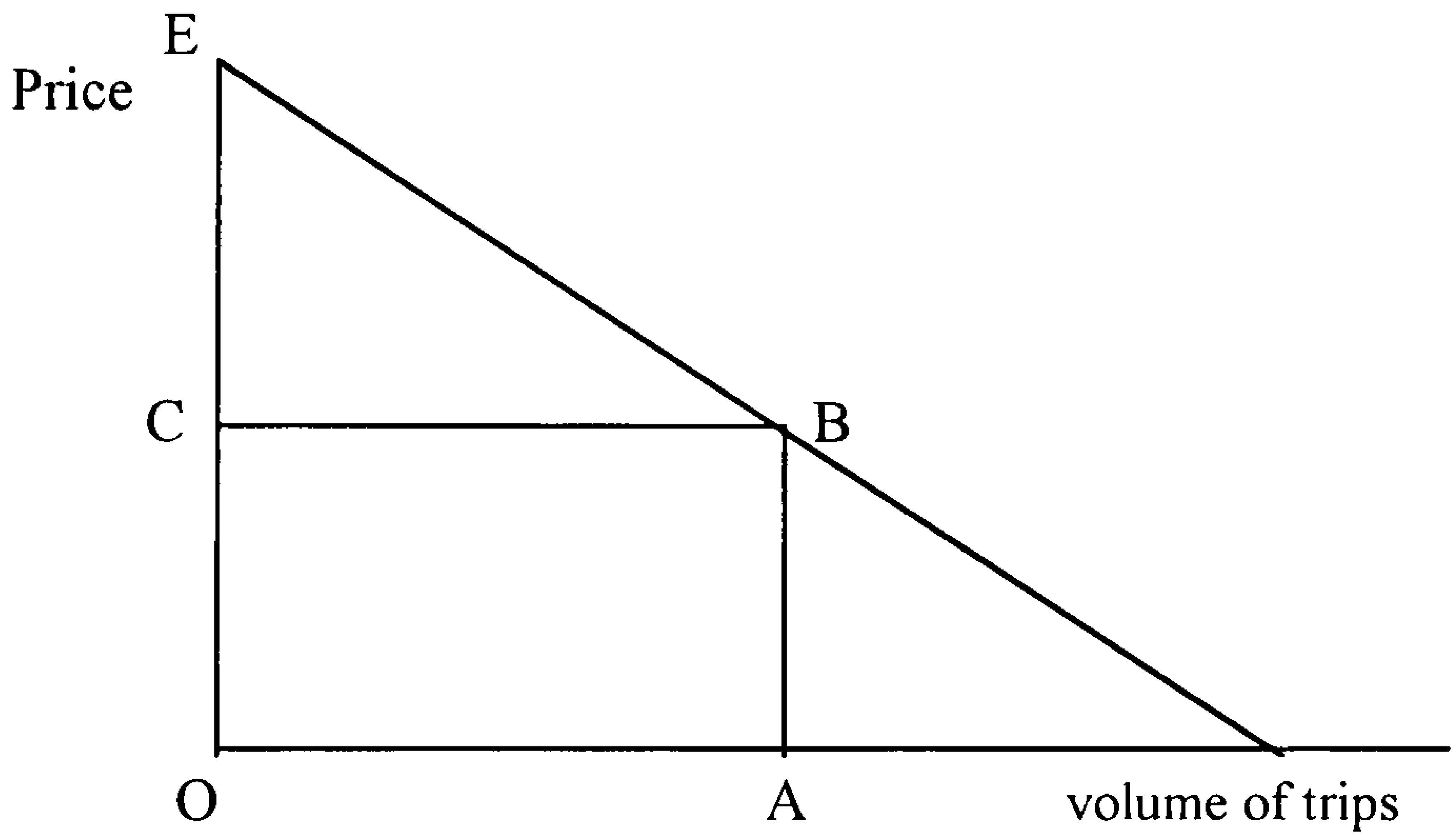



Figure 5.1 Exchange rate between economic and financial surplus

A straight line demand curve is assumed and no running costs. Based on these assumptions, certain propositions readily follow in Carr's analysis:

First, that the revenue maximizing toll receipts will be represented by the area OABC, second that this area is one half of the total area under the demand curve, and third, that the area above and to the right of the revenue area are equal to each other and to one half of this area. Thus when a toll is charged, a surplus of 50% (i.e. area CBE) above revenue paid is enjoyed - which suggests that the " Rate of Exchange" between social and financial returns should be 1.5:1. That is to say- in Carr's opinion- a social rate of return on an investment can be obtained by multiplying its financial return by a factor of 1.5. In fact this might be true only if Carr's assumptions hold. The analysis of the current study, as shown in chapter 2, concluded that the social rate of return might be above the financial rate of return. In addition, the analysis of chapter 2 also showed that the consideration of different assumptions of demand, cost and pricing makes the pre-assumption of a single rate of exchange between the two measures of investment efficiency a chimera.

4. The comparability problem has been looked at by Harrison and Mackie in 1973 (Harrison and Mackie, 1973). They consider the problem faced by a central government department responsible for the investment program of a number of sectors, in applying the rule of equating marginal returns, when the returns are measured by financial criteria in some sectors (e.g. railways), and cost benefit criteria in others (e.g. roads). A possible solution suggested by J. L Carr is put forward and they accepted that Carr is correct in proposing that cost benefit returns would be 50% higher than financial returns at the margin in the conditions he posits.

They have examined the implications of relaxing a number of Carr's assumptions. The summary of their discussion was that the ratio between cost benefit and financial returns varies according to the assumptions of demand and cost curves and pricing policy operated. This is consistent with the analysis of chapter 2, where different assumptions of pricing policy gave different exchange rates between cost benefit and financial returns.

The general conclusions of Harrison and Mackie's analyses are:

(1) No single rate of exchange between financial and cost benefit appraisal can be found.

(2) A number of different rates may be required, according to the conditions in each sector and case.

(3) Because the theoretical analysis does not offer a definite solution, more empirical work is required.

Harrison and Mackie at the end of their analysis stated that:

> *Because of the unlikelihood of finding satisfactory rates of exchange, other solutions to the problem of getting the right balance between different sectors, investments may have to be pursued more energetically e.g.: the internalising through direct subsidy, of external effects, or when possible, the pricing viability rules may themselves have to be amended.*

In fact this conclusion is consistent with the current study discussion, in chapter 4, of using some administration tolls to correct for the inconsistency of using different appraisal criteria for road and rail investment.

5. The problem of the division of the available funds between areas using different investment criteria in the transport sector have been looked at by Peaker (Peaker, 1974). The usual dichotomy being between road investment (assessed by cost savings plus user benefit) and railway investment (assessed against a financial criterion).

Peaker has declared that it is necessary for the central government agency to divide the available funds in some, preferably rational, manner between these competing modes of transport. One way which has been mooted is by application of a simple "Conversion Factor" which would enable a direct comparison to be drawn between financial rates of return and those including allowance for cost saving and user benefits; (referred to as surplus rates of return, reflecting the fact that they include both producer and consumer surplus).

Peaker discussed the existence and applicability of such a conversion factor, he has declared that it is possible to show the same conversion factor of 1.5, linking surplus and financial returns- which Carr has declared before - . It is valid when considering incremental investments by a profit maximizing organisation, provided two assumptions are valid. These are:

A) that the demand curves before and after the investment are straight: though demand may shift due (e.g.) to the impact of a new and modern image on the public eye, and:

B) that, both before and after the investment is undertaken, the facility is operating under capacity, and that the marginal cost is constant from zero traffic flow to the observed flows: though (again) the level of costs may shift (e.g. the investment may reduce marginal cost at all output/traffic flow levels below capacity).

Using a mathematical approach , Peaker has arrived to the same results which has been found and declared by Carr. This is shown in the following equation:

$$\Delta CS + \Delta R = 1.5 \times \Delta R \qquad (5.1)$$

Where:

$\Delta CS=$ the increase in consumer surplus resulting from the investment

$\Delta R=$ is the increased financial net revenue following from the investment (producer surplus)

In fact, although Peaker's analysis allows a shift in demand curve because of the investment, he reached the same results as found by Carr, that is a 50% difference between cost benefit and financial returns.

Peaker argued that, in the general case, neither of the key assumptions he posits would be valid, and it is possible to show by simple geometry, how their relaxation would have an *a priori* unpredictable effect (even as to direction) on the factor value of 1.5. One example of a case where the factor 1.5 is inapplicable is when the marginal cost curve is upward sloping: as older and less efficient, rolling stock must be used to carry higher passenger flows, more over time must be worked by the railmen, and track and signalling are increasingly extended: and the curve turns up sharply when capacity is reached. In such a case like that it is not clear *a priori* whether one should multiply the financial return by (e.g.) 1.2 or 1.8 before comparing it to the surplus return on a road project which competes for limited investment funds. The ratio of the surplus to the financial return cannot therefore even be determined as to direction because it depends on the exact shape of the marginal cost curves.

There is one further, and major, constraint on the applicability of Peaker's conversion factor arising from the fact that, in generating it, he assumed that there were no externalities (e.g. pollution) or network effects (e.g. traffic congestion). In the assessment of investment projects (road and rail) for urban and built-up areas such assumptions are patently unjustified. For such areas, the conversion factor is an inappropriate means of comparing the return to investment in financially appraised projects (e.g. rail) and surplus evaluated ones (e.g. road).

6. Nash (1976) considers that, the separate planning of inter-urban road and rail facilities, using on the one hand cost benefit and on the other hand commercial criteria, can hardly fail to distort resource allocation. The Independent Commission on Transport (1974) exemplified similar arguments by suggesting that if time savings resulting from remodelling the rail layout at Peterborough were evaluated in the same manner as road schemes (that is COBA), the first year rate of return for 1978 would

be some 57% higher than the estimated commercial rate of return. This empirical piece of evidence suggests that social returns are likely to be higher than financial returns, and this is consistent with the conclusions of the analysis in chapter 2.

7. The question of comparability between CBA and FA rates of return was considered by the Leitch Committee in 1977, which recommended a single framework which it considered would allow greater comparability between road and rail investment appraisals by including wider issues relevant to decisions on the overall allocation of resources. The Committee in their report (Department of Transport, 1977, 1979), concluded:

> *Current methods of appraising trunk roads based on cost benefit analysis do not provide a basis for comparison with the results of appraisals used for alternative modes of transport which are based on financial analysis.*

The Committee felt that there should be no insuperable difficulty in appraising rail schemes using cost benefit techniques within the overall assessment framework which they had proposed for trunk roads. They recommended that:

A) where direct alternatives arise between road and rail schemes, the competing options should be compared using a comprehensive cost benefit analysis framework.

B) strategic or policy studies conducted to compare the rates of return from investment in road and rail should be carried out on the basis of cost benefit analysis within the framework, rather than financial appraisal.

Although these recommendations are theoretically sound, applying them in practice is not that easy. This is due to the commercial objectives of railways, in particular the inter-city sector. It follows that another solution is required to bring the balance between the two modes.

8. Starkie in (1979), raised the issue of the allocation of investment to inter-urban road and rail. He conjoined the appraisal methods with the pricing policy for both road and rail, and his conclusions were:

> *In spit of the Department's claim that regard is paid to marginal returns in the different transport sectors when deciding upon the distribution of resources for investment, there seems little doubt that the existing and fundamentally incompatible methods used for appraising investment projects will not lead to*

*an appropriate allocation of funds to the inter-urban transport sector as whole or to the chief modes in that sector.*

Starkie carried on to say:

*It is essential to take into account the pricing of different transport services. Prices charged for these services affect the returns to be expected from investing in their provision regardless of which measure of economic surplus we use for measuring the efficiency of the investment. Consequently, it is important that the pricing policies are broadly compatible between modes competing for scarce resources.*

This interaction between appraisal techniques and pricing policy mentioned by Starkie was shown to be vital by this study as examined and exemplified in chapter 2, section 2.3.4, where the theoretical analysis showed that the inconsistency of pricing policy may lead to a divergence between the returns on an investment even if the same evaluation technique is used. For example, a chance of a divergence exists between cost benefit returns measured under different assumptions of pricing policy. This in fact leads to an important conclusion. That is, to bring the right balance between road and rail, not only evaluation techniques have to be consistent but also the pricing policy operated.

## 5.3 Previous Rail Studies (Empirical Side)

### *5.3.1 Introduction*

This section reviews some of the rail investment studies that were carried out using both financial and cost benefit methods to show how the results of the two techniques differed and to examine how the sources of benefits and costs that are not included in the financial framework have been dealt with in a cost benefit framework. Section 5.3.2 shows the sources of benefits that were incorporated in the cost benefit framework applied in these studies and the method of incorporating them, while section 5.3.3 summarises the results of the evaluation. The results of the evaluation are meant to illustrate the magnitude of the divergence between financial and cost benefit returns.

### *5.3.2 The Method of Cost Benefit Analysis Adopted*

The sources of benefits (and adjustments) that were incorporated in the cost benefit evaluation in most of these studies - beside the financial impacts of the scheme- are as follows:

1. Consumer surplus to rail users (user benefits)
2. Consumer surplus to remaining road users
3. Accident savings on road
4. Tax adjustments

The following paragraphs explain briefly how each of these factors has been incorporated in the cost benefit framework.

**1. Change in Consumer Surplus of Rail Users**

Users of the proposed scheme were divided into two types, *stayers*, those who used the service in case of do nothing situation and carry on using it in the do minimum situation. The change in the consumer surplus for them was considered to be the full change in their perceived costs of travel as a result of the proposed scheme. The other type of users is the additional passengers, those new users who switched -*switchers*- from other modes or new generated trips as a result of the proposed rail scheme. The change in the consumer surplus for them was estimated (based on the rule of one half), as half the change in the perceived cost of making a trip on scheme service (DTp 1984).

**2. Consumer Surplus to Remaining Road Users**

This is considered to be the impact of reduced road congestion on the remaining road users, in terms of reduction in travel time and vehicle operating costs. Time and vehicle operating cost benefits are combined and measured together and usually called consumer surplus to remaining road users or congestion reduction benefits in these studies. The time and vehicle operating cost benefits or congestion reduction benefits, of a passenger km or vehicle km are measured using the estimates of the resource cost per vehicle km travelled by road and the speed-flow relationships identified in COBA (Nash et al 1991).

**3. Accident Cost Savings**

The cost savings per a passenger km switched from road to rail was derived from the COBA injury accident rates and costs per injury by link type and assuming the mix of road types from which switchers transfer.

**4. Tax Adjustments**

These are transfer payments which are not taken into account in British Rail's financial analysis, and normally includes:

A) The loss of general indirect tax revenues to the Exchequer when consumers spend more on rail services rather than other goods.

B) The loss to the Exchequer of road taxation (excise duties and VAT) in respect of passengers no longer travelling by road.

These are the main sources of benefits and adjustments made in these studies. As can be noticed no attention is given to the environmental impacts of investment schemes. In addition, the issue of perception is not incorporated when measuring non-user benefits. This is relevant to both accidents and vehicle operating costs where a divergence between resource and perceived costs exists, and on a social assessment basis this divergence has to be corrected for.

It is one of the main intentions of the current study -in developing an appraisal framework for rail schemes- to consider and incorporate both the environmental impacts of rail schemes and the misperception in accidents and vehicle operating costs as will be explained in detail in the next chapter.

### *5.3.3 Results of the Evaluation Process of the Studies*

#### 5.3.3.1. Birmingham-London/Basingstoke Electrification Case Study

The Department of Transport on behalf of the Standing Advisory Committee on Trunk Road Investment, in 1982 it commissioned Colin Buchanan and Partners to undertake a study of a rail electrification project using comparable techniques to those used in road investment appraisal (DTp, 1984). The project in question was to electrify the line from Birmingham to Paddington via Oxford, together with the branch from Reading to Basingstoke, allowing the Birmingham-Paddington and Birmingham-Bournemouth services to be electrically hauled throughout.

The study quantified costs and benefits to British Rail, which would be taken into account in a financial appraisal, and then the benefits to passengers in terms of time savings and reduction in the need to change trains. It also estimated the effect on remaining road users of the diversion of traffic from road. It did this by applying the speed/flow relationship used in COBA. However, no very good evidence was available on what proportion of new rail users would have diverted from road; a central assumption of 50% was used, with sensitivity tests of 75% and 25%. Other factors taken into account were reductions in road accidents, loss in tax revenue from the diversion of spending from taxed road transport to untaxed rail and loss of revenue to London Transport from the diversion of some trips away from London. Results of the study are given in the following table:

Table 5.1 Birmingham-London/Basingstok Electrification. (1979 prices at 7%).

| Benefit or cost item | Net present value £m |
|---|---|
| Change in passenger revenue | 6.490 |
| Savings in operating costs | 27.955 |
| Savings in capital and maintenance costs | -40.095 |
| Financial NPV | -5.650 |
| Rail user benefits (existing and new) | 2.857 |
| Consumer surplus to remaining road users | 1.485 |
| Savings in road accident costs | 0.440 |
| Tax adjustment | -1.243 |
| Change in London Transport revenue | -0.063 |
| Social NPV | -2.175 |

Source : DTp (1984)

It may be argued that, given the current purely commercial objectives for British Rail Inter-City (profit maximisation), any improvements in service level would be likely to be associated with an increase in fares over the route in question. This would tend to reduce the discrepancy between social and financial returns. Indeed if the fare were raised so far that the traffic level on rail was unchanged, there would be no social benefits from the scheme and the two criteria would be identical. However, the ability of British Rail to raise fare in order to absorb the improvement in service quality is arguable and very much depend on the demand elasticity of the service.

The fact that the difference between social and financial NPV in this case was relatively small resulted from the fact that the major effect of the scheme was to reduce British Rail costs rather than to improve services. Moreover, conversion of suburban services to electric traction, which would undoubtedly accompany such an electrification scheme and would yield substantial social benefits, was considered outside the remit of the study and not considered in detail (Nash and Preston 1991). The study report itself concludes that:

> *"There seems no obvious reason to expect that such divergence (between financial and social appraisals) will be generally insignificant. For these reasons, the study provides some support for the conclusion of the Leitch Committee in 1977 that " strategic or policy studies conducted to compare the rates of return from investment in road and rail should be conducted on the basis of cost-benefit analysis, within the framework, rather than financial appraisal"*

### 5.3.3.2 West Yorkshire New Stations

The following table outlines the appraisal results that was carried out for six new stations in West Yorkshire. A 30-year project life was assumed, along with a 7% discount rate. All prices are expressed in 1986 prices. It can be seen from the table that the new station program was a fairly small scale example of capital investment, involving only around £0.6m, whilst, as the stations were unmanned, recurrent costs were minimal. At the time of evaluation was carried out, West Yorkshire Passenger Transport Executive (PTE) was responsible for both rail and bus operations. As a result, the gain in public transport revenue (estimated, over 30 years, at almost £1m) was calculated net of abstraction from bus services.

The results of the evaluation suggest that social NPV is about 6.4 times the financial NPV. Although, benefits to new rail users are substantially high, this is cancelled out by the negative value of the benefits to the existing users as a result of increased journey times for them. Non-user benefits are relatively high, and more than 70% of it is road accident savings. In measuring accident cost savings, neither the implications of mode switching nor the issue of user's perception to accident cost was incorporated. These two issues are very relevant when assessing rail schemes on a social basis, and incorporating them may affect the amount of non-user benefits significantly.

Table 5.2 Comparison of NPV of two rail investment programs.(30-year project life, 7% interest rate, £000, 1986 prices)

| Cost or benefit items | West Yorkshire Six new Stations on existing services | Leicester-Burton new service serving 14 new stations |
|---|---|---|
| 1. Gain in public transport revenue from new users | 997 | 8897 |
| 2. Loss in public transport revenue due to increased | - | - |
| journey time | 166 | - |
| 3. Recurrent costs | -147 | -9154 |
| 4. Capital costs | -656 | -5806 |
| **Financial NPV** | **28** | **-6063** |
| 5. Time savings to new rail users | 515 | 4582 |
| 6. Time savings to existing rail users | -472 | - |
| 7. Time savings to road users | 113 | 3304 |
| 8. Accident savings | 277 | 2612 |
| 9. Tax adjustment | -282 | -2326 |
| **Social NPV** | **179** | **2109** |
| excluding user benefits (section 56 grant NPV) | 136 | -2473 |

Source : Nash and Preston 1991

### 5.3.3.3 Leicester Burton New Rail Service

As shown in the table above, Leicester-Burton new rail service, the scheme that has been evaluated, involved an initial investment of £5.8m and recurrent operating costs equivalent to £9.2m over 30 years. The mid-point estimate of revenue indicates that around £8.9m will accrue over 30 years. Hence, under the calculations the project just fails to cover operating costs and hence makes no contribution to capital costs. The financial NPV is thus highly negative (-£6m). As the project involves a brand new service, unlike the West Yorkshire new station program, it has no effects on existing rail users. However, the time savings that accrue to users of the new service are estimated to be substantial (around £4.6m). This is more than 50% of the gain in revenue. Incorporating user and non-user benefits made the social NPV substantially positive. User benefits are the greatest source of social benefits. However, non-user benefits in terms of time and accident cost saving for road users are also significant. This case shows a typical example of a situation where social and financial NPV contradict. This has a very important implications in the investment decision. Simply because if the rail organisation only proceeds investments of financial viability, this scheme may have to wait for some times to be undertaken. One may argue that, Section 56 Grant may help in this case. In fact the case example shows that when user benefits are omitted, as Section 56 Grant guidelines require, the project has a negative NPV. Further more Section 56 Grant is available for schemes that have some regional importance.

#### 5.3.3.4 The Trans-Pennine Rail Study

The Trans-Pennine Rail Strategy Study, carried out by Transportation Planning Associates (TPA) in association with the Institute for Transport Studies at Leeds University for a consortium of Passenger Transport Executives (PTEs) and local authorities provided an opportunity to assess inter-urban rail investment schemes on a basis consistent with the approach used by the Department of Transport for highway scheme appraisal. Three overall strategies for developing Trans-Pennine rail services were studied. these are:

- Strategy A: a strategy based around an enhanced diesel service for the North Trans-Pennine route with parallel service improvement on other corridors.
- Strategy B: an approach based on electrifying the Liverpool-York route with diesel rolling stock cascaded to other services, allowing them to be improved at less cost than in Strategy A.
- Strategy C: a similar strategy to B but with an additional fast diesel service on the route from Liverpool to York via Bradford.

The study involved undertaking appraisals using Economic, Financial and "Section 56 Grant" approaches. The results of the evaluation are summarised in the following table:

Table 5.3 Evaluation of Overall Trans-Pennine Strategies (present value of costs and benefits discounted to 1994 in 1990 prices) £m

| Benefits or Costs | Strategy A | Strategy B | Strategy C |
|---|---|---|---|
| a) Costs | | | |
| Capital: Infrastructure | 2.42 | 45.93 | 45.93 |
| Rolling Stock | 13.18 | 13.42 | 21.61 |
| Operating and Maintenance | | | |
| Infrastructure | -1.03 | 6.16 | 6.16 |
| Train Services | 18.52 | 1.08 | 15.39 |
| Total | 33.09 | 66.59 | 89.10 |
| b) Benefits | | | |
| Revenue | 62.18 | 73.95 | 89.20 |
| Non-User: De-congestion | 11.43 | 21.97 | 24.46 |
| Accidents | 5.51 | 8.16 | 9.17 |
| Total | 16.94 | 30.13 | 33.63 |
| User Time Savings | 78.02 | 82.83 | 100.16 |
| C) Evaluation | | | |
| Financial appraisal | 29.09 | 7.36 | 0.1 |
| Section 56 appraisal | 46.03 | 37.48 | 33.73 |
| Economic appraisal | 124.05 | 120.32 | 133.89 |

Source: Vaughan et al 1992.

As can be seen, the evaluation process of the three strategies has not incorporated any environmental impacts. Perhaps this was to be consistent with the COBA evaluation for road schemes, where no monetary valuation is mad for the environmental impacts. User benefits in terms of time savings to rail users are the greater source of economic benefits compared with revenue and non-user benefits which is the least important of the three categories. Perhaps this is because the evaluation work was carried out using the current fare at time (Vaughan et al 1992). One might expect that user benefits might have been eroded if fare were allowed to increase, which may have improved the financial case and reduced the gap between economic and financial NPV. However, the divergence between social and financial NPV will exist unless fare increases so that rail traffic level does not change.

It is worth mentioning that, on social basis, the benefit to cost ratios of the three strategies ranged from 2.1:1 for option C to 4.7:1 for option A. Comparing this with benefit/cost ratio of 2.5:1 for road proposals expected by the Department of Transport and published in the "Roads for Prosperity" White Paper (DTp 1992), the conclusion is that when assessing on an economic basis, rail schemes may achieve benefit cost ratios as those for road schemes.

### *5.3.4 Conclusions from the Case Studies*

The general conclusion of the above case studies are:

1. The absence of the environmental impacts in the social evaluation of rail schemes.
2. When assessing non-user benefits, the studies failed to incorporate the users misperception which is very relevant in case of accident and vehicle operating costs.

## 5.4 Chapter Summary and the Way Ahead

This chapter summarises the literature of the problem of comparability between investment returns measured on different basis and how that may distort the allocation of funds. It showed that the problem had been considered as early as 1960. This was followed by an attempt to establish a single exchange rate between the financial and cost benefit returns which deemed to be difficult. The chapter also reviews some rail investment studies where both financial and cost benefit were used, in order to demonstrate how the task of cost benefit were carried out for rail schemes. The cases mentioned do not include all of the studies, and they illustrate the magnitude of the divergence between financial and cost benefit returns in each case. In most of these studies, the results of the evaluation process showed a divergence between cost benefit and financial returns (NPVs or benefit/cost ratios). The divergence differs from a case to another according to the circumstances of each case. Although, the cost benefit and financial returns differed in all cases, there is no *a priori* general statement can be drawn -from this empirical side - about the magnitude of the divergence.

Based on the results of these studies, the argument may be put forward as follows:

The divergence between cost benefit and financial returns will in general depend upon:

1. The nature of the investments in terms of their effects on the rail operator and users of the service. When the major impact is to reduce costs rather than improve services, the divergence might be relatively small, as the case of Birmingham-London electrification. But when the scheme has a great impact in improving the quality of service, the divergence might be relatively higher.

2. When the scheme leads to improvement in the quality of service, the divergence will again depend upon the following:

a) to what extent the service quality is improved.

b) to what extent rail operator can recoup the improvement in the quality of service through fare increase.

c) to what extent the improvement in service quality will attract road users to use rail instead, and then the change in consumer surplus to the remaining road users as well as the road accident cost savings will be determined.

3. The comprehensives of the social approach adopted in terms of inclusion of all possible sources of benefits and costs. And it is one of the main merits of the current study to incorporate all the relevant costs and benefits in the social appraisal of rail schemes, such as the environmental impacts, which was absent in all of the previous studies. The current study considers these impacts at the margin.

4. The accuracy of incorporating the sources of benefits and costs that are not included in the financial appraisal framework. This is very important when measuring non-user benefits. As explained above, in the previous studies no attention has been given to the issue of perception when measuring accident and vehicle operating costs savings. This may lead to an overestimate of these benefits which in turn distorts the investment decision. The measurement is based on the cost of accident times the number of road accident saved as a result of the scheme. No consideration is given to the misperception of vehicle operating cost items. However, the current study approach of measuring non-user benefits of rail schemes incorporates the misperception of road and rail accidents as well as the misperception of road vehicle operating costs. Another important aspect when measuring non-user benefits of rail schemes is to consider the conditions and circumstances of the direct alternative of the rail service being assessed. The current study approach incorporates the type of road that are of direct alternative to the rail scheme, whether it is a congested road or not,

the variations in traffic during the day, the week, the year as well as the variations of traffic from one place to another one. This is seen to make a significant difference to the evaluation results and will help in making the suitable decision of allocating investment funds between road and rail.

**References**


1. **Carr, J. L.** (1967) *Efficiency in Government Spending (Commentary).* Public Finance, pp. 48-60.
2. **Department of Transport DTp,** (1984) *Economic Evaluation Comparability Study : the application of the SACTRA framework and COBA principles to rail investment- Final Report.* Colin Buchanan and Partners, London.
3. **Department of Transport DTp** (1979) *"Report of the Leitch Committee" ACTRA* HMSO, London.
4. **Department of Transport** (1992) *Roads for Prosperity.* HMSO London.
5. **Department of Transport DTp** (1977*) Report of the Advisory Committee on Trunk Road Assessment.* HMSO, London
6. **Foster, C. A.** (1960). *"Surplus Criteria for Investment".* Bulletin of the Oxford University Institute of Statistics. Vol. XXII . pp. 337-357
7. **Harrison, A. J. and Mackie, P. J.**(1973). *The Comparability of Cost Benefit and Financial Rates of Return.* (Department of Transport), Government Economic Service Paper no. 5.
8. **Independent Commission on Transport** (1974) *Changing Directions.* Coronet, London.
9. **Nash C. A. et al** (1991) *The Future of Railways and Roads.* Institute for Public Policy Research, London.
10. **Nash C. A. , and Preston J**. (1991) *Appraisal of Rail Investment Projects: Recent British Experience.* Transport Reviews, Vol. 11, No. 4, 295-309.
11. **Nash C. A.** (1976) *Public versus private transport.* Macmillan, UK.
12. **Peaker A**. (1974*). The Allocation of Investment Funds Between Road and Rail: A Conversion Factor Linking Financial and Surplus Rates of Return.* Public Finance, PP. 49-55.

13. **Sadove A. and Fromm G.** (1965) *Transport investment and economic development.* London.

14. **Starkie, D. N. M.** (1979) *Allocation of Investment to Inter-urban Road and Rail.* Regional Studies, Vol. 13 pp. 323-336.

15. **Vaughan B. C. et al** (1992) *Comparability in Road and Rail Investment Appraisal: The Trans-Pennine Rail Study Example.* PTRC Summer Annual Meeting, Siminar C.

# Chapter 6

## The Approach of the Study

### 6.1 Introduction

Chapter 4 discussed the potential undesirable implications of the inconsistency of appraisal techniques between transport modes, in particular between road and rail. Some alternative options were put forward as solutions to the problem. After discussing the suitability and applicability of each of these options, it appeared clear that the most appealing option or solution is to make the appraisal techniques consistent across all modes in general and between road and rail in particular, by applying one common appraisal methods for assessing the investments. In addition, if the social welfare is to be maximised out of the investments in the transport sector, the common method used for all modes has to be a comprehensive social cost benefit approach. The argument in chapter four considered also the question of whether it will be possible - given the current organisational structure and financial objectives of railways - to apply a comprehensive social cost benefit approach to rail schemes. The answer, probably not an easy one. But if the answer is no, that does not mean that the consistency between transport modes cannot be achieved. The consistency between the modes can be brought, this time not by applying a common comprehensive social cost benefit approach explicitly, but rather implicitly. This may be achieved by some administration tolls that are designed and tailored to make up and match exactly the difference between the financial and social returns on the investments. This might be by the making over of grants and subsidies from the government or the responsible body to the body making financial appraisals, (in this case railways). In order to design and tailor these administration tolls, a comprehensive social cost benefit approach has to be carried out for rail investments first, so the administration instruments can be based on the results of social measurement of the investment benefits and costs. So, whether the consistency is to be brought explicitly, by applying the social appraisal approach to road and rail, or implicitly, by administration instruments, being based on the results of the social approach carried out for rail schemes, there is a need for developing a comprehensive social appraisal approach to be used in measuring the social benefits and costs of rail schemes at the margin. Developing this approach, as identified in the study purpose in chapter 1, is the main concern of this study.

Chapter 5 reviewed the literature of the comparability problem and discussed the previous rail studies and their approach in measuring the investment benefits. The chapter ended by outlining the factors that might affect the divergence between the cost benefit and financial returns on the investment, and discussed how some of these factors were not considered (e.g. environment) and some were not incorporated comprehensively (e.g. perception) in the previous studies. It also hints to the main features of the current study in its approach of measuring the rail investment benefits.

This chapter will follow the story line by outlining the approach adapted in this study and how this approach fits in fulfilling the gap of the previous work in the area of measuring the investment benefits of rail schemes. Section 6.2 outlines the 'main interest groups', that a rail scheme might have effects in. Section 6.3 demonstrates the study approach of measuring non-user benefits of a rail scheme and how this fits within the appraisal framework as a whole. Types of benefits concerned are showed, and the main stages of processing towards incorporating them are demonstrated, as well as the expected results from the approach adopted. It is not intended here to give the details of how the benefits are measured. This is done in the future relevant chapters, where each type of benefit will be given a separate chapter showing exactly how each type of benefit concerned is dealt with and measured. Section 6.4 summarises the contents of the chapter.

## 6.2 Impacts of Rail Investment

At the most general level, rail investment schemes will have effects on the following groups:

1. Rail operator: the effects on the operator will be mainly in terms of changes in costs and revenues as a result of the scheme, in addition to the initial capital cost of carrying out the project. It is worth mentioning that the impacts on the operator will to some extent depend upon the kind of investment concerned. Some schemes might not affect the operator's revenues, such as cost reducing investment schemes.

2. Rail users: impacts on rail users include changes in the quality of service (journey time, comfort, convenience etc.), if any, and the effects of the project on the level of fares.

3. Non-users: those are other members of the society who are not using the rail service in question, such as users of other modes of transport e.g. road, or even any person who does not use transport at all.

4. Other bodies: those are other bodies in the community who might be affected by the rail scheme, e.g. the impacts on the exchequer in terms of tax revenue changes.

These are the potential four groups who in general will be affected by the investment in a railway scheme. And any comprehensive framework for assessing the investment efficiency will have to include the impacts on the four groups.

## 6.3 The Study Appraisal Framework and the Approach of measuring Scheme Non-user Benefits

The purpose of the study, as identified in chapter 1, is to develop a methodology for appraising rail investment schemes that would be consistent with the cost benefit techniques used to assess road investment schemes, and which measures the social efficiency of invested resources and help in making the right investment decisions, that are based on the desirability and actual needs of the society. To achieve this purpose, the methodology framework developed has to measure the relevant benefits and costs of rail schemes *comprehensively, precisely, and accurately*. The following sections show the structure of the appraisal framework, and the approach adopted in incorporating the impacts of the scheme on non-users, and how non-user benefits are dealt with and incorporated in the framework of appraisal in what the study called, (The Benefit Algorithm), and how the three requirements mentioned above, (*comprehensivness, precision and accuracy*), were fulfilled in the adapted approach of measuring the benefits.

### *6.3.1 Structure of the Appraisal Framework and the Study Approach*

The following diagram, shows the structure of a social appraisal framework for a rail investment scheme. It illustrates the types of scheme impacts that should be included on a social assessment basis. The diagram also demonstrates the approach that adopted by the study in order to incorporate non-user impacts of rail schemes into the appraisal framework.

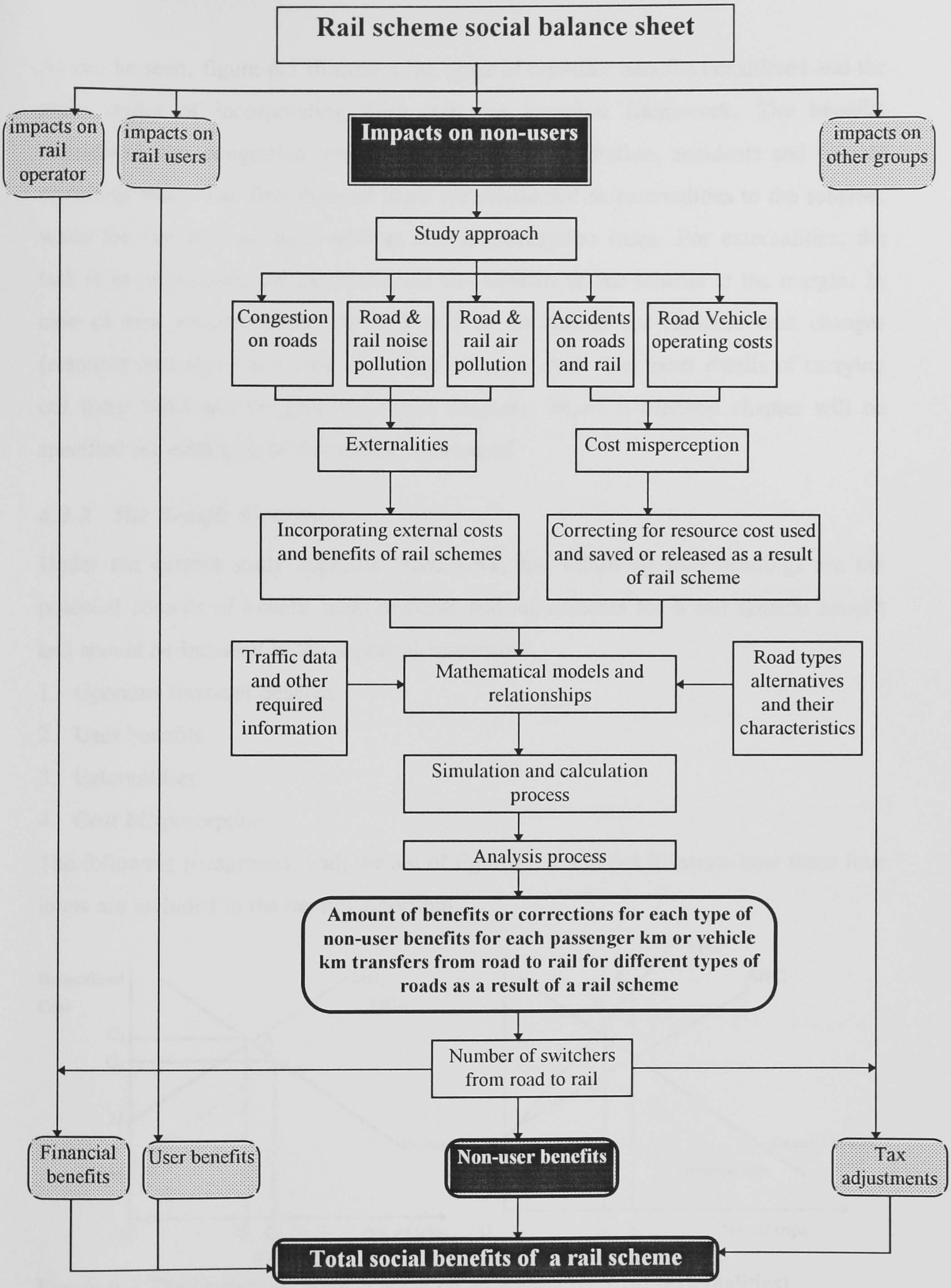



Figure 6.1 Structure of the appraisal framework and the study approach of dealing with non-user benefits

As can be seen, figure 6.1 illustrates the types of non-user benefits considered and the main stages of incorporating them into the appraisal framework. The benefits considered are, congestion time benefits, noise, air pollution, accidents and vehicle operating costs. The first three of them are considered as externalities to the scheme, while the last two are dealt with as cost misperception cases. For externalities, the task is to incorporate the external costs and benefits of the scheme at the margin. In case of cost misperception, the task will be to correct for resource cost changes (resource cost saved and used as a result of a scheme). The exact details of carrying out these tasks will be given in future chapters, where a separate chapter will be specified for each type of the benefits concerned.

### *6.3.2 The Benefit Algorithm*

Under the current study appraisal framework, the following four headings are the potential sources of benefit measurements and adjustments for a rail scheme benefit and should be included in the appraisal framework.

1. Operator financial benefits
2. User benefits
3. Externalities
4. Cost Misperception

The following paragraphs, with the aid of figures 6.2 and 6.3 illustrate how these four items are included in the benefit algorithm.

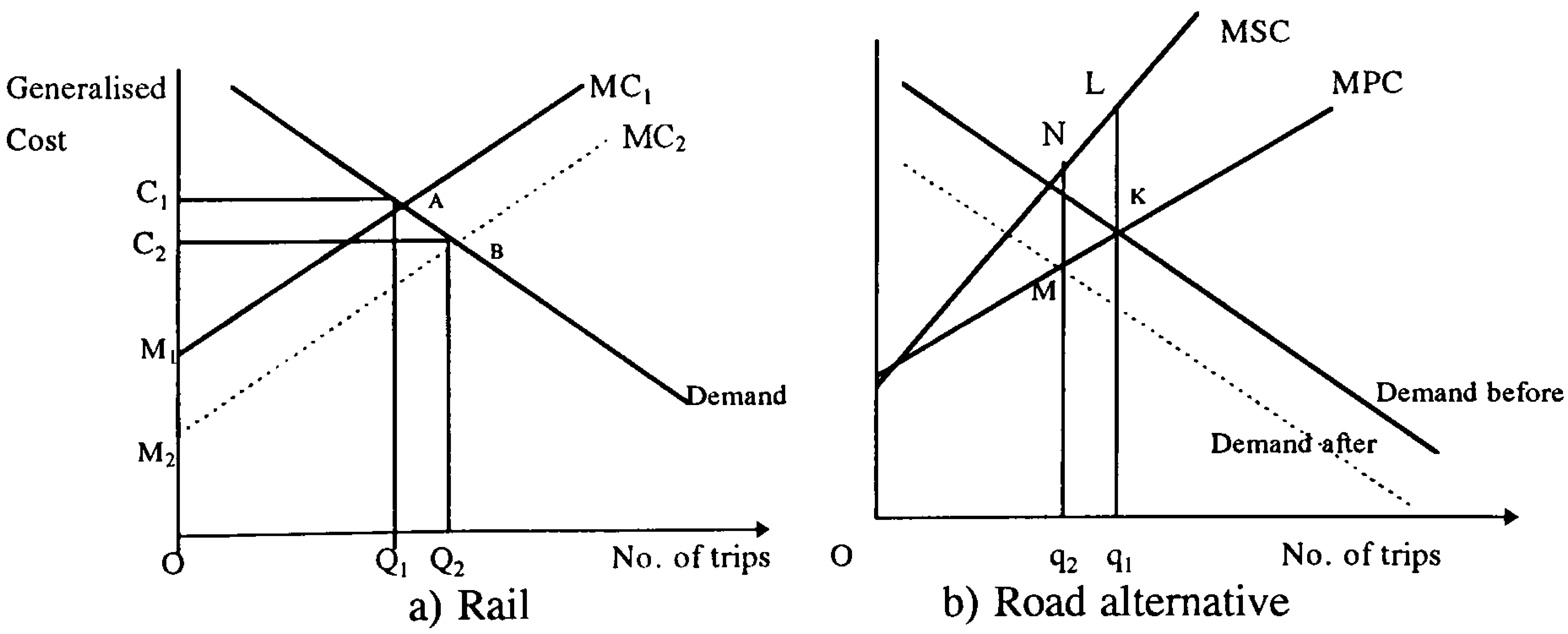
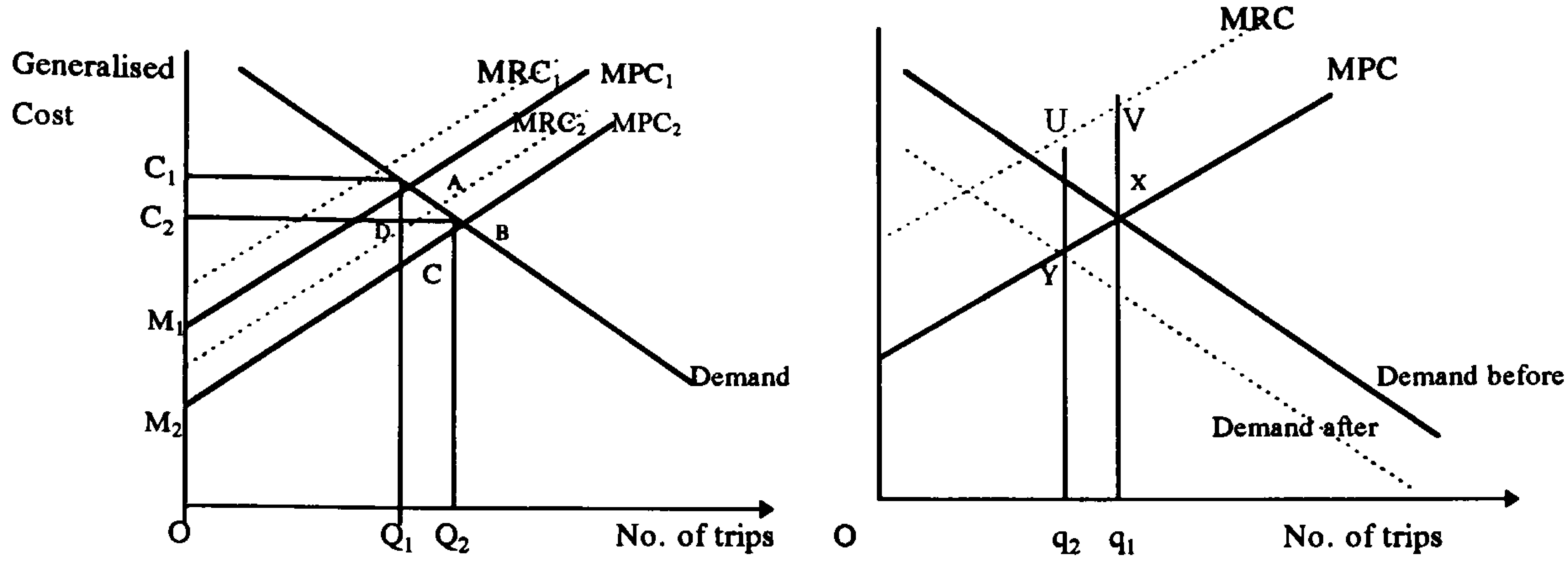



Figure 6.2 The impacts of a rail scheme on an alternative road (externalities)




a) Rail b) Road alternative

Figure 6.3 The impacts of a rail scheme on an alternative road (cost misperception)

## 1. Operator Financial Benefits (producer surplus)

As illustrated in figure 6.2, when a rail investment scheme shifts the marginal cost curve uniformly downward, the operator producer surplus will be presented by the area $C_2BM_2$-$C_1AM_1$. In mathematical form, this is:

$$NR = (TR_2 - TC_2) - (TR_1 - TC_1) \qquad (6.1)$$

Where:

$TR_2$, $TR_1$ = are total revenue after and before the investment respectively (£/period of time)

$TC_2$, $TC_1$ = are total operating costs after and before the investment (£/period of time)

NR = the financial net revenue that an operator gains out of the scheme on a given period of time (producer surplus)

## 2. User Benefits

This type of benefits occur to the railway users, in terms of improvements to the service quality as a result of the scheme in question. In figure 6.2, $C_1$ and $C_2$ are the generalised cost of travelling by rail before and after the investment. $Q_1$ and $Q_2$ are the level of trips by rail before and after situations. The area $C_1ABC_2$ presents the change in consumer surplus to rail users (stayres and new travellers). In mathematical form, this area is measured as follows:

$$UB = \frac{1}{2}(Q_1 + Q_2)(C_1 - C_2) \qquad (6.2)$$

Where

UB= the amount of benefits rail users will gain as a result of the scheme in a given period of time

$C_1$, $C_2$= travel cost by rail before and after the investment

**3. Externalities**

As figure 6.2 shows, the marginal social cost (MSC) of travel by road is above the marginal private cost (MPC) of travel. This is due to the fact that there are external costs for road travel, in a form of time delays, environmental damages, e.g. noise and air pollution. These externalities are not included in the users private travel costs, and then are not considered in their decision of making a trip on the road. When a rail scheme attracts some previous road users off the road, an area of benefits will emerge, (external benefits to the railway investment scheme), reflecting the savings in this external costs of road transport. For example if a rail scheme leads to an amount of trips equal to ($q_1$-$q_2$) in figure 6.2 to shift from roads to rail, an amount of benefits presented by the area NLKM will be gained. In mathematical form, these external benefits may be measured as follows:

$$EB = \frac{1}{2}MEC_b(q_1 - q_2) + \frac{1}{2}MEC_a(q_1 - q_2) = \frac{1}{2}(q_1 - q_2)(MEC_b + MEC_a) \qquad (6.3)$$

Where:

EB= the external benefits of a rail scheme in terms of time delays and other pollution costs would have been otherwise imposed on the remaining road users and the rest of the society if the scheme did not go a head (in do-nothing situation).

$MEC_b$, $MEC_a$= the marginal eternality cost (the difference between the marginal social travel cost and the marginal private travel cost of road) reflecting this costs of road travel that road users impose on each other and on the rest of the society without including it into account when taking a decision to make a trip on the road, for before and after the investment.

$(q_1-q_2)=$ movers from road to rail, (no. of trips) as a result of rail scheme = $(Q_2-Q_1)$ in figure 6.2.

Equation 6.3 will be used in case of addressing congestion benefits, and noise and air pollution reduction benefits. This measurement of external benefits to rail schemes (EB) as presented in equation 6.3, is based on the assumption that marginal private and social cost are straight line functions of traffic flows. In other words, this is to say that each additional trip joins the road causes an equal amount of external cost (delays and other pollution costs). In fact, this assumption is made only to ease the demonstration of externalities in figure 6.2. In reality this might not be the case. And one expects that each additional trip joins the road will impose an external cost more than the previous trip. In other words, marginal private and social cost are not straight line functions of traffic flows. In this case the measurement of the external benefits of a rail scheme has to consider the marginal external benefits of each trip transfers from road to rail.

**4. Cost Misperception**

This is a sort of correction that has to be made when assessing the social benefits of a rail scheme. As has been addressed previously, some travel costs are not perceived fully by travellers. An obvious example is road vehicle operating costs. By looking at figure 6.3 a, $MRC_1$ and $MRC_2$ are the marginal resource costs for rail travel before and after the investment, and they include both the perceived and the unperceived costs for rail travel. $MPC_1$ and $MPC_2$ are the perceived costs by rail users. On the other hand, in figure 6.3 b, road users do not perceive the full costs of travel, since the marginal resource cost MRC is above the marginal private cost of travel by road MPC. The difference between MRC and MPC is the unperceived costs of travel. When the amount of trips $q_1$-$q_2$ transfers from road to rail, and cost misperception prevails for both road and rail cases, an area of benefits equal to UVXY for road will emerge and another area of disbenefits equal to ABCD for rail will emerge. The area of benefits in road reflects the unperceived cost by those who transfer to rail (resource cost saved). The area of disbenefits in rail reflects the unperceived cost by the new users of rail (resource cost used). The form of correction to be incorporated in the benefit algorithm of the appraisal framework is as follows:

$$CF = (UTC_R - UTC_r)(Q_2 - Q_1) \tag{6.4}$$

Where:

$UTC_R$, $UTC_r$= the amount of unperceived travel costs per trip or passenger km of travel for road and rail respectively

$(Q_2-Q_1)$= movers from road to rail as a result of the investment in rail (no. of trips or passenger km)

CR= correction factor for cost misperception to be included in the benefit algorithm of a rail scheme appraisal

This correction factor will be relevant and applied when measuring vehicle operating and accident Benefits.

### *6.3.3 The Comprehensivness of the Study Approach*

The comprehensivness of the study approach is due to the inclusion of all the relevant social benefits and costs of the schemes. On a social grounds, beside the financial benefits and benefits to rail users, the following are the items included and measured in the study social cost benefit framework.

#### 6.3.3.1 Congestion Benefits

Rail schemes will probably lead to a congestion relief on roads. In fact, the extent to which this will happen depends upon so many factors, which has to be considered in the measurement process. These factors will be discussed in the following paragraphs, and how they have been incorporated in the study approach will be explained in details in the relevant future chapters. As far as this point is concerned, the study suggests that congestion impacts has to be incorporated correctly and precisely - as suggested latter in the study - and any shortcomings in incorporating it will present a defect in the social measurements of investment benefits. In fact most of the previous work (as discussed in chapter 5) in assessing rail schemes social impacts considered the impact of the schemes on road congestion relief. The method of incorporating the congestion benefits were probably less specified and congestion benefits were conjoined with vehicle operating cost impacts. This probably, brings some sort of double counting or misestimation of benefits. This point were clearly realised by the current study approach.

It is worth mentioning that as the study is considering the impacts of rail schemes on road congestion. In fact it is also, to some extent, relevant to consider the implications of congestion on the railway network. But this is found to be another big area of research which has to be looked at in the light of the whole structure of the rail network.

#### 6.3.3.2 Accidents Benefits

Accidents are a very important area that have to be considered when assessing the social impacts of rail schemes. Rail improvements will probably lead to switching some previous road users to the improved rail schemes. It follows, and to the extent rail does, an improvements to the accident situations on roads. The impacts of rail schemes on road accidents have to be considered in a social assessment approach. On the other hand, the rail accidents costs are of an importance also. The current study approach incorporates the implications of rail scheme impacts on both rail and road accidents. In fact, accident cost savings on roads were considered by the previous studies as discussed in chapter 5. The main difference between these studies and the current study approach is the method of incorporation of accident cost savings. The previous studies considered a scheme that lead to one accident less on roads, will bring an accident benefit equal to the whole cost of that accident. The current study argues that this may carry a chance of double counting and then brings the issue of accident cost perception into consideration. The study argues that only the correction of accident cost misperception that is relevant to the evaluation. Another main difference between this study and the previous ones is the incorporation of mode switching implications on rail accidents which has not been considered in the previous studies as discussed in chapter 5.

#### 6.3.3.3 Vehicle Operating Costs

If a rail scheme attracts some road users off the road, this switching will have some effects on the remaining road users, in terms of travel speed and time. The implications of time are considered under quantifying the congestion benefits. The impacts on speed and then on vehicle operating costs of the road stayers are to be considered separately. In fact, the impacts of rail schemes on vehicle operating costs were considered in the previous studies conjoined with time impacts. The current study approach is looking at vehicle operating cost impacts in its own, and as a separate issue. This is found to be the correct method of incorporating it. The reason is that the method of measuring vehicle operating costs benefits is different from the method of measuring congestion benefits. The former, being considered as a case of cost misperception, is measured through equation 6.4 above while the latter, being a sort of externalities, is measured through equation 6.3. The way both types of benefits are estimated will be explained in details in the relevant future chapters.

#### 6.3.3.4 Environmental Impacts

This is a very important source of benefits to rail schemes. This is because of the fact that roads are responsible for a greater portion of the environmental impacts such as noise and air pollution compared with rail transport as shown in chapter 1 (TEST, 1991). The previous studies of assessing the social costs and benefits have given little or no attention to this kind of impacts. That was probably because of the difficulties of quantifying the environmental effects, or sometimes the scheme being assessed thought to have little impacts on the environment. The current study approach stressing in the importance of incorporating the environmental impacts of rail schemes into the social appraisal framework, especially in a climate where road traffic is growing rapidly, leading to an accumulating damaging impacts on the environment.

As has been shown in chapter one there are so many impacts on the environment caused by transport. The two main sources of environmental damage are air pollution and noise. The current study approach is considering these two main impacts. Noise and air pollution for both rail and road are quantified in order to measure how much benefits will a rail scheme bring to the community in terms of noise and air pollution reduction, and which should be incorporated in a social framework of appraisal.

These are the four sources of benefits and costs that are considered and estimated under the current study approach. In fact a rail scheme might have some other sources of benefit such as development impacts. But this type of impacts probably does not reflect any real benefit to the society. This from the possibility that most of it is just a transfers. Because of that and the factual difficulties of tracing this kind of transfers, it is not considered under the current study.

### *6.3.4 The Precision of the Study Approach*

The current study appraisal approach is very precise in incorporating the social benefits of rail schemes into a social comprehensive framework. This Precision can be discussed under three main titles:

#### 6.3.4.1 Incorporating Externalities

**What is an externality?**

The question of what must be considered as an externality is not easy to answer. The answer depends on the level of aggregation employed (the extent to which the transport sector is to be broken down into sub-sectors when we attempt to define the cost liability of each action), and on where to draw the line between harmful and innocuous influence. In general, and as shown in chapter 1, an externality exists when an individual, firm, or a body through his action causes benefit or dis-benefit to another individual, firm, or body without taking these effects (benefits or dis-benefits) of his behaviour into account in his decision of making the action.

**Why incorporate externalities?**

If the pricing system throughout the transport sector is capable of making users pay the true costs of their trips, thus all the externalities are internalised, and the distortions caused by them will diminish. But, if this internalisation process is not applied or partly applied, in this case externalities have to be accounted for when considering the assessment of investment in the transport sector services. Looking at externalities as either resource cost used (external costs), or resource cost saved or released (external benefits). By incorporating externalities in the investment assessment process, we are correcting for the use of the resource costs. Taking the resource cost saved or released as a benefit to the scheme and considering the resource cost used as a cost to the scheme. To elaborate in this, when a rail scheme, for example, attracts some road users off the road, this will probably imply a resource cost saved or released equal to the amount of external costs caused by those who moved to use rail instead of road (movers), in terms of congestion time saved, noise and air pollution reduction on the road. On the other hand, those movers may cause some external costs on their trips by rail, would not have been caused had they not moved, which will imply some use of a resource cost, in terms of extra rail noise and air pollution as a result of those new users of the rail services.

When assessing investment on a social grounds, the question of external impacts of projects is a very important one, and has to be brought in. As has been discussed in the previous chapters, transport sector investments have many external impacts. This externalities have really to be considered at the margin if a comprehensive social approach is to be used. It is the current study approach that brings this external impacts at the margin into the appraisal framework. This is found to be relevant when measuring congestion time benefits, noise and air pollution. A rail scheme that leads to a passenger km or vehicle km to be transferred from road to rail will bring a social benefits equal to marginal time cost saved as a result of this transfer and would have been imposed on other road users if this transfer had not happen. This is really what should be incorporated in the social appraisal framework, and what is measured under the study approach.

Environmental impacts is the second kind of externalities which is included under the study approach. Noise and air pollution benefits are estimated for road and rail at the margin.

#### 6.3.4.2 Disaggregation by Road Types

The amount of benefits a rail scheme brings through attracting users off the road, is a function of many factors. Beside the type of the investment on the railways being developed (replacement, pure expansion, etc.), the alternative road characteristics will share into determining the magnitude of the benefits. It is the intention of the study to disaggregate the benefits gained from rail schemes-in terms of impacts on remaining road users- by road types. The types of roads disaggregated by are:

1. Motorways
2. Major Urban Central Roads
3. Major Urban Non-central Roads
4. Rural Dual Carriageway Roads
5. Rural Single Carriageway Roads

6. Minor Urban Central Roads
7. Minor Urban Non-central Roads
8. Minor Rural Single Roads

Considering the alternative road type is very essential since it will allow the framework appraisal to be a universal one, that can be applied straightforwardly, once the road alternative is assigned. Also it will be valid for a large majority of rail schemes, since a range of road types is considered.

#### 6.3.4.3 Incorporation of Traffic Variations

Beside allowing for different types, the current study approach is trying to measure the scheme benefits as precise as possible by incorporating the real variations of traffic flows on the British roads and the variations of the traffic over time and place. In reality for each type of roads listed above, traffic will vary from time to time and from place to another. Instead of basing the measurements of the benefits on some average hourly traffic flows, the current study approach allows for the following variations in traffic to be incorporated in measuring the benefits:

1. Traffic variations during the day (24 hours variations)
2. Traffic variations during the week (7 days variations)
3. Traffic variations during the year (12 months variations)
4. Traffic variations from place to another on the network, a sample distribution of 22-24 sites on the traffic distribution on the network is used.

The allowance of the traffic variations in the measurement process brings greater precision into the measured benefits which makes the framework of appraisal very precise. Traffic variations are incorporated in measuring congestion time benefits, vehicle operating cost benefits (misperception), and noise benefits. The method of measurements will be explained in detail in the relevant chapters in the rest of the thesis.

### *6.3.5 The Accuracy of the Study Approach*

One of the main features of the study approach is the accuracy of measuring the benefits of investments. If benefits or costs mismeasured or measured inaccurately while assessing scheme benefits, the resulting decisions may be wrong and then will lead to an undesirable implications. So it is vital to consider the matter of accuracy in developing an appraisal framework such that suggested by this study. In the previous studies such as discussed in chapter 5, the issue of perception were not considered. What is important here is to stress the vitality of this issue especially when assessing schemes on a social basis. Transport has so many examples where misperception can occur. Travellers may misperceive some costs of their trips, such as some vehicle operating cost items. The reasons of misperception were discussed in previous chapters. This misperception creates an area of distortions if it is not corrected for. The approach of the current study takes care of and incorporates the misperceived costs into the appraisal framework. This is found to be relevant in assessing vehicle operating cost and accident benefits.

## 6.4 Chapter Summary

This chapter is devoted to demonstrate the approach of the study in incorporating non-user benefits of rail schemes and how this approach fits within the social appraisal framework. Non-user benefits concerned and measured are congestion time benefits, noise, air pollution, accidents and vehicle operating costs. The first three are considered to be externalities (either external benefits or costs to rail scheme), while the last two are dealt with as a case of cost misperception. The chapter shows the main stages of incorporating these benefits within a social appraisal framework and the expected results from the analysis. The details of the simulation and calculation process as well as the exact results of the analysis are all given in the future relevant chapters. A specified chapter is given to each type of the concerned non-user benefits.

### References

1. **TEST** (1991) *Wrong side of the tracks? impacts of road and rail on the environment: a basis for discussion.* London

# Chapter 7

## Externalities (Road Congestion Time Benefits): Methodology

### 7.1 Introduction

The previous chapter outlined the study approach of incorporating the non-user benefits of rail schemes into a social appraisal framework. The types of non-user benefits to be incorporated were defined to be either externalities, (congestion, noise and air pollution), or cost misperception cases, (accidents and vehicle operating costs). The methods of measuring these benefits and the results of measurement, as mentioned in chapter 6, are detailed and discussed in this chapter and the chapters that follow.

This chapter and the chapter that follow are concerned with the first and perhaps the most crucial type of non-user benefits. This is the road congestion time benefits. It is crucial due to the fact that it touches the daily life of everybody in the society, either directly, or indirectly. The direct impacts of congestion on roads, are delays for motorists and travellers as well as goods, stress and annoyance to drivers and travellers. The indirect impacts, are due to the interaction between congestion and other environmentally damaging effects, such as noise and air pollution, as well as the interaction with accidents.

Time is one of the main resources in a society and probably the most valuable resource a person has. Hence any time wasted presents a waste of the well-being of individuals as well as the society at large. A policy that rationalises the use of time through minimising the time wasted will of course benefit and improve the well-being of individuals involved and the society as a whole. This means that it is essential to incorporate the time external costs of road congestion into the assessment process of the alternative public transport investment, and to measure this externality as accurately and precisely as possible.

The incorporation of the time externality rationalises the use of a very important resource (time), and will help in rationalising the use of investment resources, by directing the investment towards the efficient and most beneficial use. It follows, that any misestimation of time externality will distort and confuse the results of the assessment process, and then will distort the investment decision.

This chapter is concerned with outlining and explaining the methodology and steps of the process of measuring the congestion time cost externality for the UK road network.

The chapter starts, in section 7.2 by showing how time externality happens due to the interaction between drivers on the road when congestion builds up. Then section 7.3 identifies the main determinants of this type of externality and section 7.4 explains how time externality is derived mathematically. After that, section 7.5 details the method used for measuring congestion time externality for British road network.

## 7.2 Road Congestion and Time Externality

### *7.2.1 Introduction to Traffic Congestion*

The demand for transport is not constant over time. Transport infrastructure, although flexible in the long run, has a finite capacity at any given period of time. When users of a particular facility begin to interfere with other users due to the capacity of the infrastructure being limited, then congestion externalities arise. Of course, some degree of congestion is almost unavoidable if transport facilities are not to stand idle most of the time, but the question is how much congestion is desirable. Since people accept some level of congestion but resent excessive congestion, because of the time and inconvenience costs imposed, there is some implied notion of an optimal degree of congestion.

It is worth adding, that congestion does not only impose costs on the road user in terms of time wasted and fuel, *the pure congestion costs*, but the stopping and starting it entails can also worsen atmospheric and other forms of pollution. The problem is very acute for local forms of pollution because road traffic congestion, tends to be focused in areas where people work and live.

### *7.2.2 Interaction Between Road users and Congestion Time Externality*

Neglecting the issues of air pollution and noise damage, etc. for the time being, the costs of making a trip on a road have three elements:

1. first, is the user's own costs of using the uncongested road (time, fuel, other operating costs, risk etc.)
2. second, the congestion cost faced by the marginal user of the road (this increases with the flow of traffic due to slower journey times)
3. third, the congestion costs imposed by the marginal road user on other users of the road.

When a road user decides to make a trip on a road, he only considers the first two types of costs in his decision of travel as the costs of his trip. In other words, any individual user entering the road will only consider the costs he personally bears, he will, in most circumstances, either be unaware of or unwilling to consider the additional congestion costs he imposes on the other road users. Consequently, the individual motorist will only consider the average costs experienced by road users and will take no account of the congestion impact of his trip on other vehicles.

Bearing in mind that, externalities exist when the activities of one group affect the welfare of another group without any payment or compensation being made, this congestion impact of a road user on the rest of road users is a clear obvious example of an externality, that is caused by the interaction between road users and the interfere with each other.

Figure 7.1 shows a graphical demonstration of congestion time externality. DD is the demand curve for travel by road, representing different travel demands for different levels of generalised cost of travel. The curve MPC, represents the marginal private cost curve - that is, the additional cost (time and money costs) borne and perceived by the new trip-maker alone. While MSC, represents the marginal social cost for the new trip-maker and existing road users of an addition to the traffic flow. The difference between MPC and MSC curves at any traffic flow reflects the external congestion time cost at that flow. In other words, it is equal to the value of time imposed by the marginal trip-maker on the rest of users, and that is not included in his perceived cost of the trip.

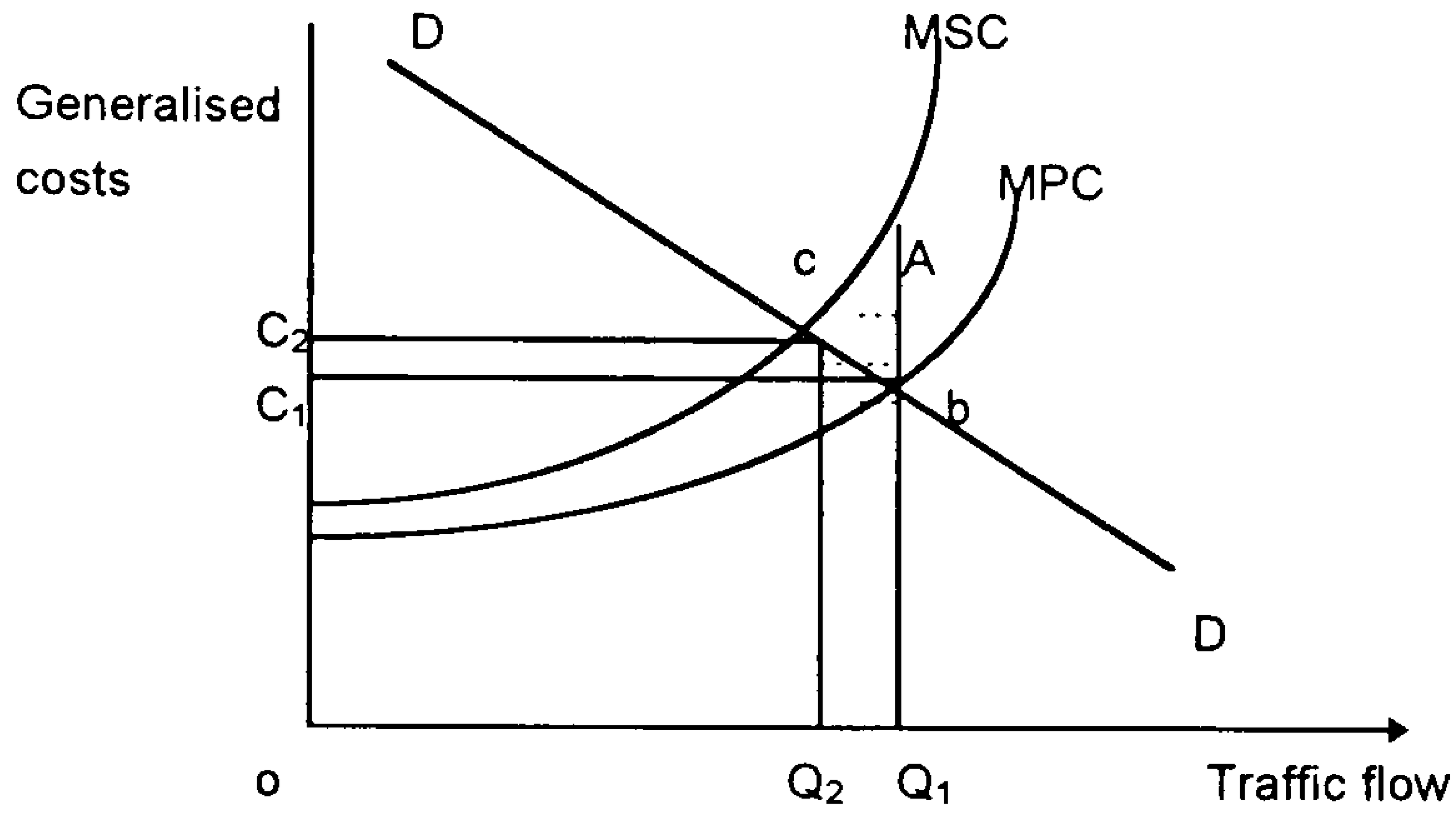


Figure 7.1 External congestion time cost

Referring to figure 7.1, in the absence of congestion tolls, and because trip-makers ignore the congestion that they impose on others, the actual traffic flow level is expected to be $OQ_1$, this is the level where the marginal private cost for motorists is equal to the marginal benefits they derive from the trip (as presented by demand curve). While, the optimal flow level is $OQ_2$, that is the flow level in which the marginal social cost of an additional trip will be equal to the marginal benefit of the trip. Limiting traffic flow to the optimal level (point C on the graph) will avoid an area of dead-weight loss CAB, as a result of excessive traffic congestion. This can only be achieved by designing a toll or tax system that matches exactly and make over the difference between the costs trip-maker considers and the total actual costs he really cause when making a trip. Put differently, the toll has to be exactly equal to the marginal congestion time external cost, otherwise it will be distorting to the whole system. That brings home, the essential and crucial need to measure the marginal external congestion time cost very accurately, and precisely.

### 7.3 Determinants of Marginal Congestion Time Externality

As explained above congestion time externality happens as a result of road users interfering with each other because of the capacity of road is limited. It follows that the key factor is the flow of traffic in relation to the capacity of the road. For uncongested roads, one expects to find marginal private and social costs of trips are equal, while on a built-up road the magnitude of congestion time external cost will be vital. So if the key factor is traffic flow (presents the demand side) in relation to capacity of the road (presents the supply side) the characteristics of both supply and demand will in turn be the main determinants of the congestion time externality. The following figure demonstrates these determinants.

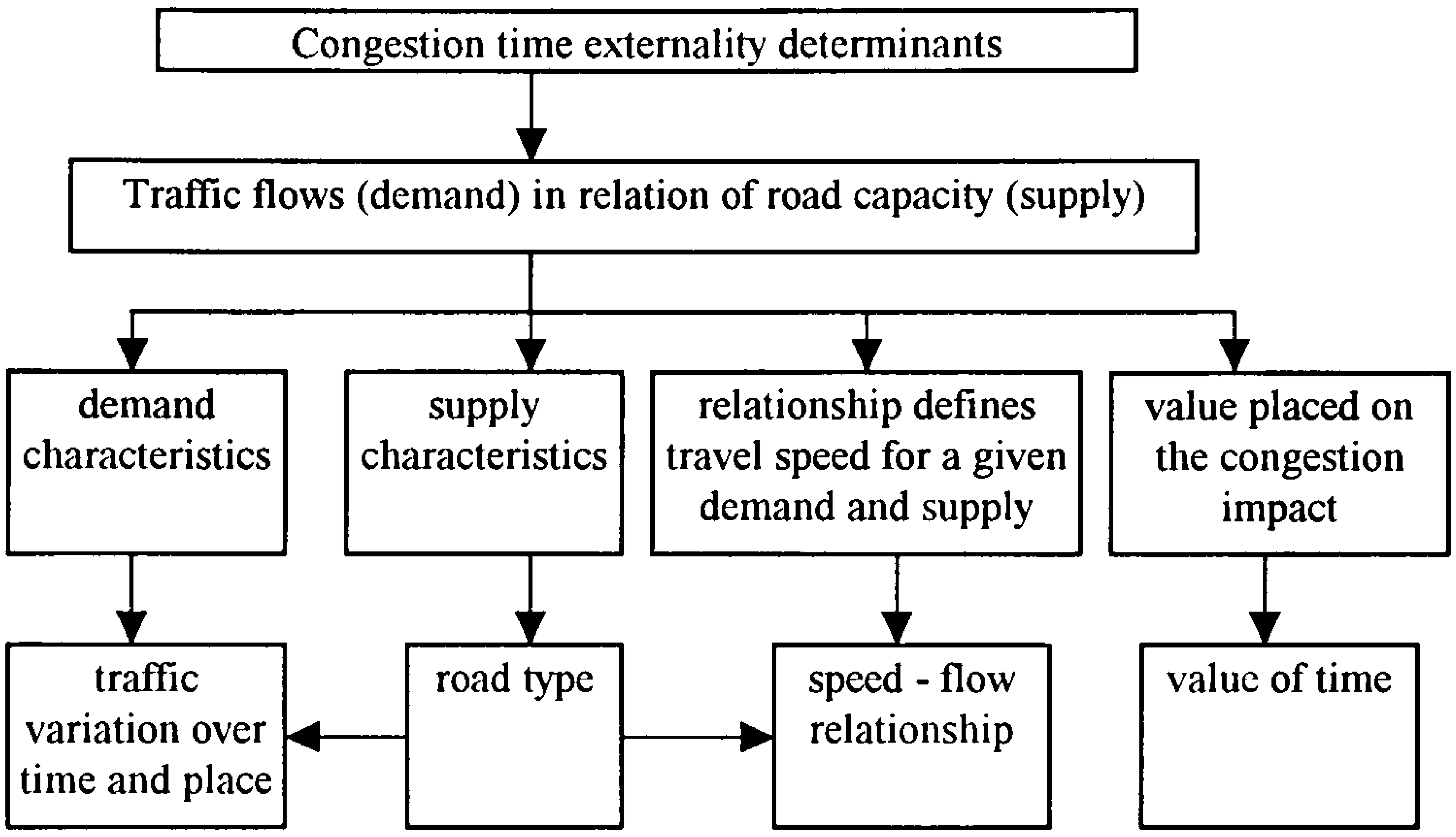



Figure 7.2 Determinants of congestion time externality

### 7.3.1 *Time Variation*

Traffic flows on a road are subject to variations throughout the day, (peak, off peak, day time off peak, night time travel), reflecting different travel demands from time to another during the day. Variation of traffic flows also exists throughout the week and the year, reflecting travel demand variations from day to another or from month to another throughout the year. These variations with time will in general depend upon the social structure of the society as a whole and the characteristics of travel demands. It follows, for a given road, congestion time externality will vary with the variation on the flow levels, probably from hour to another throughout the day, and from day to another throughout the week as well as from one month to another in a year. This is a very important determinant to the congestion time externality, and that has to be handled carefully and taken account of when measuring this type of externality.

The study approach as will be explained latter in this chapter, has taken account of these variations, which are deemed to have a significant impact on the results as will be seen latter.

### 7.3.2 *Road Type*

Beside the variations on traffic over time, the type of the road concerned will play a very important role into the measurement of congestion time cost externality. Traffic flows on a rural single road will differ from that on a built-up road. The flows on the latter will vary from one place to another, central or non-central. In addition, the road type and characteristics will have some important implications on the travel speed for a given traffic flow. This in turn will affect the magnitude and the extent of congestion time externality.

Again the approach of the study has considered this issue of road type through the measurement of congestion time externality. A broad range of road types has been selected, as shown in the previous chapter.

### *7.3.3 Speed-flow Relationship*

Since congestion time externality, indicates the value of time imposed on the trip-makers by an additional trip-maker, who does not consider this impact in his decision of making a trip, the relationship between traffic flows and speed will determine the ultimate congestion impact of a given flow of traffic on a given type of road. The shape of the speed-flow relationship is a key factor.

The approach of this study, as explained in details latter, has based the calculations of Marginal Congestion Time Externality (MCTE) on a mix of speed-flow relationships that are found to be most suitable for the road types concerned.

### *7.3.4 Value of Time*

This is a very important determinant of MCTE, since a value has to be placed on the extra time imposed on road users as a result of congestion. The value of time in turn is, to some extent, a function of the type of the journey made, whether it is a work trip, shopping trip or a leisure trip. The value of time used by the study approach are those used by COBA in assessing road schemes. A discussion will be made latter on in this chapter about the importance of the value of time and the possibilities of using different values of time in order to have more precise and accurate results.

## 7.4 Derivation of Congestion Time Cost Externality

The standard method of estimating the marginal congestion time externality (MCTE) of an extra vehicle in the traffic stream is as follows:

First, a relationship between travel speed (km/h) and traffic flow (pcu/hr) where pcu are passenger car units has to be defined. Then second to estimate the congestion impact of different types of vehicles in different circumstances. This is shown as follows:

If the time cost of travel per km for a representative vehicle is expressed by the following relationship:

$$C = \frac{1}{S} \qquad (7.1)$$

where:

C = time cost per vehicle km (h/pcu km)

S = travel speed (km/h)

The total time cost of a flow of vehicles (q) per hour on the road will be:

$$TC = Cq \qquad (7.2)$$

Where:

TC = total time cost for a flow of vehicles per kilometre

When an additional vehicle is added to the flow, the total social time cost is increased as follows:

$$\frac{\partial TC}{\partial q} = C + q\frac{\partial C}{\partial q} \qquad (7.3)$$

Where:

$\partial TC/\partial q$ = is the increase in the total social time cost as a result of the additional vehicle that joined the flow.

The first term in equation 7.3 (C) is the private time cost borne by the additional vehicle itself. The second part is the extra time cost borne by other road users as a result of the additional vehicle, and this is the Marginal Congestion Time Externality (MCTE). From equation 7.3,

$$MCTE = q\frac{\partial C}{\partial q} \qquad (7.4)$$

Where:

MCTE = marginal congestion time externality (h/pcu km)

If v is the value of time (£/pcu hour), equation 7.4 can be used to identify the value of MCTE as follows:

$$MCTE^{*} = vq\frac{\partial C}{\partial q} \qquad (7.5)$$

Where:

$MCTE^{*}$ = marginal congestion time cost externality (£/pcu km)

MCTE and $MCTE^{*}$ will be measured for the UK road network. The measurement process will incorporate traffic flow variations over time (daily, weekly, and yearly variations) and the location variations in traffic on the road network. The following sections detail the method of measurement while the results are shown in the next chapter.

## 7.5 Methodology of Measuring Marginal Time Externality

### *7.5.1 Methodology Framework*

The framework of the methodology used to measure the marginal congestion time externality for each type of road for the UK road network is demonstrated in figure 7.3. The following sections explain the work steps in details.

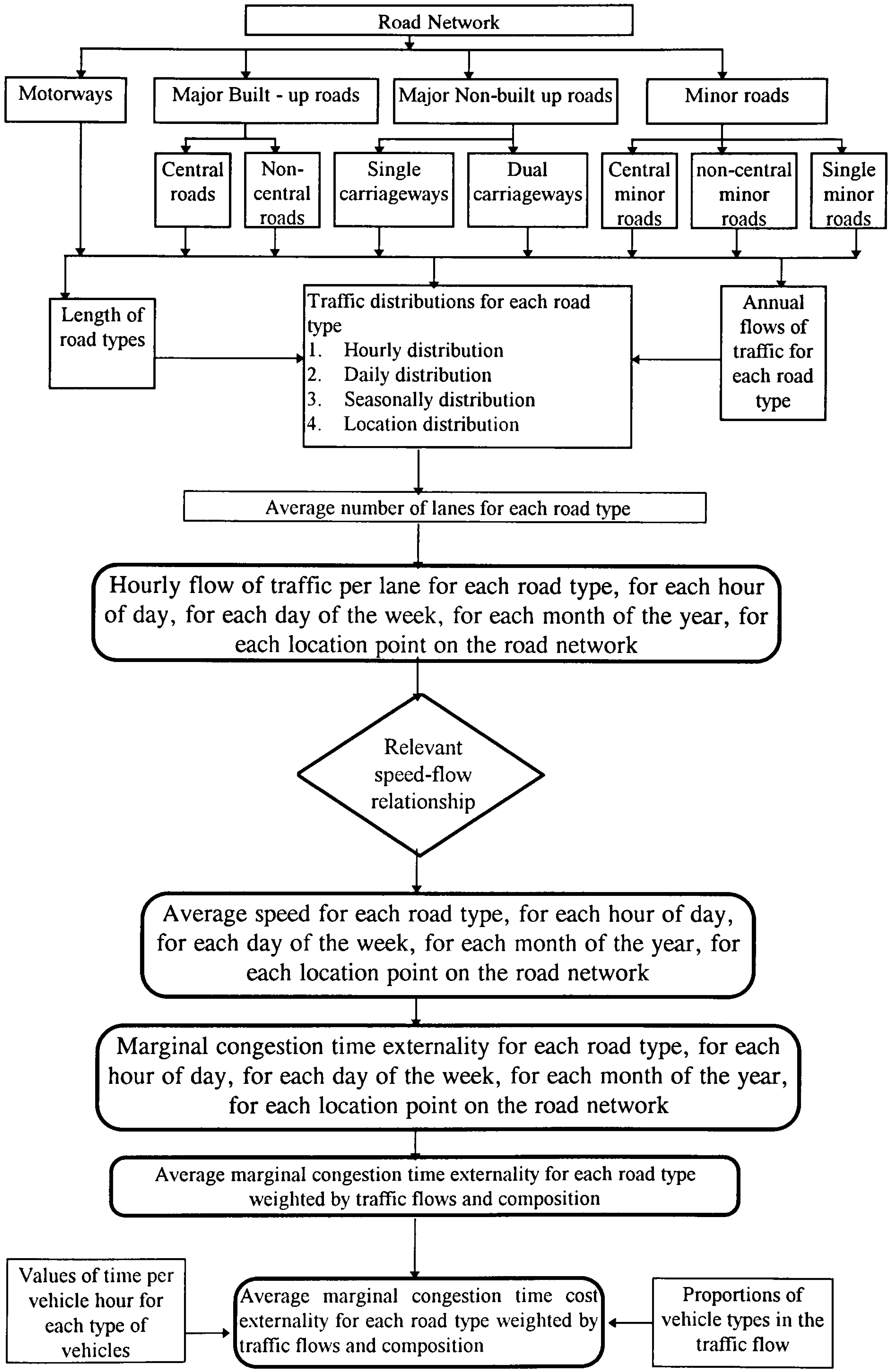



Figure 7.3 Methodology framework of measuring time cost externality

### 7.5.2 *Steps of the Process*

The following sections explain the steps of the process, containing all the assumptions made, the sources of data and other required information, mathematical models and relationships used, and the calculations made, in a story line along with figure 7.3 showing how the marginal congestion time externality is measured for the UK road network.

#### 7.5.2.1 Step One: Road Types

Traffic flows and length statistics for the UK road network are broken down for the following road classes (DTp, 1993):

1. Motorways
2. Major built-up roads : identified as all of those with a speed limit of 40 mile per hour or less (irrespective of whether there are buildings or not)
3. Major non-built up roads : identified as all roads with speed limit in excess of 40 mile per hour
4. All minor roads: identified as B , C and unclassified roads

□ For the purpose of the study, and in order to measure congestion time cost externality for a broader range of road types, major built-up roads are broken down into:

1. Major urban central roads : major roads in central areas where central areas are defined as those including the main shops, offices and central rail stations, with high density of land used and frequent multi-story developments.
2. Major urban non-central roads : comprise roads in the remainder of the urban areas.

□ Major non-built up roads are broken down to:

1. Single carriageway roads
2. Dual carriageway roads

□ Minor roads are divided into three types:

1. Minor urban central roads : B, C, and unclassified roads in central urban areas.

2. Minor urban non-central roads : B, C, and unclassified roads in the remainder of the urban areas.
3. Minor rural single roads : B, C, and unclassified roads in rural areas.

This process gives 8 types of road which represent the entire road network, and for which congestion time externality is measured.

#### 7.5.2.2 Step Two: Road Traffic and Length Data

Annual traffic flows (billion vehicle kilometres) and road length are given as mentioned above (DTp 1993) for the four broad types of roads (motorways, major built-up, major non-built up, and minor roads). On the basis mentioned in step one above, the traffic and length data are adapted to the 8 types of road as follows:

1. **Motorways:** as mentioned above traffic and length data are given separately for motorways.

**2. Major built-up roads**

Total vehicle kilometre travelled (VKT) and length of major built-up roads are split between major urban central and non-central roads. Central urban roads are assumed to accommodate for 20% of VKT, and the rest 80% is on non-central roads. Based on information from COBA, central roads account for 11% of the total length of built-up roads, this figure is used by the study to split the total length of built-up roads between central and non-central urban roads.

**3. Major non-built-up roads**

Traffic and length statistics are given for this types of roads in total and split into trunk and principal roads. Some additional information obtained from the Department of Transport suggested the following:

a) 30% of trunk roads are single carriageways and the rest is dual carriageways.

b) 80% of principle roads are single carriageways and the rest is dual carriageways.

Based on this information, traffic and length data are split between single and dual carriageways and used to measure the marginal congestion time externality for these two types of roads.

**4. Minor roads**

Traffic data are given as a total for all minor roads together. Some assumptions have to be made for splitting the traffic between the three types of minor roads identified by the study above. Minor urban central roads are assumed to accommodate for 10% of all minor road traffic. The rest is split between minor urban non-central and minor rural single roads as 60 and 30% respectively.

Road length data for the three types of minor roads are given in the Department of Transport Statistics (DTp, 1992). About 55% of minor roads are rural and the rest is in built-up areas, 5% of which is in central urban areas and the rest 40% is in urban non-central areas.

#### 7.5.2.3 Step Three: Traffic Distributions

In order to measure the marginal time externality, the variations of traffic flows are incorporated, so the ultimate results can be based on the actual traffic streams on the roads. Four traffic distributions are incorporated. These are:

a) **Traffic distribution by month**, giving the seasonal variation throughout the year (12 month variations).

b) **Traffic distribution by day of week**, giving the daily variations in the traffic (Monday to Sunday variations).

c) **Traffic distribution by time of day**, indicating the hourly variations of traffic flows (24 hour variations).

d) **Traffic distribution by location on the road network**, placing a picture of the variations of the traffic flows from place to another on the road network.

The first three distributions (seasonally, daily, and hourly) are found to be broken down by different road classes for all motor vehicles in the Department of Transport Statistics (DTp, 1993, 1994a). The distributions are set in the form of indices reflecting the variations of traffic flows from month to another throughout the year, from day to another throughout the week, and hour to hour variations throughout the day. The indices are set relative to the average monthly, daily and hourly traffic flows. These indices are used in the calculations of the hourly per lane flows of traffic and then the corresponding speeds and MCTE and MCTE*.

**Traffic distribution by location on the road network**

In the Department of Transport statistics, the distribution of traffic flows by location on the road network is not given in the same form as the first three distributions mentioned above . As shown in table 7.1, the distribution of all motor vehicle flow by road class is given as a percentage of sites counted for each range of average daily flow of vehicles (DTp, 1993).

This distribution is used to generate a location distribution of traffic flows in a form of indices indicating the variations of traffic flows from one point to another relative to the average point in the road network. The generated indices would give a picture of the variations of traffic flows over the entire network, and then would be consistent with the other three distributions of traffic (seasonally, daily, hourly).

Table 7.1 Distribution of all motor vehicle flow by road class

| | Percentage of sites counted | | | |
|---|---|---|---|---|
| Range of average daily flow of vehicles | Motorways | Major built-up roads | Major non-built-up roads | Minor roads |
| 0-499 | 0 | 0.25 | 2 | 37 |
| 500-999 | 0 | 0.25 | 3 | 14 |
| 1000-2499 | 0.5 | 1 | 9 | 18 |
| 2500-4999 | 0.5 | 4 | 15 | 14 |
| 5000-7499 | 0.5 | 6 | 14 | 7 |
| 7500-9999 | 0.5 | 9 | 12 | 4 |
| 10000-24999 | 13 | 58 | 33 | 5 |
| 25000-49999 | 36 | 19 | 11 | 1 |
| 50000-74999 | 28 | 2 | 1 | 0 |
| 75000-99999 | 13 | 0.25 | 0 | 0 |
| 100000-124999 | 5 | 0.25 | 0 | 0 |
| 125000 or more | 3 | 0 | 0 | 0 |
| all ranges | 100 | 100 | 100 | 100 |

Source: Department of Transport 1993

The process of generating the location distribution of traffic flows is as follows:

1. The percentage of sites counted for each range of traffic flows in table 7.1 are accumulated as shown in table 7.2.

Table 7.2 Accumulated percentage of sites counted by road class

| | Percentage of sites counted accumulated by range of vehicle flow | | | |
|---|---|---|---|---|
| Range of average daily flow of vehicles | Motorways | Major built-up roads | Major non-built-up roads | Minor roads |
| 0-499 | 0 | 0.25 | 2 | 37 |
| 0-999 | 0 | 0.5 | 5 | 51 |
| 0-2499 | 0.5 | 1.5 | 14 | 69 |
| 0-4999 | 1 | 5.5 | 29 | 83 |
| 0-7499 | 1.5 | 11.5 | 43 | 90 |
| 0-9999 | 2 | 20.5 | 55 | 94 |
| 0-24999 | 15 | 78.5 | 88 | 99 |
| 0-49999 | 51 | 97.5 | 99 | 100 |
| 0-74999 | 79 | 99.5 | 100 | |
| 0-99999 | 92 | 99.75 | | |
| 0-124999 | 97 | 100 | | |
| 0-125000 or more | 100 | | | |

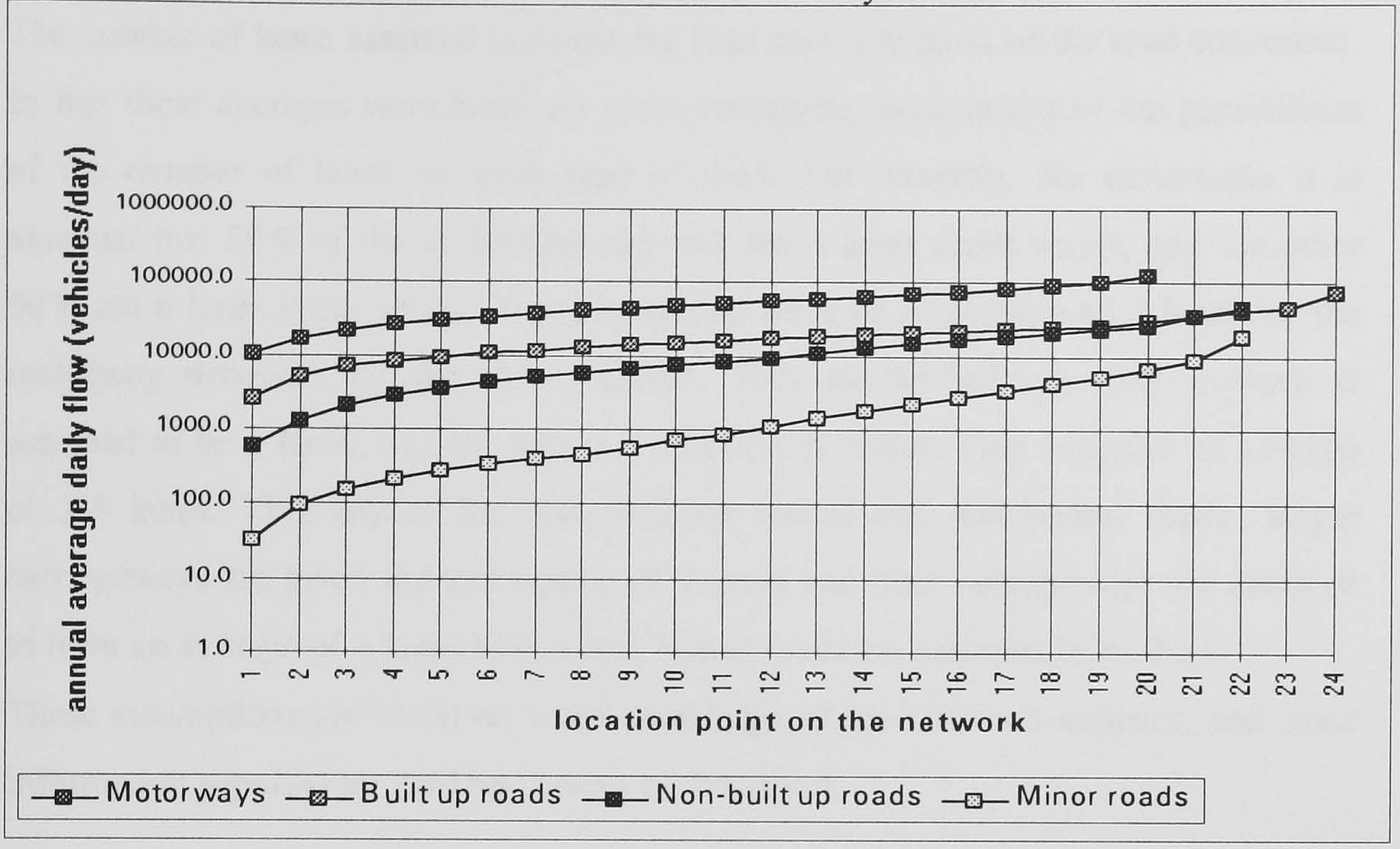
This table is derived from table 7.1

2. The accumulated percentage of sites counted are replaced by a number of points representing each percentage counted for each range of daily flow of traffic. For example, for motorways, table 7.2 shows that 15% of the sites counted for the range of 0 to 24999 vehicles per day. This is represented by 3 points out of 20 point representing the 100% of sites counted for motorways. On the same basis, this process is carried out for all types of roads giving the representative distribution in table 7.3 and graphically in figure 7.4.

Table 7.3 Adjusted Location distribution for traffic flows

| location | Vehicles/day | | | | Index Average location point = 100 | | | |
|---|---|---|---|---|---|---|---|---|
| Point on the network | Motorways | built up Roads | Non-built up roads | Minor roads | Motorways | built up Roads | Non-built up roads | Minor roads |
| 1 | 10576.9 | 2656.3 | 583.3 | 33.8 | 19.5 | 12.5 | 4.6 | 1.2 |
| 2 | 16346.2 | 5208.3 | 1333.3 | 94.6 | 30.1 | 24.4 | 10.4 | 3.4 |
| 3 | 22115.4 | 6979.2 | 2083.3 | 155.4 | 40.7 | 32.8 | 16.3 | 5.6 |
| 4 | 26736.1 | 8333.3 | 2833.3 | 216.2 | 49.2 | 39.1 | 22.2 | 7.8 |
| 5 | 30208.3 | 9513.9 | 3583.3 | 277.0 | 55.6 | 44.7 | 28.0 | 10.0 |
| 6 | 33680.6 | 10646.6 | 4333.3 | 337.8 | 62.0 | 50.0 | 33.9 | 12.1 |
| 7 | 37152.8 | 11745.7 | 5089.3 | 398.6 | 68.3 | 55.1 | 39.8 | 14.3 |
| 8 | 40625.0 | 12844.8 | 5892.9 | 459.5 | 74.7 | 60.3 | 46.1 | 16.5 |
| 9 | 44097.2 | 13944.0 | 6696.4 | 553.6 | 81.1 | 65.4 | 52.4 | 19.9 |
| 10 | 47569.4 | 15043.1 | 7500.0 | 714.3 | 87.5 | 70.6 | 58.6 | 25.7 |
| 11 | 51339.3 | 16142.2 | 8437.5 | 875.0 | 94.4 | 75.8 | 66.0 | 31.5 |
| 12 | 55803.6 | 17241.4 | 9375.0 | 1083.3 | 102.7 | 80.9 | 73.3 | 39.0 |
| 13 | 60267.9 | 18340.5 | 10681.8 | 1458.3 | 110.9 | 86.1 | 83.5 | 52.4 |
| 14 | 64732.1 | 19439.7 | 12727.3 | 1833.3 | 119.1 | 91.2 | 99.5 | 65.9 |
| 15 | 69196.4 | 20538.8 | 14772.7 | 2208.3 | 127.3 | 96.4 | 115.5 | 79.4 |
| 16 | 73660.7 | 21637.9 | 16818.2 | 2678.6 | 135.5 | 101.6 | 131.5 | 96.3 |
| 17 | 81730.8 | 22737.1 | 18863.6 | 3482.1 | 150.4 | 106.7 | 147.5 | 125.2 |
| 18 | 91346.2 | 23836.2 | 21136.4 | 4285.7 | 168.0 | 111.9 | 165.3 | 154.1 |
| 19 | 102500 | 24935.3 | 22954.5 | 5178.6 | 188.6 | 117.0 | 179.5 | 186.2 |
| 20 | 127500 | 30263.2 | 25000.0 | 6785.7 | 234.6 | 142.0 | 195.5 | 244.0 |
| 21 | | 35855.3 | 35227.3 | 9062.5 | | 168.3 | 275.4 | 325.9 |
| 22 | | 41447.4 | 45454.5 | 19000.0 | | 194.5 | 355.4 | 683.3 |
| 23 | | 47039.5 | | | | 220.8 | | |
| 24 | | 75000.0 | | | | 352.0 | | |

Figure 7.4 Distribution of all motor vehicle traffic flow by road class




These four distributions, give an illustration of traffic flows on the road network and are incorporated in the process of measuring the marginal congestion time externality.

#### 7.5.2.4 Step Four: Number of Lanes by Road Type

In order to make traffic flows suitable for the speed-flow relationships used in the methodology of measuring MCTE and MCTE*, flows have to be measured per hour per lane. So some assumptions are made about the average number of lanes for each road type of the 8 types of the study. These assumptions are:

Table 7.4 Assumptions of the average number of lanes for different roads

| Road type | Average number of lanes assumed (two way) |
|---|---|
| 1. Motorways | 5 |
| 2. Major central urban roads | 3.5 |
| 3. Major non-central urban roads | 3.5 |
| 4. Single carriageway roads | 2 |
| 5. Dual carriageway roads | 4 |
| 6. Minor central urban roads | 2 |
| 7. Minor non-central urban roads | 2 |
| 8. Minor single rural roads | 2 |

The number of lanes assumed indicates the total two way lanes of the road concerned. In fact these averages were based on some underlying assumptions of the possibilities of the number of lanes for each type of road. For example, for motorways it is assumed that 50% of the motorways network are 4 lanes (both ways), and the other 50% are 6 lanes (both ways). This assumption leads to an average of 5 lanes for the motorway network. By the same manner, 75% of the built-up road network is assumed to be 4 lanes, and the rest is 2 lanes (both ways). This will give an average of 3.5 lanes. This applies for both built-up central and non-central roads. Single carriageways are given the assumption of 2 lanes and dual carriageways are assumed to have an average of 4 lanes both ways. Minor roads are assumed to be 2 lane.

These assumptions are based on some knowledge of the UK road network, and some information supplied by the Department of Transport.

#### 7.5.2.5 Step Five: Hourly Flow of Traffic

The hourly flow of traffic is calculated for all types of roads as follows:

$$q_r^{mdhl} = \frac{VKT_r \times I_r^m \times I_r^d \times I_r^h \times I_r^l}{RL_r \times N_r \times H} \qquad (7.6)$$

Where:

$q_r^{mdhl}$ = traffic flow per hour per lane for the corresponding road type r, for the corresponding month of year m, day of week d, hour of day h, location on the network l (pcu/ hour/lane)

$I_r^m, I_r^d, I_r^h, I_r^l$ = indices of traffic distributions reflecting traffic flows for the corresponding road type r ,month m, day d, hour h and location l relative to the average monthly, daily, hourly and location flows.

$RL_r$ = road length, total length of the network for the corresponding road type r (kilometres).

$VKT_r$ = annual vehicle kilometres travelled on the corresponding road type r (pcu kilometres)

$N_r$ = average number of lanes assumed for the corresponding road type r (total both ways lanes).

H = are number of hours per year (365 days x 24 hours).

Equation 7.6 is used to calculate the hourly per lane traffic flow (pcu /h/lane) for each hour of day, for each day of week, for each month of the year and for each representative location point on the road network. This is done for all the 8 road types.

#### 7.5.2.6 Step Six: Speed- flow Relationship and Speed Calculations

**A) Speed-flow Relationship**

In traffic modelling and assignment, it is not travel speed which is of interest, but rather its use for measuring journey time and travel delays on road links.

When modelling traffic congestion, one must be clear as what is needed, and what the proposed speed-flow relationship actually measures. Road users usually demand completed trips from origin to destination rather than the use of a particular stretch of road or link of road. Hence, speed-flow relationships should measure the average speed for a given trip from start to the end. However, most of the relationships developed by traffic engineers are for link speeds.

The Department of Transport, in planning for road building and maintenance uses formulae based on studies carried out by the Transport and Road Research Laboratory (TRRL 1979a, 1979b, 1980a, 1980b, Duncan et al 1980, and Marlow 1978).

The formulae are given in details in the Cost Benefit Analysis COBA manual (DTp, 1981). COBA contains eight sets of speed-flow curves, including curves for rural, suburban, urban central and non-central roads. The general form of the formula is as follows:

$$S = \alpha - \beta q \qquad (7.7)$$

Where:

S = speed (km/h)

q = flow of vehicles per lane per hour (pcu/hr/3.65m lane)

$\alpha, \beta$ = constants.

The values of $\alpha$ depends on the geometric characteristics of the road (number of intersections, percentage of development, percentage of heavy vehicles, bendiness, sum of rises and falls per unit distance (m/km), etc.).

$\beta$ is the slope of the speed-flow curve and depends upon the road type and flows of traffic. For rural roads, the value of the slope $\beta$ is a function of the flows of traffic giving a steeper slope for the speed-flow curve beyond a certain traffic flow.

In built-up areas, the road network become more dense and intersections play a more significant role in determining travel speeds compared with rural roads. COBA speed-flow formulas for urban roads make allowance for delays at junctions and intersections. However, the formula developed for rural roads do not incorporate junction delays. In general, therefore, junctions on rural roads are always modelled explicitly.

Link capacities in COBA are set to be equal the highest levels of traffic flow per standard lane (3.65m) that have been observed when the speed-flow curves were developed. Speeds are allowed to continue drooping with increasing flows beyond capacities until a minimum speed is reached. The minimum speeds set in COBA are 45 km/h for motorways and other rural roads. For urban central and non-central the minimum speeds are 15 and 25 km/h respectively.

With this constraint of minimum speed in COBA, the realism of the predicted speed might be questioned. Maintaining those minimum speeds does not allow for the occurrence of higher traffic flows. The occurrence of high and over capacity flows may be limited for rural roads and motorways. However, in case of urban roads, over capacity and high levels of traffic flows are more likely to occur. In such a case, the developed COBA speed-flow relationship might not be realistic in predicting the average travel speeds in urban areas.

With a limit set in COBA on the effect of congestion by the assumption of minimum speed independent of demand when demand exceeds capacity, some other models have been developed to take account of demand in excess of capacity. These models assume that in the region of demand in excess of capacity, there is an additional delay that varies with the difference between flows and capacity. The most widely used relationship is the BPR (Bureau of Public Roads, 1964). The relationship is expressed in a form of a time cost/flow curve as follows (Thomas, 1991):

$$T = T_f\left(1 + a(\frac{q}{M})^b\right) \qquad (7.8)$$

Where:

| | |
|---|---|
| T = | travel time (h/km) |
| $T_f$ = | free flow travel time (h/km) |
| q = | traffic flow per standard lane per hour (pcu/h/lane) |
| M = | practical capacity (pcu/h/lane) |
| a, b = | constants with suggested values of 0.15 and 4 respectively. |

The time cost/flow curve of equation 7.8 is used to derive the speed-flow relationship, to give the following form:

$$S = \frac{S^0}{1 + a(\frac{q}{M})^b} \qquad (7.9)$$

Where:

| | |
|---|---|
| S = | average speed (km/h) |
| $S^0$ = | free flow speed, average speed when flow of traffic is equal zero (km/h) |

The formula allows flows to exceed capacity and measures the impacts on average speeds in the congested conditions. Hence it is more appropriate for predicting speeds on urban areas where congestion is more likely to occur.

**B) Speed Calculations**

**1. Rural Roads**

Calculations of the speed for rural roads are based on the COBA (DTp, 1981) speed-flow relationship. The manual of the COBA program gives speed-flow relationships for different road classes in a straight line form, as shown in equation 7.7 above. Based on this formula, speeds are calculated for rural roads as follows:

$$S_r^{mdhl} = \alpha_r - \beta_r^{mdhl} q_r^{mdhl} \qquad (7.10)$$

Where:

$S_r^{mdhl}$ = average speed for rural road type r, in month m, on day d, at hour h, and for location point l (km/h)

$q_r^{mdhl}$ = flow of vehicles per lane per hour for rural road type r, in month m, on day d, at hour h, and for location point l (pcu/h/3.65m lane)

$\alpha_r$ = the value of the constant $\alpha$ for rural road type r

$\beta_r^{mdhl}$ = the value of the speed flow slope for rural road type r, in month m, on day d, at hour h, and for location point l

As can be seen, the terms $\alpha$ and $\beta$ will depend upon the type and characteristics of the road (number of intersections, percentage of development, percentage of heavy vehicles, bendiness, sum of rises and falls per unit distance (m/km), etc.). In addition the value of the slope $\beta$ is a function of the hourly per lane traffic flow.

Speed calculations are carried out for each type of rural road using this speed-flow relationship and the relevant values of the terms $\alpha$ and $\beta$ from the COBA manual, and based on the hourly per lane traffic flow calculated by equation 7.6. So speed (km/h) is calculated for each rural road type, for each hour of day, for each day of week, for each month of the year, and for each location on the road network.

**2. Urban Roads**

Speed calculations for urban roads are based on the speed-flow relationship from BPR that explained above and shown in equation 7.9. Using this formula and the hourly per lane flow measured in equation 7.6 above, speed is calculated for urban roads as follows:

$$S_r^{mdhl} = \frac{S_r^0}{1 + a(\frac{q_r^{mdhl}}{M_r})^b} \qquad (7.11)$$

**Where:**

$S_r^{mdhl}$ = speed for urban road type r, in month m, on day d, at hour h, and for location point l (km/h)

$S_r^0$ = free flow speed for urban road type r

$M_r$ = capacity of urban road type r (pcu/h/lane)

The values of $S_r^0$ and $M_r$ are taken from COBA. The free flow speed for urban central and non-central roads are 35.5 and 50 km/h respectively.

#### 7.5.2.7 Step Seven: Marginal Congestion Time Externality

Bearing in mind the method of deriving the marginal congestion time externality, as shown in section 7.4, and with the speed-flow relationships used by the study for rural and urban roads, as shown above by equation 7.7 and 7.9, marginal congestion time externality is measured as follows:

**1. Rural Roads**

$$MCTE_r^{mdhl} = \frac{\beta_r^{mdhl} q_r^{mdhl}}{(S_r^{mdhl})^2} \qquad (7.12)$$

Where:

$MCTE_r^{mdhl}$ = marginal congestion time externality (h/pcu km), reflecting the time imposed on road users as a result of an extra pcu km joining the road for rural road type r, in month m, on day d, at hour h, and for location point l.

Basing on the values of traffic flows per hour per lane (q) and speed (S) that are calculated by equation 7.6 and 7.10, and using the COBA relevant values for β, equation 7.12 is used to measure the marginal congestion time externality for different rural road types, in each hour of day, for each day of week, for each month of the year and for each location point on the network. As mentioned before, the value of speed- flow slope β , is a function of the traffic flows. In other words, β has different values for different traffic flow levels. This has been incorporated into the calculation process.

**2. Urban Roads**

Based on the speed-flow formula used by the study for urban roads, the marginal congestion time externality is measured as follows:

$$MCTE_r^{mdhl} = \frac{ab}{S_r^0}\left(\frac{q_r^{mdhl}}{M_r}\right)^b \qquad (7.13)$$

**Where:**

$MCTE_r^{mdhl}$ = marginal congestion time externality (h/pcu km), reflecting the time imposed on road users as a result of an extra pcu km joining the road for urban road type r, in month m, on day d, at hour h, and for location point l.

Basing on the values of traffic flows per hour per lane (q) that are calculated by equation 7.6 , and using the values for a and b, equation 7.13 is used to measure the marginal congestion time externality for different urban road types, in each hour of day, for each day of week, for each month of the year and for each location point on the network.

### 7.5.2.8 Step Eight: Average Weighted Marginal Time Externality

For each road type, the intention is to produce a value for the marginal congestion time externality that reflects and incorporates the variations in traffic (seasonally throughout the year, daily throughout the week, hour to hour during the day, and the distribution throughout the entire network), and incorporates road type characteristics. This is done by the average weighted value of marginal congestion time externality That is calculated as follows:

$$MCTE_r = \frac{\sum_{m=1}^{12}\sum_{d=1}^{7}\sum_{h=1}^{24}\sum_{L=1}^{L} MCTE_r^{mdhl} \times q_r^{mdhl} \times S_r^{mdhl}}{\sum_{m=1}^{12}\sum_{d=1}^{7}\sum_{h=1}^{24}\sum_{L=1}^{L} q_r^{mdhl} \times S_r^{mdhl}} \qquad (7.14)$$

Where:

$MCTE_r$ = average weighted marginal congestion time externality for road type r (h/pcu km).

Equation 7.14, gives the average extra time that is imposed on road users as a result of a pcu km joining the road for each road type, weighted by the vehicle kilometre travelled at each hour of the day, each day of the week, each month of the year and each location point on the network. This can be translated into money using the value of time as shown in the following step.

#### 7.5.2.9 Step Nine: Marginal Congestion Time Cost Externality

In this step, the value of the time externality measured by equation 7.14 ($MCTE_r$) is translated into money by using the value of time for each type of vehicles and the proportions of each vehicle type in the total traffic flow. The values of time that are used for appraising road investment schemes and included in the COBA manual are used in this study. The resource values of time for 1988 were as shown in table 7.5.

Table 7.5 Values of time for 1988 and 1993 prices and values

| Vehicle type | Pence per hour | |
|---|---|---|
| | 1988 values[1] | Updated values for 1993 |
| 1. Average car | 468.80 | 629.07 |
| 2. Light goods vehicles | 859.00 | 1152.66 |
| 3. Other goods vehicles | 622.50 | 835.31 |
| 4. Passenger service vehicle | 3213.70 | 4312.35 |

1. COBA values (Department of Transport, 1981)

The COBA values of time are updated for 1993 prices and values based on the change in the Gross Domestic Product (GDP), which is found to have increased by 2% approximately from 1988 to 1993 and the retail price index, which showed an increase of 31.5% approximately in prices during the period 1988-1993. This update gives the values shown in table 7.5 for 1993 values and prices, which are used for transforming the time externality into money using the values of times for 1993 as follows:

$$MCTE_r^* = MCTE_r\left(C_r T_c + L_r \times T_{LGV} + O_r \times T_{OGV} + P_r \times T_{PSV}\right) \qquad (7.15)$$

Where:

$MCTE_r^*$ = average marginal congestion time cost externality for road type r (£/pcu km).

$C_r$, $L_r$, $O_r$, $P_r$ = proportions of cars, light goods vehicles, other goods vehicles, and passenger service vehicles for road type r.

$T_c$, $T_{LGV}$, $T_{OGV}$, $T_{PSV}$ = values of time for the four types of vehicles respectively (£/vehicle hour).

#### 7.5.2.10 Step Ten: Average Weighted Travel Speed by Road Class

For each road class, a value for travel speed that reflects the variations in traffic flows and incorporates road type characteristics is produced. This is carried out by estimating the weighted average speed that is weighted by the vehicle kilometre travelled at each hour of day, each day of week, each month of the year, and each location point on the network of roads. Equation 7.16 shows the calculation process.

$$S_r = \frac{\sum_{m=1}^{12}\sum_{d=1}^{7}\sum_{h=1}^{24}\sum_{l=1}^{l} S_r^{mdhl} \times q_r^{mdhl}}{\sum_{m=1}^{12}\sum_{d=1}^{7}\sum_{h=1}^{24}\sum_{l=1}^{l} q_r^{mdhl}} \qquad (7.16)$$

Where:

$S_r$ = average weighted speed of travel for road type r (km/h)

### 7.5.2.11 Step Eleven: Calculation and Measurement Process

A computer program has been developed to carry out the burden of the calculations process. A flowchart showing the structure and how the steps of the work (1 to 10) are incorporated and undertaken by the program as well as a copy of the program itself are given in appendix 1.

### 7.5.2.12 Step Twelve : Distribution of Congestion Time Cost

To elaborate more, in addition to measuring the marginal congestion time cost externality for each road type, the aim is to create a distribution demonstrating the percentage of vehicle kilometre travelled on the road network for each category of congestion time cost. This is to give a clear picture of the magnitude of congestion time cost for different road types. The results are shown in the next chapter.

### 7.5.2.13 Step Thirteen: Speed Distribution

For more elaboration, a distribution for speed for each road type is given. The distribution gives a picture of different speed level categories and the proportions of vehicles travelled at each speed category. This is carried out by the program and the resultant distribution is discussed latter in the next chapter.

### 7.5.2.14 Step Fourteen: Congestion Time Cost and Speed Forecasts

This methodology process is used to predict the congestion time cost and speed in the future years. This is carried out by feeding the projected traffic flows form the Department of Transport National Road Traffic Forecasts (DTp, 1993), to the program using the same methodology outlined above to have an estimation of the marginal time externality and speed for future years. In this context, road network length did not change. One may argue that road network may be extended in the corresponding future years. Although, the projection of road building and the road building plan are usually announced in advance, the actual achievement may differ significantly from the plans, which may makes it difficult to have a presumption of the growth of the network of roads.

### 7.6 Chapter Summary

This chapter details the methodology adapted for measuring the marginal congestion time cost for British road network, which in turn may reflect the congestion time benefits of rail investment schemes. It shows how the breakdown of road types are selected and how traffic and length data are adapted for the selected road types. The real variations in traffic flows (hourly, daily, seasonally, and location) are incorporated so that a precise and accurate measurement of congestion time cost for different road types is carried out. The chapter shows how these distributions are incorporated and the adjustments carried out for the location distribution to be consistent with the other three distributions of traffic.

### References


1. **Department of Transport, DTp** (1992) *Road Lengths in Great Britain 1993.* Prepared by the government statistics service.
2. **Department of Transport, DTp** (1993) *Transport Statistics Report: Road Traffic Statistics Great Britain 1993.* Prepared by the government statistics service.
3. **Department of Transport, DTp** (1994a) *Transport Statistics Report: Road Traffic Statistics Great Britain 1994.* Prepared by the government statistics service.
4. **Department of Transport, DTp** (1994b) *Transport Statistics Report: Road Travel Speeds in English Urban Areas.* Prepared by the government statistics service.
5. **Department of Transport** (1981), *COBA* 9. HMSO, London.
6. **TRRL (Transport and Road Research Laboratory),** (1979a) *A study of speed-flow relations on rural motorways and all-purpose dual carriageways.* TRRL LF 779.
7. **TRRL (Transport and Road Research Laboratory),** (1979b) *Speed-flow formulae for rural motorways and all-purpose dual carriageways.* TRRL LF 780.
8. **TRRL (Transport and Road Research Laboratory),** (1980a) *A study of speed-flow geometry relations on rural single carriageways.* TRRL LF 923.
9. **TRRL (Transport and Road Research Laboratory),** (1980b) *Speed-flow geometry formulae on rural single carriageways.* TRRL LF 924.
10. **Duncan, N. C. et al** (1980) *Traffic speeds in towns - a further analysis of the urban congestion surveys.* Traffic engineering and control, December 1980.

11. **Marlow, M. et al** (1978) *Urban congestion study 1976: traffic flows and speeds in eight towns and five conurbations.* TRRL SR 438.

12. **Bureau of Public Roads** (1964) *Traffic assignment manual.* US Department of Commerce, Washington, D. C.

13. **Thomas R.** (1991) *Traffic assignment techniques.* Avebury Technical, USA.

# Chapter 8

## Externalities (Road Congestion Time Benefits):Results

### 8.1 Introduction

The previous chapter explained the method used for estimating the congestion time externality for the UK road network. This chapter presents and discusses the results of the measurement.

### 8.2 Marginal Congestion Time Externality by Road and Vehicle Type

#### *8.2.1 The Study Results*

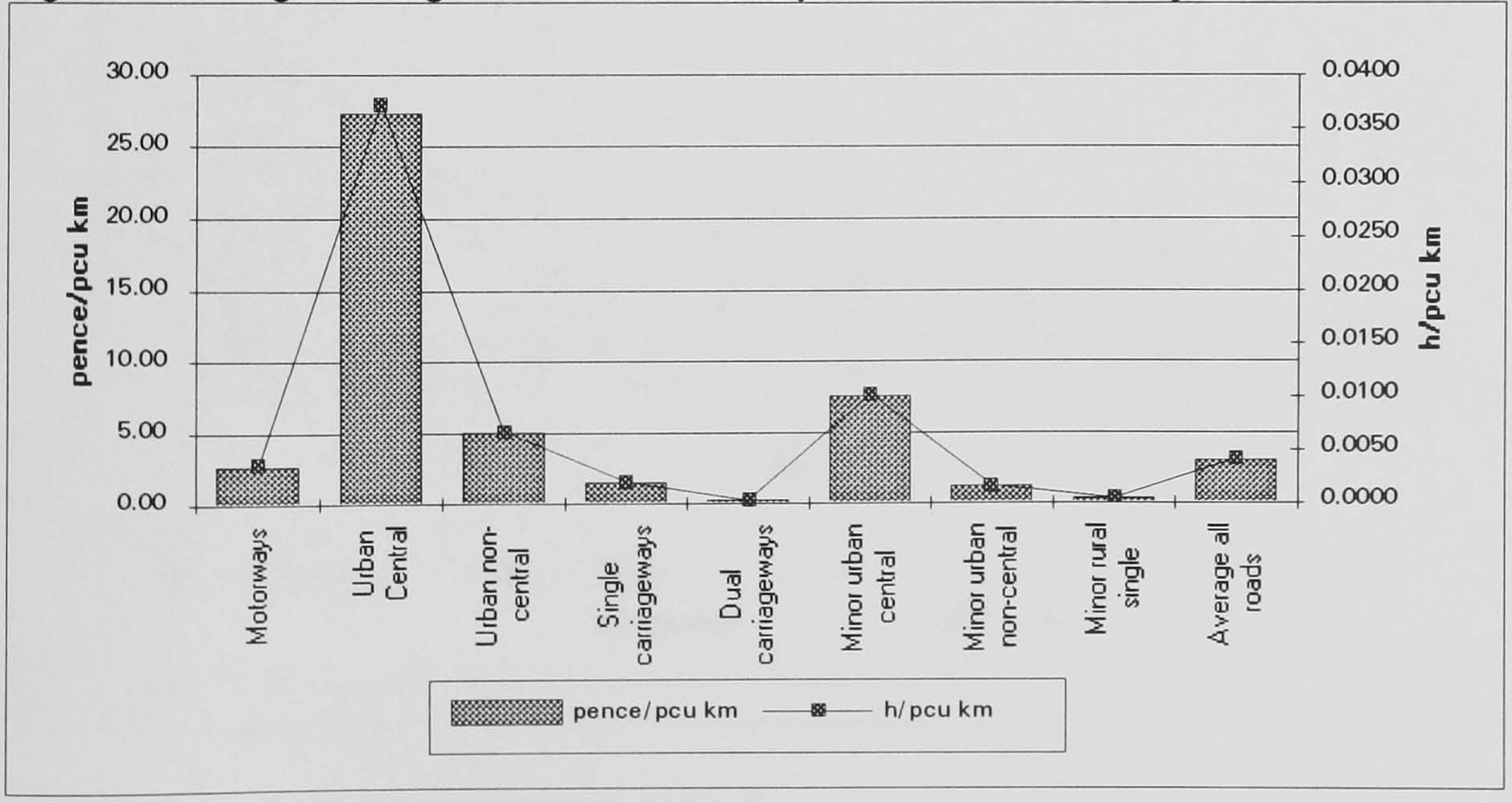
#### A) Marginal Congestion Time Cost by Road Type

Table 8.1 and figure 8.2 show the results of the measurement process for marginal congestion time cost. As can be seen, urban roads in the central areas are causing the highest congestion time cost, on average a time cost of 27.3 pence approximately is imposed on other road users for each personal car unit kilometre (pcu km) joining a central urban road. On the other hand, dual carriageway roads proved to have the lowest marginal time externality, only 0.19 pence for each pcu km. Other types of roads ranged from 0.32 pence per pcu km for minor single roads in rural areas to 7.5 pence per pcu km for minor urban central road. The average weighted marginal congestion cost for all roads is approximately 3 pence per pcu km. This average is weighted by the percentage of pcu km travelled on each road type shown in column 4 table 8.1. If this average is multiplied by the total pcu km travelled for 1993, (441.36 billions pcu km), this will give a total congestion cost of £13.44 billions approximately.

Table 8.1 Marginal congestion time cost externality for different road types for 1993 values and prices

| Road Types | Marginal time externality<br>h/pcu km | Marginal congestion time cost externality<br>pence/pcu km | % of Vehicle Kilometre Travelled | Index of marginal congestion time cost<br>average = 100 |
|---|---|---|---|---|
| 1. Motorways | 0.0037 | 2.68 | 16.37 | 88.16 |
| 2. Major urban central road | 0.0374 | 27.30 | 3.75 | 896.60 |
| 3. Major urban non-central road | 0.0069 | 5.01 | 15.01 | 164.58 |
| 4. Rural single carriageway | 0.0021 | 1.52 | 15.96 | 49.96 |
| 5. Rural dual carriageways | 0.0003 | 0.19 | 13.38 | 6.11 |
| 6. Minor urban central road | 0.0103 | 7.55 | 3.55 | 247.93 |
| 7. Minor urban non-central road | 0.0017 | 1.21 | 21.31 | 39.81 |
| 8. Minor rural single road | 0.0004 | 0.32 | 10.65 | 10.60 |
| • Average weighted all roads | 0.0042 | 3.04 | 100.00 | 100.00 |
| • Total congestion cost (billions) | 13.44 | | | |

Figure 8.1 Marginal congestion time externality for 1993 values and prices



### B) Marginal Congestion Time Cost by Time of Day and Road Type

Average weighted marginal time cost is also estimated by hour of day for different road types. Figures 8.2 and 8.3 demonstrate the results for urban and rural roads.

Figure 8.2 Marginal congestion time cost per time of day for urban roads

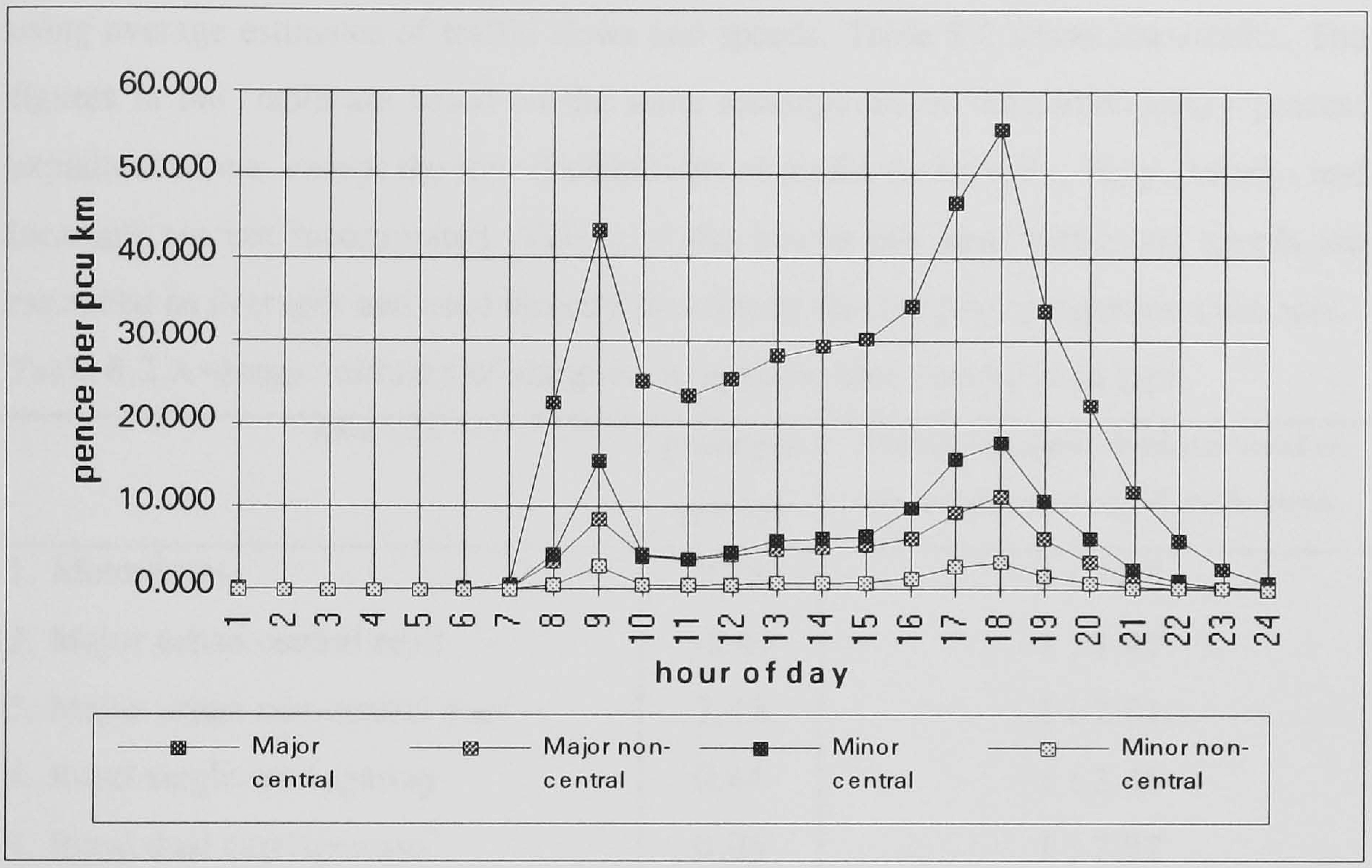
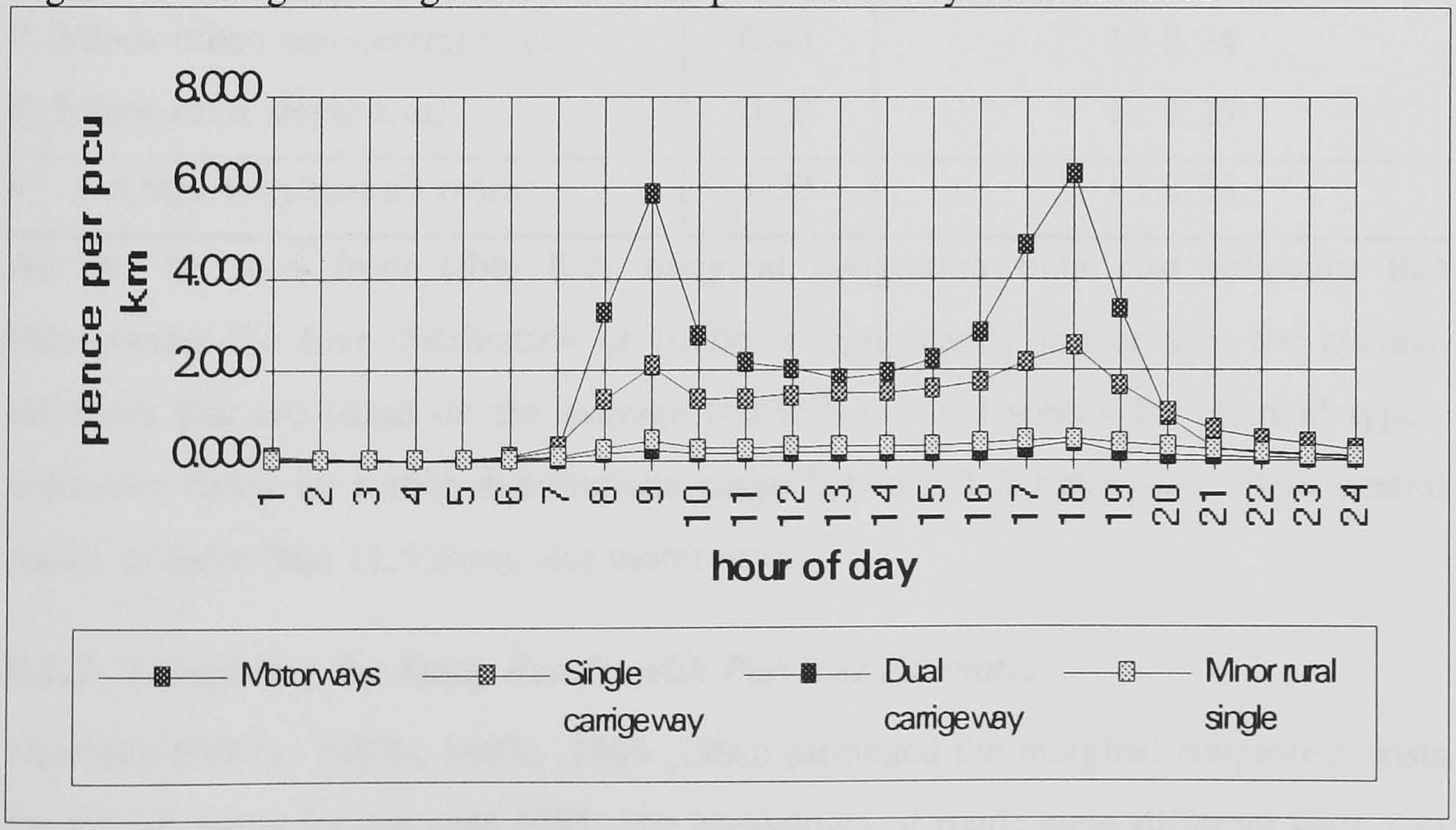



Figure 8.3 Marginal congestion time cost per time of day for rural roads



### C) Average Estimates of Marginal Congestion Time Externality

For the purpose of comparing the results based on the typical distributions of traffic with that measured on the basis of average values of speeds and flows of traffic, the value of the marginal congestion time cost is measured for different types of roads using average estimates of traffic flows and speeds. Table 8.2 shows the results. The figures in the table are based on the same assumptions of the methodology process explained above, except the four distributions of traffic (seasonally, daily, hourly, and location) are not incorporated. Values of the hourly per lane traffic and speeds are estimated as averages and used directly to estimate the marginal congestion time cost.

Table 8.2 Average estimates of marginal congestion time cost by road type

| Road type | pence per pcu km | Average estimate : estimates based on the real distributions of traffic flows |
|---|---|---|
| 1. Motorways | 0.23 | 1 : 11.8 |
| 2. Major urban central road | 18.49 | 1 : 1.47 |
| 3. Major urban non-central road | 2.49 | 1 : 2.01 |
| 4. Rural single carriageway | 0.44 | 1 : 3.45 |
| 5. Rural dual carriageways | 0.06 | 1 : 2.97 |
| 6. Minor urban central road | 1.40 | 1 : 5.37 |
| 7. Minor urban non-central road | 0.44 | 1 : 2.74 |
| 8. Minor rural single road | 0.03 | 1 : 9.25 |
| • Average weighted all roads | 1.33 | 1 : 2.28 |

As can be seen from table 8.2, marginal congestion time cost estimates that incorporates the four distribution of traffic is significantly higher than the average estimates that are based on the average traffic flows and speeds for all road types. Estimates based on traffic distributions range between 1.5 times -for urban central roads- to more than 11.5 times -for motorways.

### *8.2.2 Comparing the Study Results with Pervious Estimates*

Newbery (1987a, 1987b, 1987c ,1988 ,1990) estimated the marginal congestion costs for British roads for the year 1985. His breakdown of roads were different from this study, except for motorways and rural dual carriageway. Beside motorways, dual rural carriageways, Newbery chose to divide roads into urban central (peak and off-peak), urban non-central (peak and off-peak), small towns (peak and off-peak), and other rural roads. His method produced an average weighted for all roads of 1.7 pence per pcu km for 1985.

In 1990 Newbery updated the 1985 estimates by the increase in traffic over the period. His estimates for 1990 were 0.26 and 0.07 pence per pcu km for motorways and dual rural carriageways respectively, and he produced an average weighted congestion cost of 3.4p per pcu km for all roads as shown in table 8.3

To make these estimates comparable with the current study figures, they are updated for 1993 values and prices. Since traffic flows on the UK road network has not changed significantly during the period 1990-1993 (DTp, 1993), they are only updated by the change in the value of time during the period. This is carried out by updating these estimates by the change in Gross Domestic Product (GDP) which is found to have decreased by 0.9% during the period 1990-1993. In addition, prices are found to have increased by 11.5% during the period concerned, so a correction is made to incorporate the inflation impacts. Updating Newbery estimates for 1993 values and prices, would give the figures shown in table 8.3.

Table 8.3 Previous estimates of congestion time cost updated for 1993 values and prices

| *Road type* | 1990 estimates pence/pcu km | Updated for 1993 values and prices pence/pcu km |
|---|---|---|
| Motorway | 0.26 | 0.29 |
| Urban central peak | 36.37 | 40.20 |
| Urban central off peak | 29.23 | 32.30 |
| Non-central peak | 15.86 | 17.50 |
| Non-central off peak | 8.74 | 9.65 |
| Small town peak | 6.89 | 7.60 |
| Small town off peak | 4.2 | 4.60 |
| Other urban | 0.08 | 0.09 |
| Rural dual carriageway | 0.07 | 0.07 |
| Other trunk and Principal | 0.19 | 0.21 |
| Other rural | 0.05 | 0.05 |
| Average weighted | 3.4 | 3.76 |

The table is adapted from Newbery 1990

The current study breakdown of road types is meant to be suitable for incorporating rail scheme benefits. Newbery's breakdown of road is different, since his purpose was to illustrate a basis for road pricing. So, comparing the estimates of the current study with the previous estimates of marginal congestion externality cannot be made for all road types due to the use of different breakdown of road class. However, the figures for motorways and dual carriageways can be compared.

**1. Motorways:**

The current study produces a marginal congestion cost of 2.68 pence per pcu km on motorways. This figure is about 9 times as much as the figure produced by Newbery's estimates.

This is mainly due to the method of measuring MCTE in both cases. The current study estimates are based on the typical distributions of traffic flows, while Newbery figures are based on a crude estimates of the distribution of traffic flows on motorways. In his estimates, Newbery assumed that 7 percent of vehicle kilometre travel on motorways occurs at hourly flows of more than 1200 pcu per hour per standard lane, and the rest occurs at hourly flows of less than 1200 pcu/h/lane. The current study calculations of the hourly per lane flows suggested that 23 percent of vehicle kilometre travel at hourly per lane flow of more than 1200 pcu, and the rest 77 percent occurs at hourly flows less than 1200 pcu.

Using COBA speed-flow formula, Newbery estimated the value of MCTE to be the average weighted of its value for flow above and below 1200 pcu/h/lane. This method imply that MCTE takes only two values, one for the range of flows 0 to 1200 and the other is for flows above 1200. This approach may underestimate the value of MCTE, because if flows of traffic change from hour to another throughout the day, speeds and then the delays travellers impose on each other vary accordingly. And when this variation in traffic over time and place is incorporated as the current study does, the value of MCTE is estimated to be much higher.

**2. Dual Carriageways**

The current study produces a value for MCTE for dual carriageways of 0.19 pence per pcu km. This is more than two and half times the figure produced in Newbery's estimates. The reason is that the latter estimates are based on the average values of flows and speeds (Newbery, 1987a, 1987b) and then when allowing for the typical variations of traffic over time and place, as the current study does, the estimated figure is much higher.

It is worth mentioning that for dual carriageways, the value of marginal congestion time cost estimated on average basis by this study as shown in table 8.2, is not significantly different from the figure produced in Newbery's estimates.

### *8.2.3 Marginal Congestion Time for Different Vehicle Class*

Table 8.4 shows the estimated congestion time externality for each vehicle class on different types of roads. The figures are weighted by the percentage of kilometre travelled by each vehicle class on different types of roads. The figures for buses and heavy goods vehicles are based on the assumption that a bus is equal to 1.6 personal car unit (pcu), and a heavy goods vehicle is equal to 2 pcu. These are the values used in the trunk road appraisal framework explained in COBA.

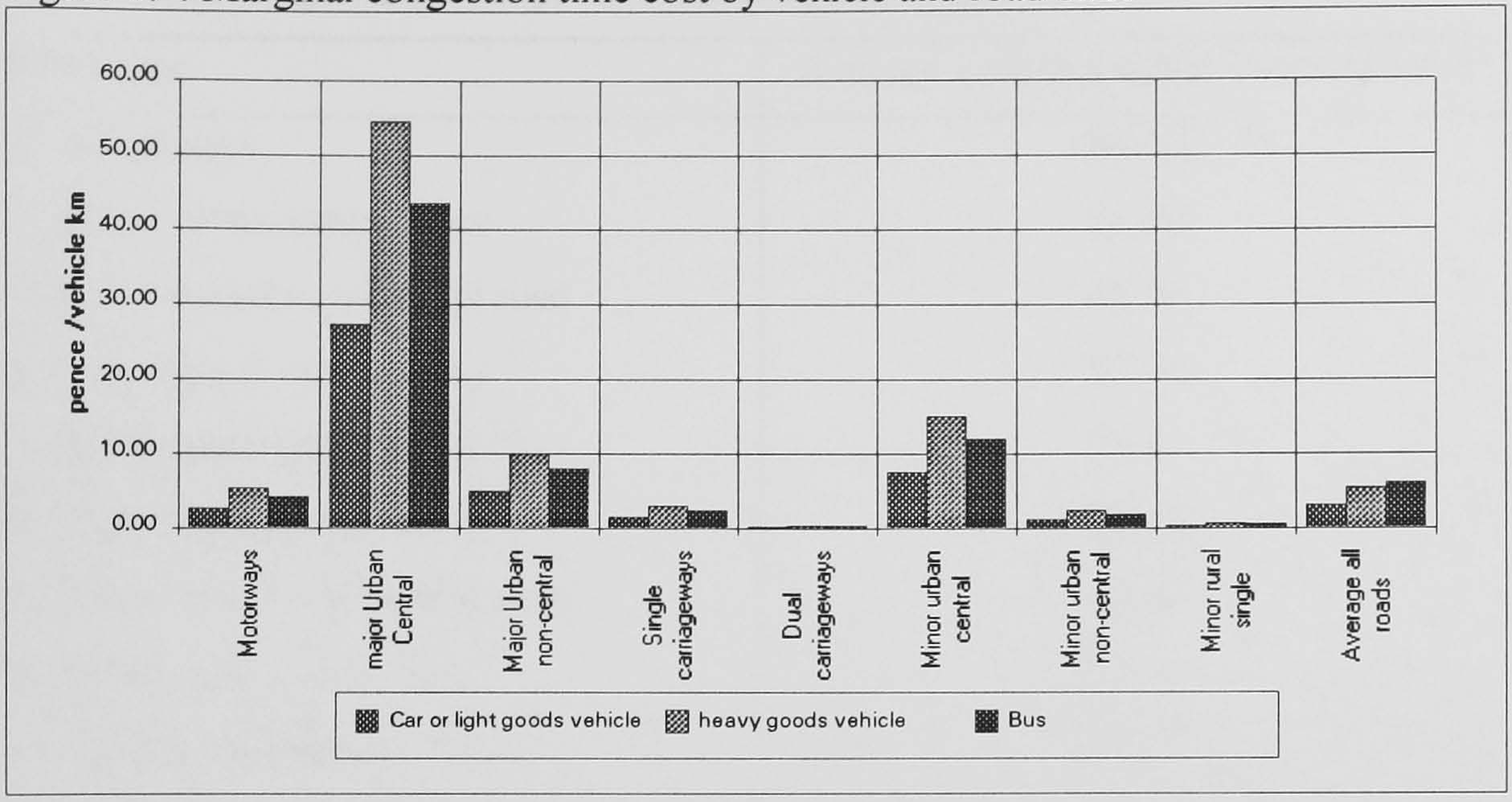
Table 8.4 Marginal congestion time externality by road and vehicle class

| | Pence per vehicle km | | |
|---|---|---|---|
| Road type | Car or LGV | Heavy goods vehicle | Bus |
| 1. Motorways | 2.68 | 5.37 | 4.29 |
| 2. Major urban central road | 27.30 | 54.59 | 43.67 |
| 3. Major urban non-central road | 5.01 | 10.02 | 8.02 |
| 4. Rural single carriageway | 1.52 | 3.04 | 2.43 |
| 5. Rural dual carriageways | 0.19 | 0.37 | 0.30 |
| 6. Minor urban central road | 7.55 | 15.10 | 12.08 |
| 7. Minor urban non-central road | 1.21 | 2.42 | 1.94 |
| 8. Minor rural single road | 0.32 | 0.65 | 0.52 |
| • Average weighted all road | 3.08[1] 3.03[2] | 5.48 | 6.09 |

1 = average for car

2 = average for light goods vehicle

Figure 8. 4 Marginal congestion time cost by vehicle and road class




As can be seen from table 8.4 and figure 8.4, buses have the highest marginal congestion time cost (6.09 pence per bus km on average). This is mainly due to the distribution of bus kilometre travelled on different roads, where , more than 50 percent of bus kilometre travel on urban roads (central and non-central), with high level of marginal congestion time cost.

The average values for cars and light goods vehicles are not significantly different. This is due to the very similar distribution of vehicle kilometre travelled for both of them.

### *8.3 Average Speed by Road Class*

Table 8.5 shows average speeds for different road types. These averages, as explained in step 10 of the methodology process in chapter 7, are weighted by the percentage of vehicle kilometre travelled at different times of the day, week, year and places.

Table 8.5 Average weighted speed of travel by road type

| Road type | Average weighted speed of travel km/h |
|---|---|
| 1. Motorways | 86.00 |
| 2. Major urban central road | 26.66 |
| 3. Major urban non-central road | 46.05 |
| 4. Rural single carriageway [(1)] | 57.72 |
| 5. Rural dual carriageways [(1)] | 73.14 |
| 6. Minor urban central road | 32.52 |
| 7. Minor urban non-central road | 48.98 |
| 8. Minor rural single road [(1)] | 62.69 |
| • Average weighted all road | 59.26 |

(1) Average speed is corrected to incorporate junction delays on these roads

As explained before, the COBA speed-flow relationship is used in the process of measuring MCTE and speeds for rural roads. Speed-flow formulae for rural roads do not incorporate junction delays (DTp, 1981). This means the calculated average speed is above the real speed on those roads. To obtain the average actual speed, delays at junctions have to be incorporated. This is carried out for rural single and dual carriageways and minor rural single roads. The underlying assumptions are:

1. There is a junction every 5 kilometre on these roads.
2. A time delay of 20 seconds for each junction.

Based on these assumptions, the measured speed is corrected to incorporate junction delays, and the results are shown in table 8.5 above.

The estimated average speeds of the study are compared with and discussed in the light of the results of National Travel Surveys when presenting speed distributions in the following sections.

## 8.4 Distribution of Congestion Time Cost and Speed

The aim here is, beside having an average weighted estimates for MCTE and speeds, to illustrate and identify the proportion of vehicle kilometre travelled for each category of marginal congestion time cost and speed. This is carried out by categorising the congestion cost and speed and calculating the percentage of vehicle kilometre travelled for each category. The following demonstrates the results for different road types:

### *8.4.1 Motorways*

Figure 8.5 and 8.6 present the distributions of marginal congestion cost and speed for motorways.

Figure 8.5 Marginal congestion cost distribution for motorways

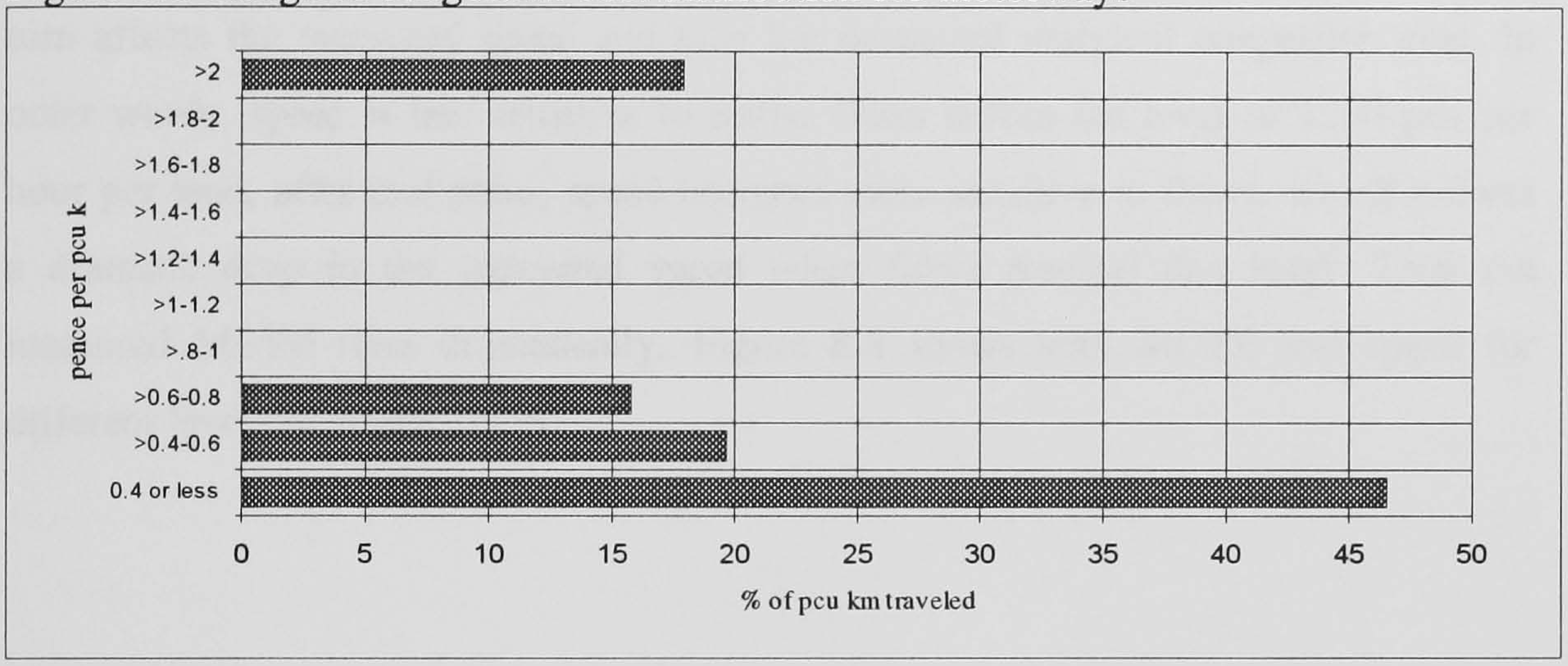
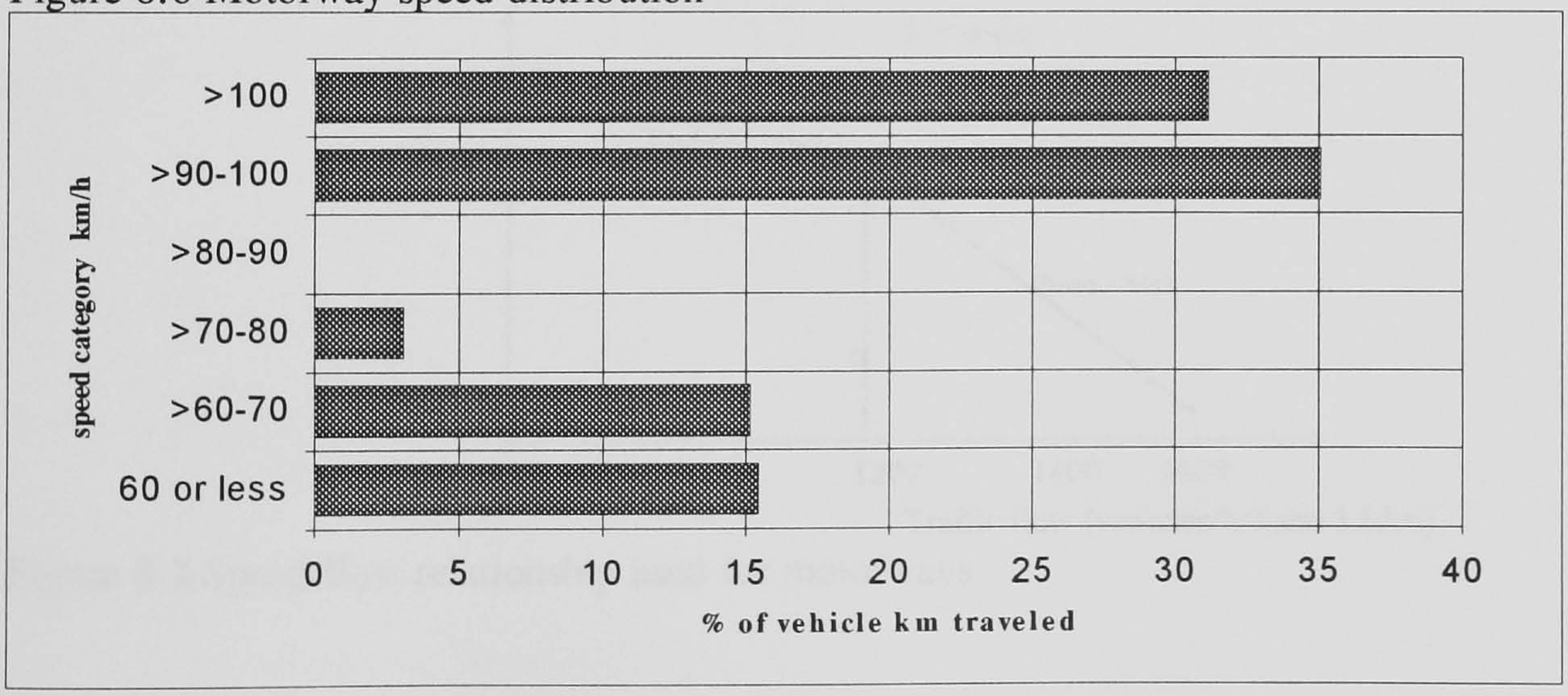



Figure 8.6 Motorway speed distribution




### 1. Congestion Cost Distribution

As can be seen from figure 8.5, for about 47% of Personal Car Unit Kilometre Travelled (PCUKT) on motorways, marginal congestion cost is 0.4p or less per pcu km and the rest of PCUKT falls into three categories of marginal congestion cost. About 19% for >0.4-0.6p, 16% for >0.6-0.8p and 18% for >2p. As can be noticed there are no observations for categories >0.8-2p. This is due to the speed-flow relationship used. The slope of COBA speed flow relationship for motorways is a function of flow of traffic. For flows less than 1200 pcu/hour/lane, the slope takes the value of 0.006 and zero for light and heavy vehicles respectively. But once the flow reached 1200 or more these values become 0.027 and 0.014 respectively. This in turn affects the measured speed and then the measured marginal congestion cost. In other words, speed is less sensitive to traffic flows before the level of 1200 pcu per hour per lane, after that point, speed becomes more sensitive to flows, which reflects a dramatic drop in the measured speed when flows reached that level. Then the measured MCTE rises dramatically. Figure 8.8 shows both MCTE and speed for different levels of traffic flows.

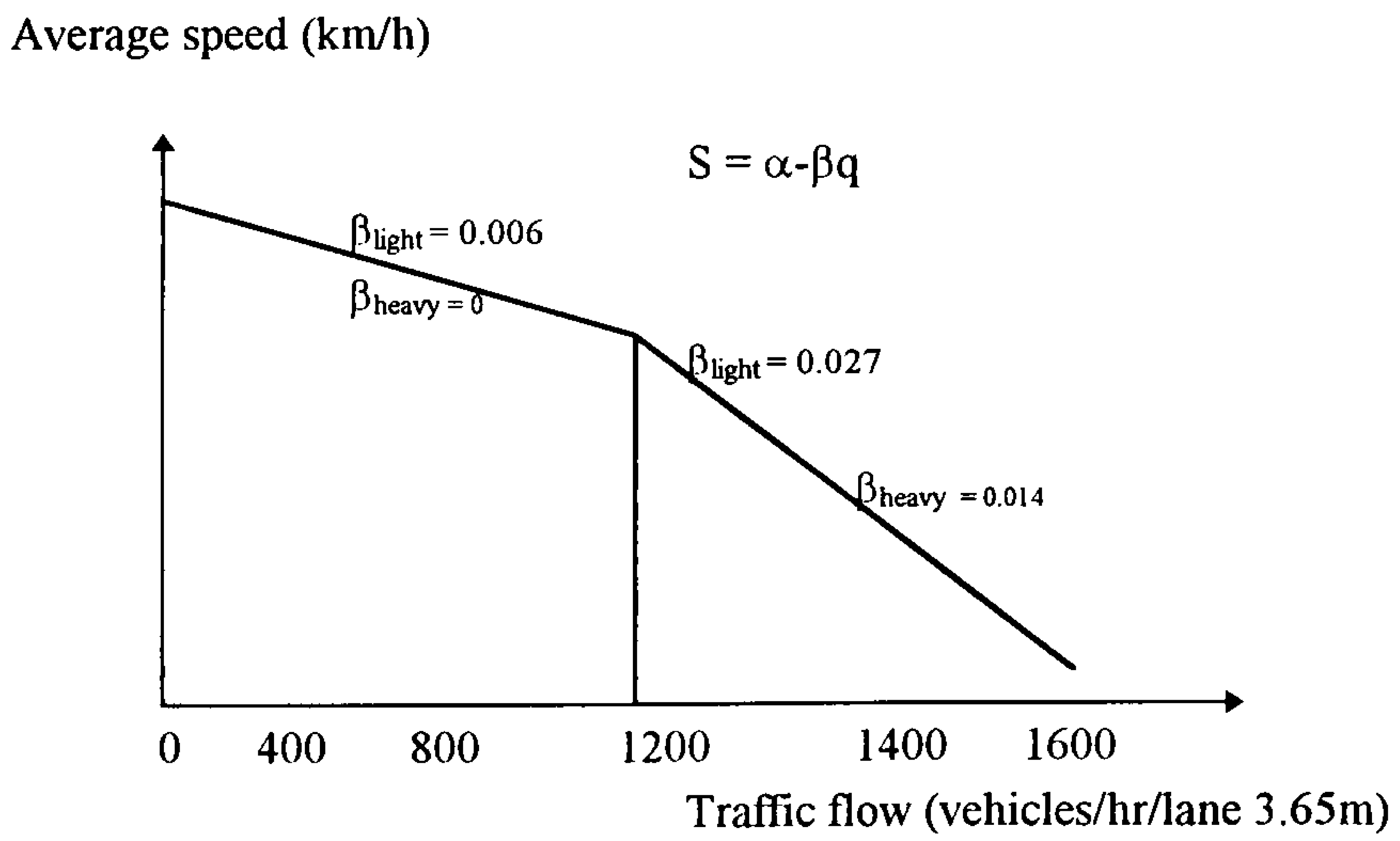
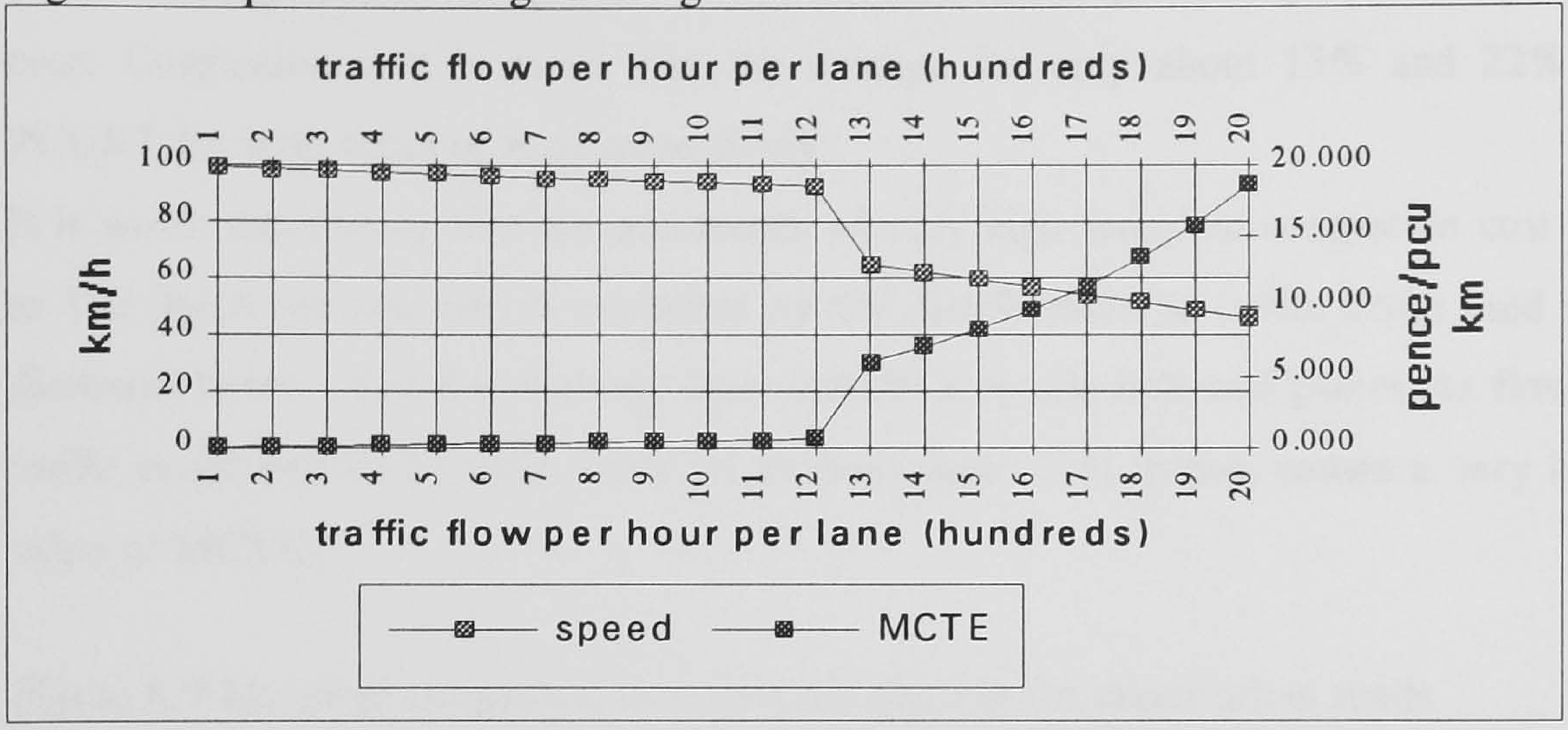



Figure 8.7 Speed-flow relationship used for motorways

Figure 8.8 Speed and marginal congestion cost for different traffic flows




## 2. Speed Distribution

Motorways' speed distribution shows that about 35% of pcu km travelled at speed category of >90-100 km/h and about 31% at speed more than 100 km/h. This means that over 65 percent of pcu km travel at speed of over 90 km/h. The estimated average weighted speed for motorways is 86 km/h.

This average is significantly different from the National Traffic Survey results for 1992 (DTp, 1993). Based on the distribution of speed that is taken from 18 motorway sites, the average is estimated and weighted by the number of vehicles observed, this gives an average speed of 109 km/h. However, this average provides estimates of speeds unconstrained by congestion or other road conditions on motorways. So the results of the current study may provide a reasonable and more accurate approximation to speeds on the motorway network and one that is more suitable for measuring the congestion time costs.

### *8.4.2 Built-up Major Roads*

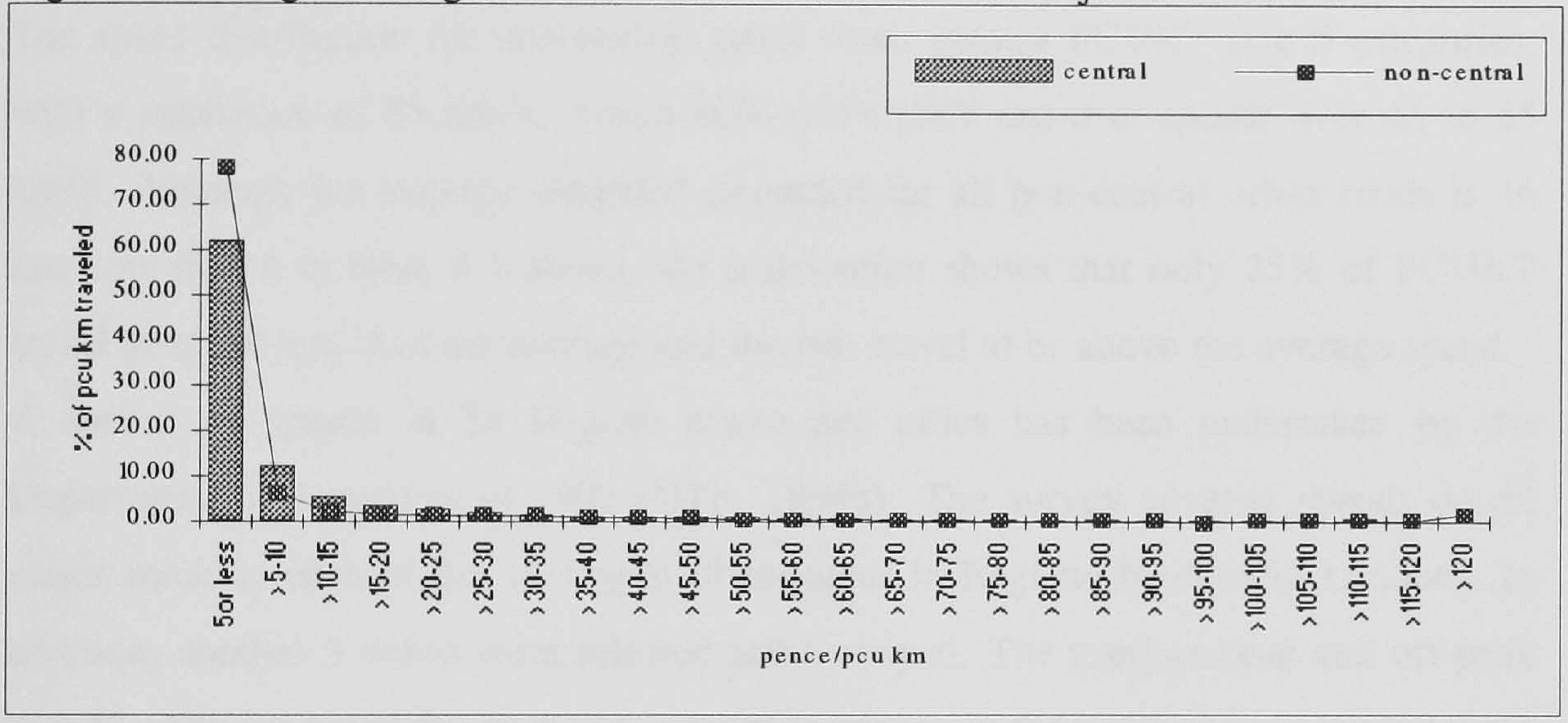
Figures 8.9 and 8.10 show the distributions of marginal congestion cost and speeds for major built-up roads.

## 1. Congestion Cost Distribution

As can be seen from figure 8.9, marginal congestion cost is 5p or less for 62 and 78 percent of PCUKT travelled for major urban central and non-central roads respectively. Overall, marginal congestion cost takes the form of an extended one tail distribution. If more categories are created after 120p, the distribution would have continued to give lower proportions of PCUKT for each higher category of congestion cost. Congestion cost is more than the average for only about 13% and 22% of PCUKT for both types of road respectively.

It is worth mentioning that the occurrence of very high marginal congestion cost (up to 100 pence per pcu km) is explained by the distributions of traffic flows used and discussed before. The distributions show that for a certain time and places the flow of traffic could be two or three times the average flow. This in turn causes a very high value of MCTE.

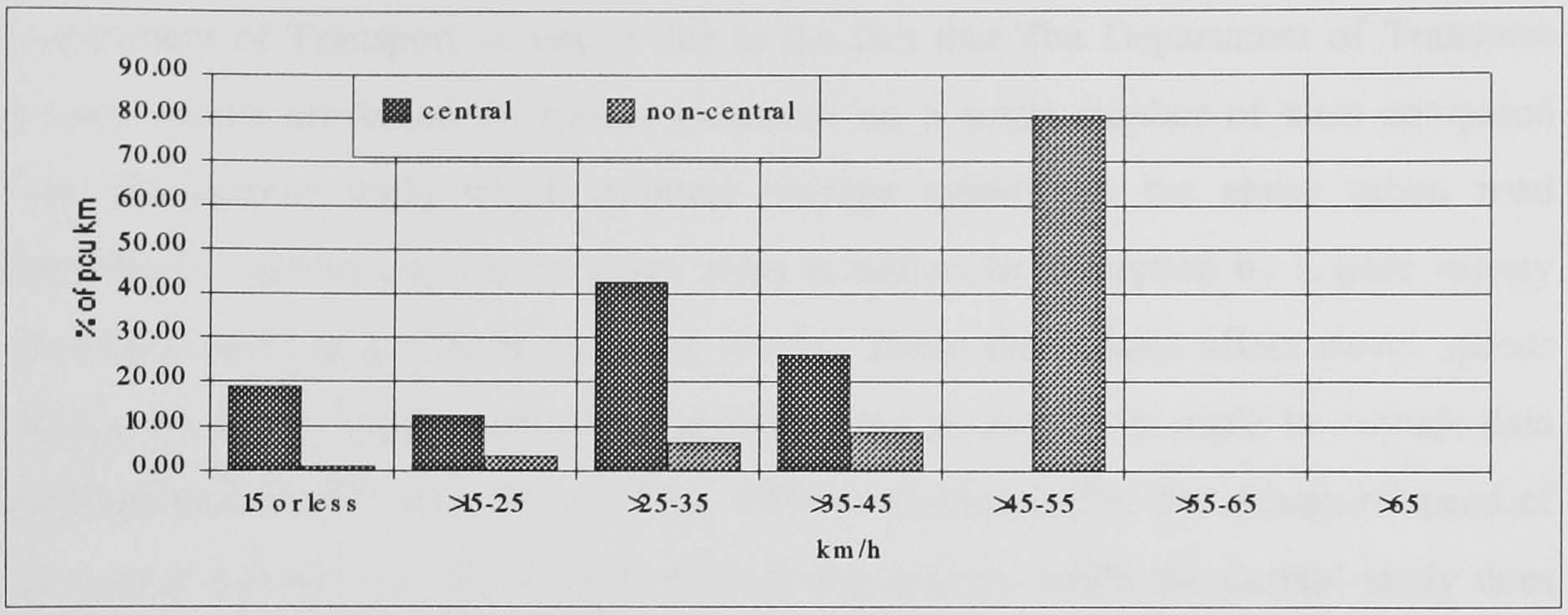
Figure 8.9 Marginal congestion time cost distribution for major urban roads




## 2. Speed Distribution

As illustrated in figure 8.10 traffic speeds on central urban roads fall in about 4 categories. Although the measured average weighted is 26.6 km/h, about 31% of PCUKT is at speeds less than the average speeds with about 18% at speeds between 10 and 15 km/h. This explains the existence of a proportion of PCUKT travel at marginal congestion cost as high as 100 pence per pcu km.

Figure 8.10 Speed distribution for major urban roads




The speed distribution for non-central urban roads groups PCUKT into 5 categories, with a maximum of 55 km/h. About 80% of PCUKT occur at speeds over 45 to 55 km/h. Although the average weighted estimated for all non-central urban roads is 46 km/h as shown in table 8.5 above, the distribution shows that only 25% of PCUKT travel at speed less than the average and the rest travel at or above the average speed.

A survey of speeds in 24 English towns and cities has been undertaken by the Department of Transport in 1993 (DTp, 1994b). The survey covered speeds on all major roads in each of the 19 largest urban areas in England (excluding London). In addition, another 5 towns were selected and surveyed. The average peak and off-peak speeds were estimated for each area. Average speeds in the peak periods ranged from 25.4 km/h in Leicester to 59.2 km/h in Peterborough. In the off-peak periods, average speeds ranged from 31.5 km/h in Sheffield and Grimsby/Cleethorpes to 62 km/h in Peterborough.

To compare the survey results with the estimated average speeds for major urban roads in this study, an average speed for the 24 areas is estimated. This is carried out by weighting the measured speed of each area by the length of the surveyed network of that area and estimating average for all areas. This gives an average speed for all areas of 32 and 39 km/h for peak and off-peak periods respectively. Assuming that peak period is one quarter of the time, this gives overall average speed of 37.5 km/h. The current study produces average speeds of 26.7 and 46 km/h for major urban central and non-central roads respectively. Based on the assumption that central areas are 11 percent of the total urban areas, this gives an average of about 43.8 km/h.

The slight difference between the study average and the average produced by the Department of Transport survey is due to the fact that The Department of Transport Survey results are based on speeds measured on a small number of sites compared with the current study which estimate average speeds for the entire urban road network. In addition, traffic in urban areas is subject to disruption by a wide variety of events, such as accidents and road works. These disruptions affect travel speeds negatively. In the Department of Transport survey no attempt is made to exclude data gathered during such disruptions (DTp, 1994b). Consequently, the measured speed of the survey incorporates the impacts of such disruptions, while the current study does not. This in turn explains the difference in the average speeds produced in both cases.

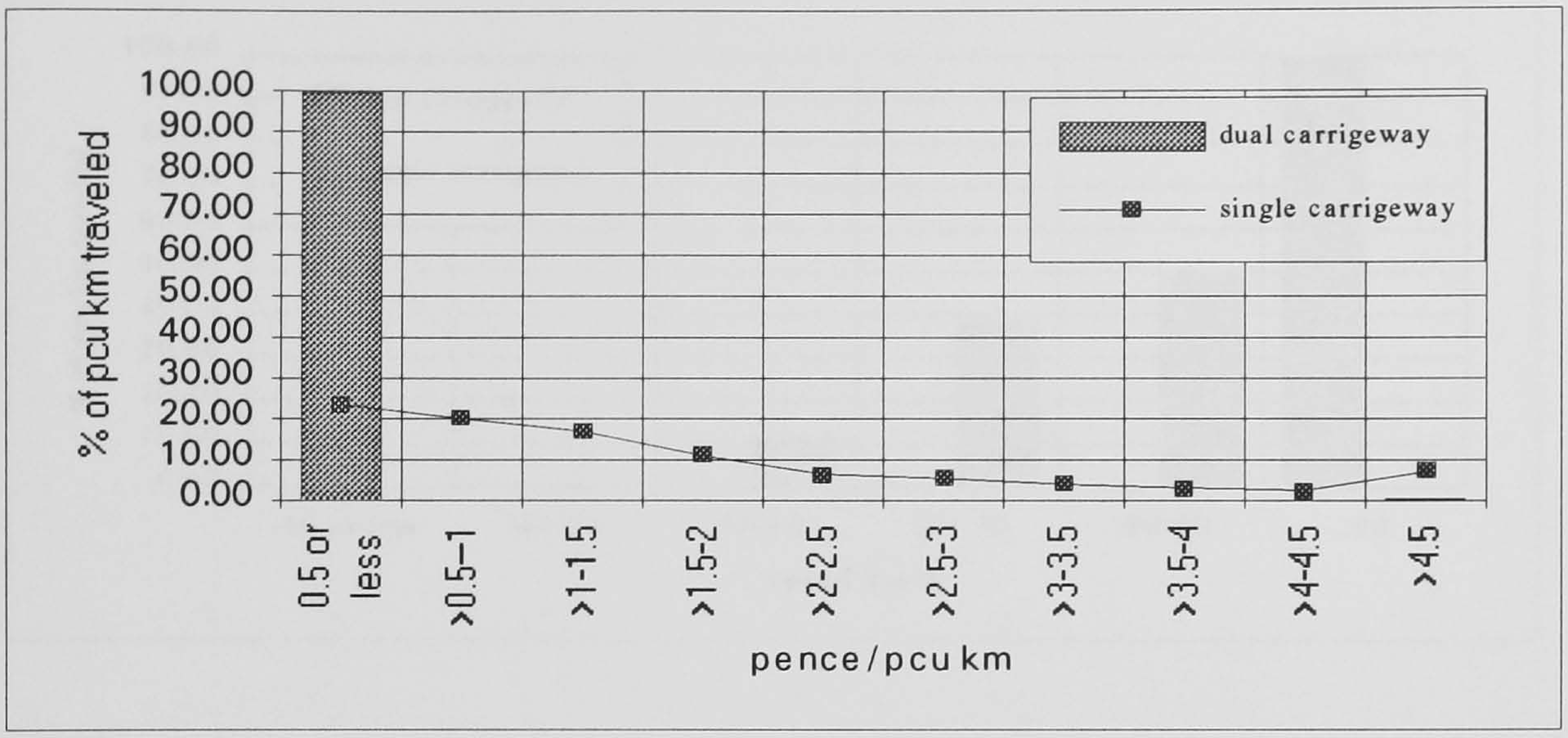
### *8.4.3 Major Rural Roads*

Figures 8.11 and 8.12 demonstrate the distributions of marginal congestion cost and speeds for rural major roads.

**1. Congestion Cost Distribution**

Marginal congestion cost distribution for single carriageways again is in the shape of one tail distribution as shown in figure 8.11, with about 23% of PCUKT for a marginal congestion cost of 0.5 pence or less per pcu km, and then a diminishing proportions of PCUKT for higher categories of marginal congestion cost. The distribution shows that less than 10% of PCUKT at the average weighted marginal cost (1.52p), while about 60% travelled at marginal cost less than the average, and the rest travels at marginal cost above the average. Dual carriageway distribution allocates PCUKT to only two groups with most of PCUKT at marginal cost of 0.5 pence or less. There is a very small proportion of PCUKT at more than 4.5 pence per pcu km.

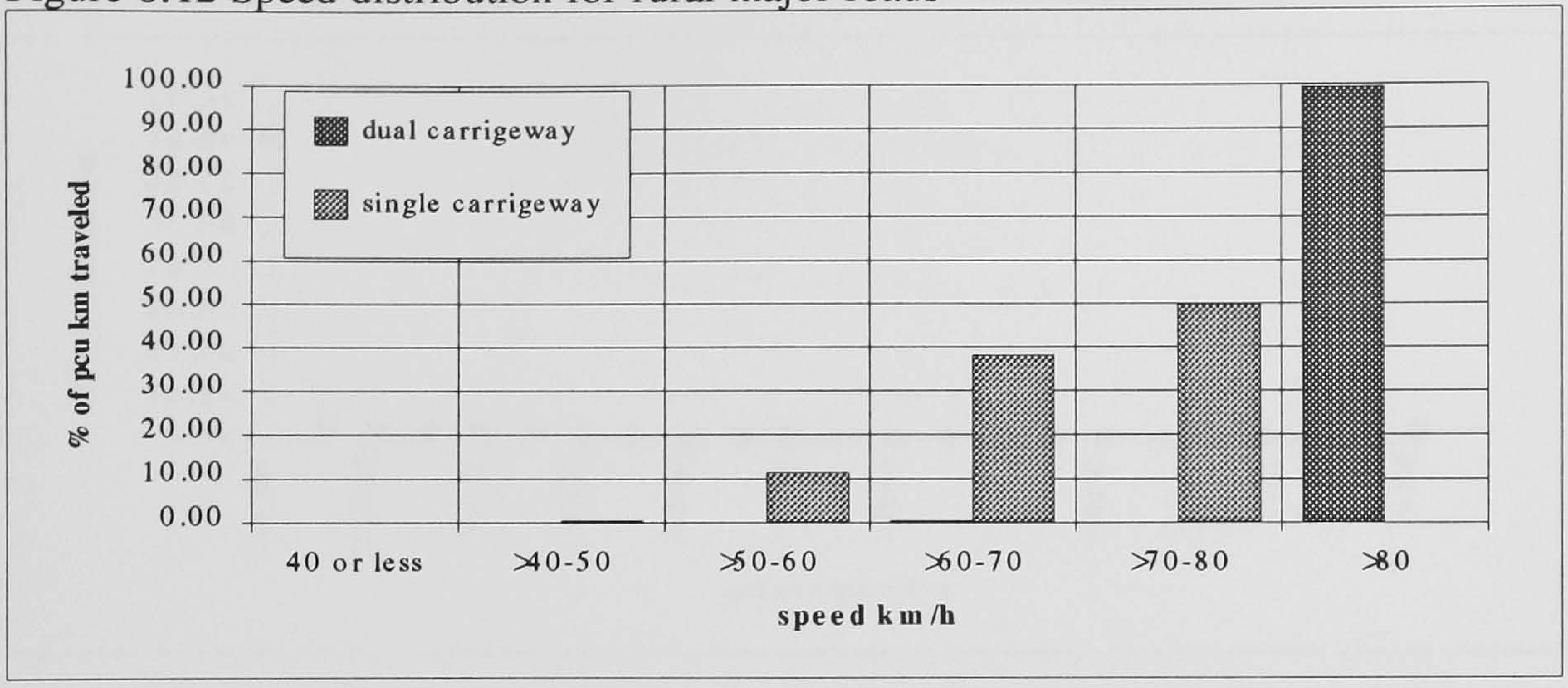
Figure 8.11 Marginal congestion time cost distribution for rural major roads




## 2. Speed Distribution

As figure 8.12 shows, the distribution for speeds on single carriageways shows that most of the PCUKT (85%) is at speeds of more than 60 km/h, maximum speed of 80 km/h, with an average weighted of about 57 km/h approximately after incorporating junction delays. The National Traffic Survey (NTS) (DTp, 1993) results, based on 24 single carriageway "A" road sites, show that for a small percentage of the vehicles, the speed was less than 40 km/h, and the greater portion of the sites falls in speed category of 48-96 km/h. The average weighted speed of the National Traffic Survey results for all vehicles is found to be 72 km/h. This average is significantly different from the average of the current study. This is due to the fact that NTS average does measure average speeds unconstrained from any congestion impacts, while the current study results by incorporating the traffic distributions on the network, the measured speeds are more realistic and appropriate for estimating congestion costs. In addition, the distribution of the speed shows some difference compared with the NTS distributions for single carriageways. This is also explained by the fact that the NTS results are measured at a sample of sites on non-built up roads, and in principal they provide estimates of speeds unconstrained by congestion or other road conditions. So, the results of the current study may reflect the congestion on single carriageways more realistically.

Figure 8.12 Speed distribution for rural major roads




The distribution of speed on dual carriageways shows that more than 98% of PCUKT is at speeds of more than 80 km/h, and a maximum speed of 95 km/h with an average weighted speed of 73 km/h approximately. This average incorporates the delays at junctions. The speed distribution of NTS, which again was based on a measurement for speed from 3 dual carriageway sites (DTp, 1993), shows that the speed measured falls in a broader range of categories compared with the current study results. Speed categories were between 50 and over 100 km/h. The estimated average weighted based on this figures is 103 km/h. In fact this average is different from the current study average of speed and so is the distribution. This is partly due to the fact that NTS results were taken from a speed measurement from only 3 dual carriageway sites, and partly because the current study incorporates congestion impacts, and in a general statement the current study results could be relied upon more accurately, since it incorporates different traffic flow variations, and measured speed for the whole dual road network.

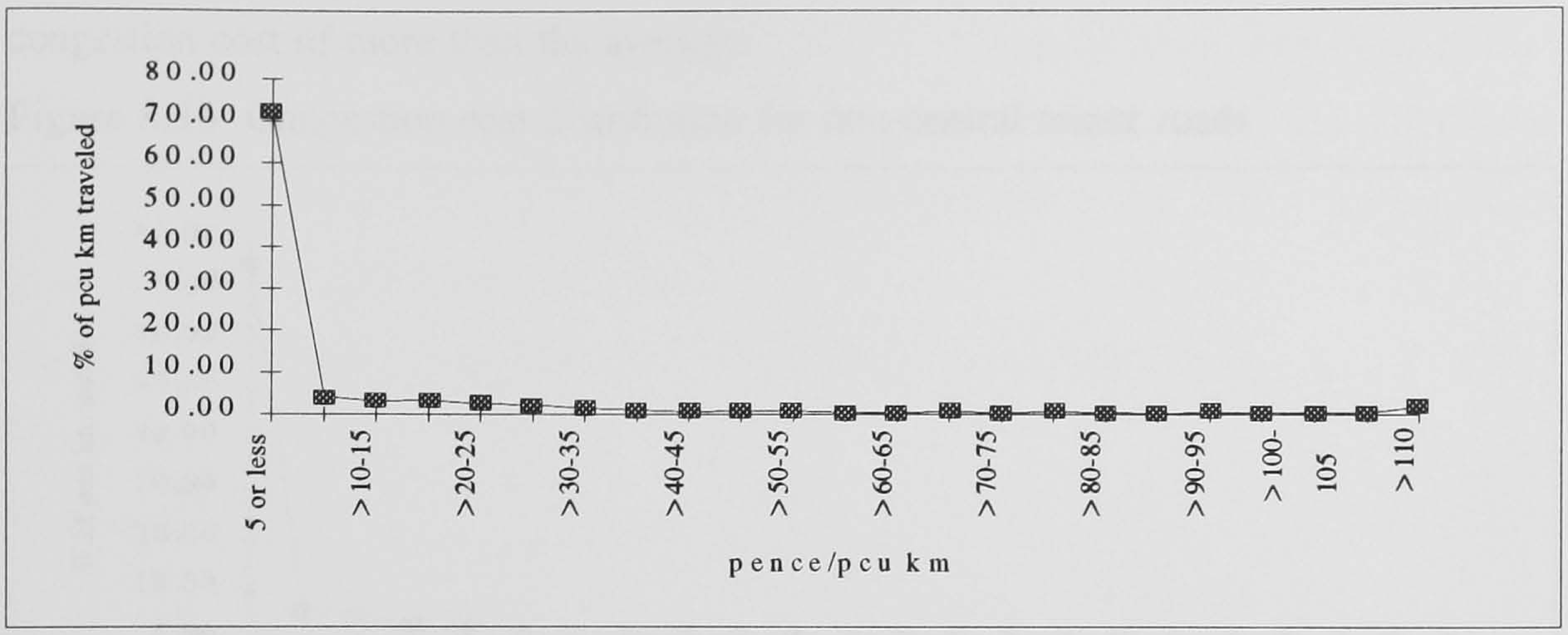
### *8.4.4 Minor Roads*

**A) Minor Central Roads**

**1. Congestion Time Cost Distribution**

As can be seen, for about 70% of PCUKT, marginal congestion cost is 5 p or less per pcu km, then the congestion cost is taking a one tail distribution like other road types, with a weighted average of 7.5 pence approximately.

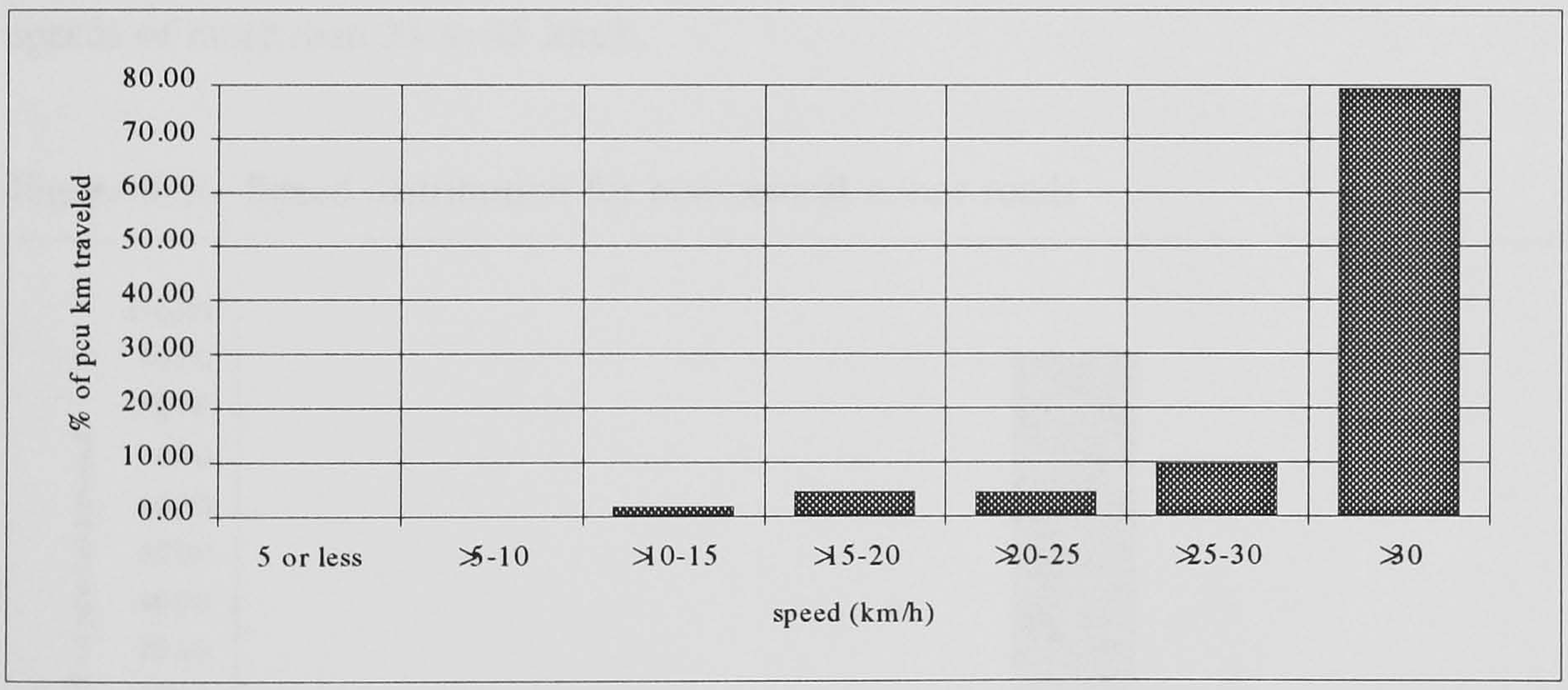
Figure 8.13 Congestion cost distribution for central minor roads




## 2. Speed Distribution

The speed distribution for minor central roads shows that for about 79% of PCUKT, speed is more than 30 km/h. The rest of PCUKT (20%) is distributed for categories of speed between 30 and 10 km/h. The average weighted speed is about 32 km/h.

Figure 8.14 Speed distribution for central minor roads

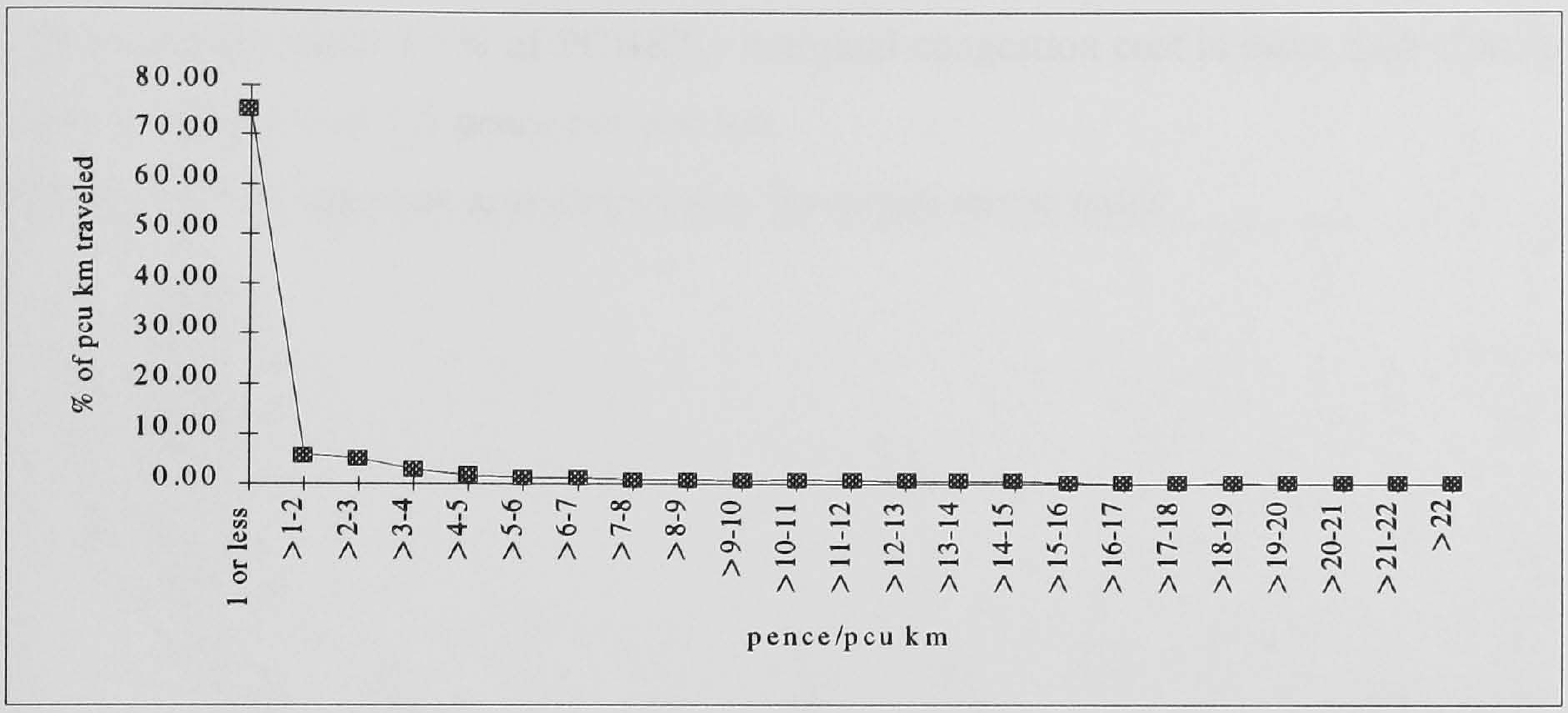



## B) Non-central Minor Roads

## 1. Congestion Cost Distribution

Again we have a one tail distribution, with about three quarter of PCUKT at marginal congestion cost of 1 pence or less, then showing a diminishing proportions of PCUKT for higher categories of congestion cost. Although the average weighted marginal congestion cost is about 1.2 pence per pcu km , only 20% occurs at a congestion cost of more than the average.

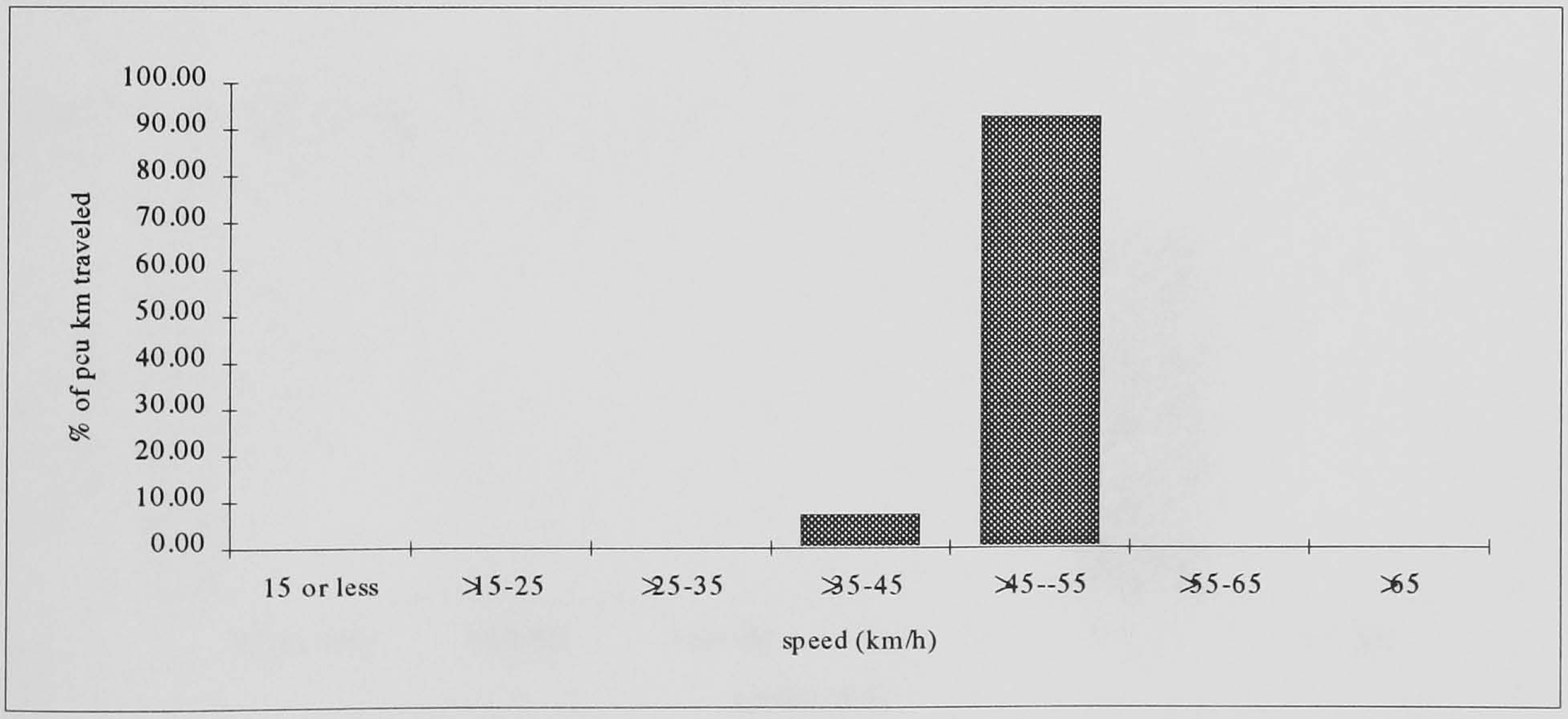
Figure 8.15 Congestion cost distribution for non-central minor roads




## 2. Speed Distribution

For non-central minor roads, about 92% of PCUKT is in the speed category of more than 45 to 55 km/h with a maximum speed of 55 km/h. The rest of PCUKT occurs at speeds of more than 35 to 45 km/h.

Figure 8.16 Speed distribution for non-central minor roads

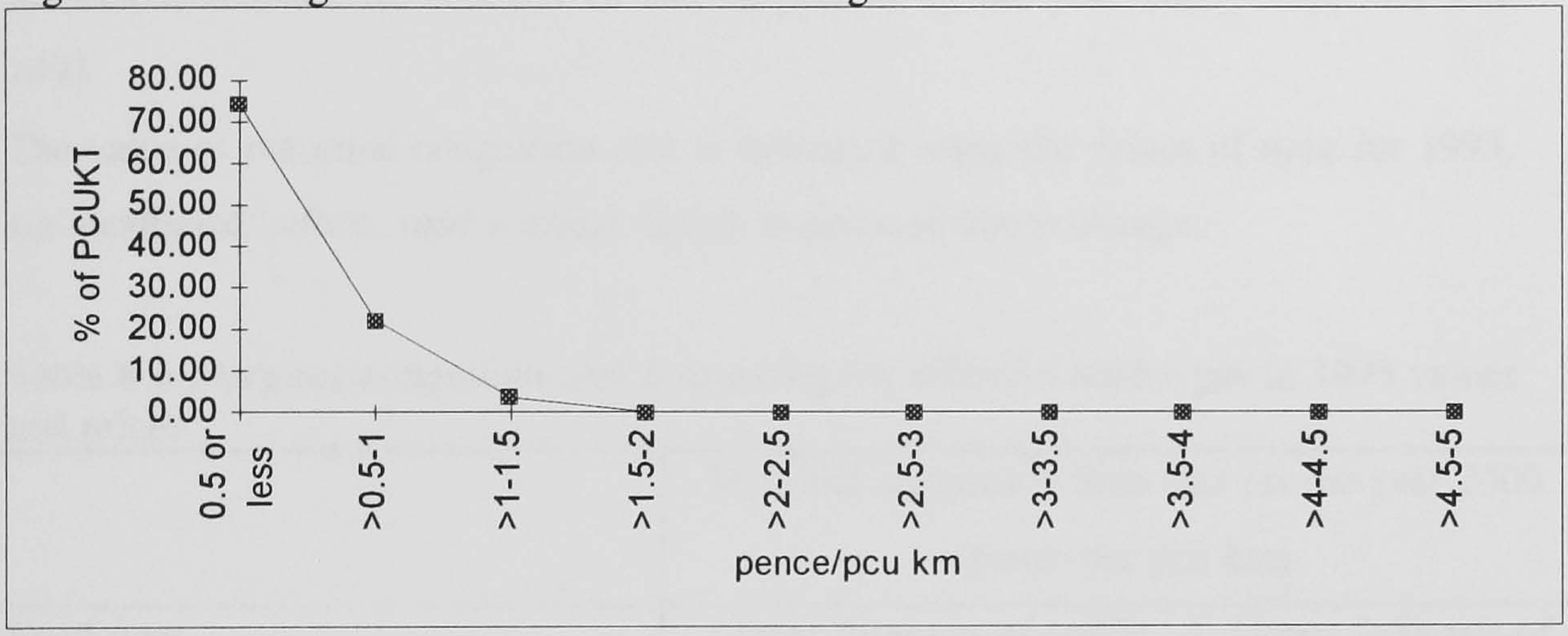



## C) Single Minor roads

## 1 Congestion Cost Distribution

The distribution is not very different from other road types in terms of shape. Around 75% of PCUKT at marginal congestion cost of 0.5 pence or less, with an estimated average weighted marginal cost of about 0.32 pence per pcu km. The distribution shows that for about 3.5% of PCUKT, marginal congestion cost is more than 1 pence with a maximum of 1.5 pence per pcu km.

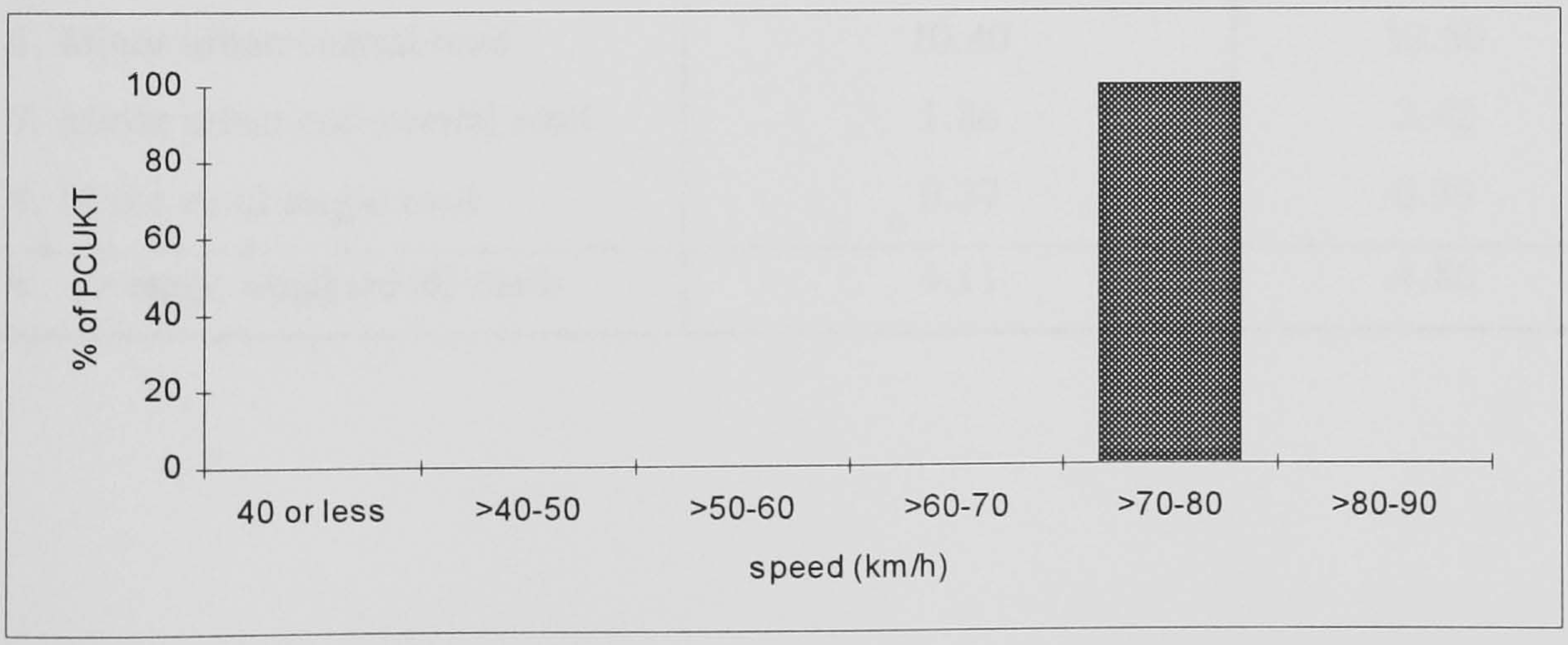
Figure 8.17 Congestion cost distribution for single minor roads




## 2 Speed Distribution

The distribution for speeds of single minor roads shows that all of PCUKT falls in the category of >70-80 km/h. When incorporating junction delays, the average weighted speed is 62.7 km/h.

Figure 8.18 Speed distribution for single minor roads



## 8.5 Marginal Congestion Time Cost and Speed Forecasting

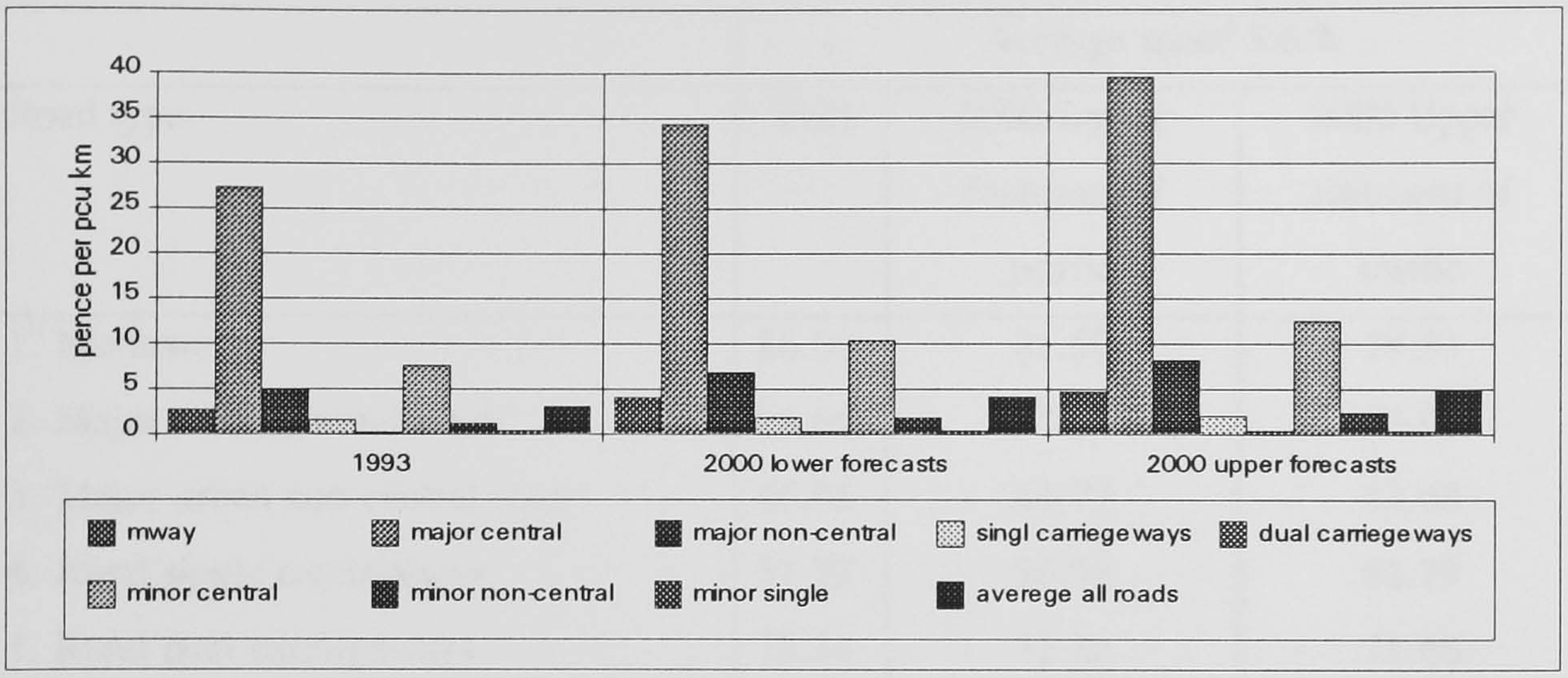
Tables 8.6 and 8.7 present the results of marginal time cost and speed for the year 2000. This is estimated by applying the same methodology (steps 1-10) explained in chapter 7 and using the lower and upper traffic forecasts contained in National Road Traffic Forecasts Great Britain 1989, (DTp, 1994a). All motor vehicle traffic is forecast to increase by between 13 and 22 percent by the year 2000, compared with 1993.

The value of marginal congestion cost is estimated using the values of time for 1993. As mentioned before, road network length is assumed not to change.

Table 8.6 Marginal congestion cost forecasting for different road types in 1993 values and prices

| | Marginal congestion time cost for the year 2000 (pence per pcu km) | |
|---|---|---|
| Road type | Lower forecasts of traffic | Upper forecasts of traffic |
| 1. Motorways | 4.08 | 4.74 |
| 2. Major urban central road | 34.35 | 39.57 |
| 3. Major urban non-central road | 6.82 | 8.17 |
| 4. Rural single carriageway | 1.79 | 2.00 |
| 5. Rural dual carriageways | 0.25 | 0.32 |
| 6. Minor urban central road | 10.40 | 12.50 |
| 7. Minor urban non-central road | 1.86 | 2.42 |
| 8. Minor rural single road | 0.37 | 0.39 |
| • Average weighted all roads | 4.11 | 4.86 |

Figure 8.19 Marginal congestion cost for the year 2000




As can be seen from table 8.6 above, the average weighted marginal congestion cost for all roads increases by 35 and 60 percent as a result of 13 and 22 percent increase in traffic respectively. This means for each 1 percent increase in traffic, marginal congestion cost increases by about 2.7 percent. In other words, the elasticity of marginal congestion cost with respect to traffic is about 2.7.

Table 8.7 shows that the average weighted speed for all roads decreases by 2.5 and 4.2 percent as a result of 13 and 22 percent increase in traffic respectively. This means for each 1 percent increase in traffic, speed decreases by about 0.19 percent. In other words, the elasticity of speed with respect to traffic is about 0.19 in absolute values.

Table 8.7 Speed forecasts by road types

| | Average speed km/h | | |
|---|---|---|---|
| Road type | 1993 | 2000 Lower forecasts of traffic | 2000 Upper forecasts of traffic |
| 1. Motorways | 86.00 | 81.50 | 78.34 |
| 2. Major urban central road | 26.66 | 25.04 | 23.97 |
| 3. Major urban non-central road | 46.05 | 44.77 | 43.68 |
| 4. Rural single carriageway | 57.72 | 56.58 | 55.79 |
| 5. Rural dual carriageways | 73.14 | 72.20 | 71.68 |
| 6. Minor urban central road | 32.52 | 31.51 | 30.18 |
| 7. Minor urban non-central road | 48.98 | 48.45 | 48.01 |
| 8. Minor rural single road | 62.69 | 62.24 | 62.12 |
| • Average weighted all road | 59.26 | 57.78 | 56.76 |

## 8.6 Chapter Summary and Conclusions

The results of the measurements are presented and show that central urban roads are responsible for the highest marginal congestion cost (27.3 p per pcu km), while dual carriageways are of the lowest marginal congestion cost (0.19 p per pcu km). For the 1993 traffic flows this is equivalent to a total congestion time cost of £13.44 billions.

The chapter compares the results of the current study with the previous estimates of congestion time cost -after updating them to be comparable with the current study figures- and concludes that there is a difference between the current study results and the previous estimates. The study results are found to be much higher for some road types, example; motorways and dual carriageways, compared with previous estimates, and this is explained by the method used in both cases. While previous estimates were very much based on average values for traffic flows and speeds, the current study methodology incorporates the real variations in traffic in order to estimate the real impact on speeds and congestion cost. MCTE estimates based on the four distributions of traffic is between 1.5 (for major central urban roads) and 11.8 (in case of motorways) times as much as that based on average values of flows and speeds.

A comparison is made between the estimated average speed for major urban roads with that produced by the Department of Transport Survey of speeds in English urban areas, 1994. The comparison showed a slight difference between the measured speeds in both cases. This is explained by the fact that The Department of Transport survey results are based on speed measured on a small sample of sites. In addition, traffic in urban areas is prone to disruption by a wide variety of events. For example accidents and road works. In the Department of Transport survey, no attempt is made to exclude data gathered during such disruption. Then the surveyed speed is expected to be slightly lower compared with the current study estimates.

The chapter presented a distribution for both marginal congestion cost and speed for different road types. For all road types, congestion time cost takes the shape of one tail distribution, showing a diminishing proportions of PCUKT for higher categories of marginal congestion cost.

Speed distributions for motorways and other non-built up roads were discussed in the light of the results of National Traffic Survey (NTS). It is noticed that, there is a divergence or difference between the study results and the NTS results. This difference is explained by the fact that NTS results are based on traffic speed measured at a sample of sites on non-built up roads, and then do not comprehensively reflect the real traffic on the roads. Hence the current study speed distributions are more reliable and then more appropriate for the purpose of congestion time cost measurements.

The chapter then ends by providing a projection of congestion time cost for the year 2000 based on the upper and lower traffic forecasts. The elasticity of marginal congestion cost with respect to traffic is estimated in average to be 2.7, and the speed elasticity with respect to traffic is estimated in average to be -0.19.

**References**

1. **Department of Transport, DTp** (1993) *Transport Statistics Report: Road Traffic Statistics Great Britain 1993.* Prepared by the Government Statistical Service.
2. **Department of Transport, DTp** (1994a) *Transport Statistics Report: Road Traffic Statistics Great Britain 1994.* Prepared by the Government Statistical Service.

3. **Department of Transport, DTp** (1994b) *Transport Statistics Report: Road Travel Speeds in English Urban Areas.* Prepared by the Government Statistical Service.
4. **Department of Transport** (1981 ) *COBA 9.* HMSO, London.
5. **Newbery, D. M. G.** (1987a) *Road user charges and the taxation of road transport.* IMF working paper WP/87/5. Washington D.C.
6. **Newbery, D. M. G.** (1987b) *Cost recovery from optimally designed roads.* Churchill college, Cambridge, England.
7. **Newbery, D. M. G.** (1987c) *Road user charges in Britain.* Discussion paper series, no. 174. Centre for Economic Policy Research.
8. **Newbery, D. M. G.** (1988) *Road user charges in Britain.* The Economic Journal. Vol. 98. pp. 161-176
9. **Newbery, D. M. G.** (1990*) Pricing and congestion: economic principles relevant to pricing roads.* Oxford Review of Economic Policy, vol. 6 no. 2.

# Chapter 9

## Externalities (Noise Pollution Benefits)

### 9.1 Introduction

This chapter is devoted to the second type of non-user benefits of rail investment schemes concerned in the study. This is road traffic noise pollution.

Noise pollution is considered to be one of the main sources of external costs generated by transport users and inflicted on the non-travelling public. In the United Kingdom, a study cited by Sharp and Jennings (1976) put the cost of reducing road traffic noise by 10 dBA at £14.2 billion in 1972. Quinet (OECD, 1990b) suggests that traffic noise may give rise to damages in the form of productivity loss and annoyance amounting to 0.1 per cent of GNP. In 1991 for the UK, this is equivalent to £0.6 billion. But the Quinet figure does not express the total cost of traffic noise, since it does not include other effects of noise such as health impacts. For other modes of transport, Quinet suggests the figures of 0.01 percent of GNP or £0.06 billions. Quinet added that the majority of road traffic noise comes from heavy goods vehicles. This evidence illustrates the magnitude of noise impacts for both road and other modes of transport, which suggests that road traffic noise is much more damaging compared with other modes of transport, in particular railways.

It follows that a policy which reduces road traffic, will create an area of benefits to the society in terms of less noise damage for those who are affected by road traffic noise. This means it is essential to consider noise impacts when assessing, on a social basis, the benefits and costs of rail investment schemes.

It is the main concern of this chapter to look at the noise impacts of both road and rail at the margin, in a process to measure the amount of benefit that will emerge as a result of a vehicle km transfer from road to rail, and that has to be included as a non-user benefit in the benefit side of a rail investment scheme. The aim is to disaggregate the noise benefits by road types, so noise benefits of a rail investment scheme can be quantified once the alternative road type is assigned. This will be carried out for 8 road types for the UK road network (the same breakdown of roads as for the case of congestion time cost benefits in chapter 7).

Since road noise costs will be measured at the margin to be incorporated in a social appraisal framework for rail investment schemes, it is also relevant to consider the noise cost of railways. Hence it is also the concern of this chapter to consider rail noise costs, so the climate becomes visible for assessing the social costs and benefits of a rail investment scheme.

The chapter starts by a general definition of noise in section 9.2. Then section 9.3 explains why noise is considered to be one of the transport externalities. After that section 9.4 discusses the units for measuring road and railway noise, followed by an illustration of the extent and magnitude of railway and road noise in the United Kingdom in section 9.5. A comparison between the annoyance caused by road and rail noise is discussed in section 9.6. A brief discussion about the techniques and procedures of quantifying the cost of transport noise is given in section 9.7. Section 9.8 forms the heart of the chapter. It details the study methodology of estimating the marginal and average cost of road noise for the United Kingdom road network. This includes all the assumptions made, the data and information required and used as well as their sources, the mathematical models and relationships used, and the results of the measurement process. Section 9.9 shows the calculation process of rail noise costs. At the end, a summary of the contents and a conclusion of the findings of the chapter is given in section 9.10.

## 9.2 Noise and Sound

Noise, often defined as unwanted sound, is caused by small pressure fluctuations in the air (Sharp and Jennings, 1976), (DTp, 1991). But which sounds are wanted and which are not depends on human judgement, a jet plane, a symphony orchestra and a busy motorway may all have the same sound level in dB(A) and there might be some individuals who enjoy the sound of the symphony and dislike the sound of the jet plane. Time is another determinant of wanted and unwanted sounds. An individual may be bothered so much by a sound of a heavy truck early in the morning, but he might not annoyed to much if this was during the day. In fact there is no objective test which can be used to classify the wanted and unwanted sound. On the other hand, there is some levels of noise that can be accepted by the individuals without being annoyed or disturbed. This will depend, beside other things, on the source of the sound or noise. It will be shown latter, the relationship between noise levels of road and rail and annoyance.

The reasons for disliking noise are that, it may be regarded as intrinsically unpleasant, because it interferes with some wanted sound such as speech or music, because it interferes with work performance, especially where this requires mental concentration, because it disrupts sleep, and because it has physiological effects.

## 9.3 Transport Noise as an Externality

Noise of transport modes is a clear example of pure pollution. In other words, there are some users who do abuse the medium, the -polluters- while others are relatively passive victims of such abuse -the public-, e. g. a busy motorway or a jet plane make the noise, housewives and families living adjacent to the road or the airport are forced to submit to the noise. This creates an area of externalities, where the polluter affects the well-being of other groups without being charged or making any compensation to those who are affected.

If noise is paid for in any form of charges, this area of externalities would have been avoided. But as far as noise costs are not charged for, or only partly charged for, the externalities exist. Although efforts have long been going on to quantify the noise costs of transport modes as a basis for containing this type of externality in any form, the application of any noise charges is still limited. It is extremely difficult to devise a satisfactory way of charging for noise pollution. Apart from restraining the use of vehicles (particularly heavy goods vehicles) in urban and residential areas by road pricing, the only other alternative appears to be the use of command and control regulations covering the design and construction of motor vehicles. The maximum limits for noise are currently 84 dB(A) for heavy goods vehicles and 77 dB(A) for cars. However, there is no metered testing of the noise levels of vehicles in the UK either in the MOT test or at the roadside (Pearce, 1993).

An investment policy that incorporates the costs of transport noise at the margins into the assessment process will bring benefits to the society and the users of transport services, by directing the investment resources toward the most desirable and noise friendly modes.

## 9.4 Measurement of Transport Noise

Houtman and Immers (1987) describe how noise can be objectively quantified in various ways:

1. Noise level in Decibels (dBs)
2. Loudness in Sones
3. Loudness level in Phons
4. Frequency characteristics in Hertz
5. Interval time in Seconds

However, the standard measure of noise is the decibel (dB). This is a unit of sound pressure level related to a standard reference level of 0.00002 Newtons per square meter (TEST, 1991). Various types of decibel are commonly used. For example, the dB measure which gives greatest emphasis to those frequencies most audible to the human ear is the A-weighted decibel. This measurement however may not adequately reflect the low frequencies emitted by diesel locomotives (OECD, 1988; Flindell, 1983). Decibels are rated on a logarithmic scale. Therefore increasing volume by one dB will barely be noticeable, while increasing it by 10 dB would be described by the average listener as a doubling of loudness (OECD 1973). For the purpose of comparison, the following shows some of the noise levels in dB(A):

Table 9.1 Typical Noise Levels in dB(A)

| | |
|---|---|
| 1. Aircraft at takeoff | 120 |
| 2. Pneumatic drill (at 1 m distance) | 100 |
| 3. Lorry, motorcycle, underground train | 90 |
| 4. Busy cross-roads | 80 |
| 5. Noise level near a motorway | 70 |
| 6. Busy street through open windows | 60 |
| 7. Busy street through closed windows | 50 |
| 8. Bird song | 45 |
| 9. Quiet room | 35 |
| 10. Broadcasting studio | 20 |

Source: OECD (1988); OECD (1973)

For the measurement and comparison of transport noise, the $LA_{eq}$ (equivalent sound level in decibels) is commonly used. $LA_{eq}$ is a measure that gives a single figure sound reading, expressed in decibels, for a given period of time. Thus $LA_{eq}$, 24h is a widely accepted 24-hour value of $LA_{eq}$. $LA_{eq}$ is particularly useful as it is a unit that represents the constant level of noise which, in energy terms, equals the varying noise throughout the period (Nelson, 1978). Other measures of transport noise include $LA_{10}$, $LA_{50}$, $LA_{90}$ measures. These refer to any noise levels exceeded for over 10% , 50%, and 90% of the time respectively (TEST, 1991). In a recent report (TEST 1991), it is suggested that $LA_{eq}$ is the most appropriate method by which to assess the overall impact of transport noise since it accommodates all facets of the noise climate. As will be seen latter in this chapter, the noise level for each road type of the UK road network is measured in $LA_{eq}$ scale, and this is used to measure the marginal and average noise cost for each road type.

## 9.5 Magnitude of Exposure to Road and Rail Noise

The following table illustrates the national population exposure to land transport noise for the UK case.

Table 9.2 United Kingdom national population exposure to land transport noise (percent)[1]

| Outdoor sound level in $L_{eq}$[dB(A)][2] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Road transport noise [3] | | | | | Railways noise [4] | | | | |
| >55 | >60 | >65 | >70 | >75 | >55 | >60 | >65 | >70 | >75 |
| 50 | 25 | 11 | 4 | 0.6 | | 0.9 | 0.3 | 0.1 | |

1. percentages are commutative and not additive (for example: The % of persons exposed to >55 dB(A) includes % of persons exposed to >60 dB(A), etc.)

2. daytime $L_{eq}$ (6-22 hours) measured in front of the most exposed facades of buildings.

3. road traffic noise : $L_{eq}$ averaged (06.00-24.00), 1972 survey, England only

4. railways: 1976 data, great Britain only ($L_{eq}$ 24 hours)

Source : (OED, 1990a)

Surveys have shown that of all sources of noise nuisance, road traffic noise is most often stated to be the dominant source. In thirteen OECD member countries, between

7% and 31% of the population are exposed to a road traffic noise level of over 65 dB(A) compared to between 0.4% and 4% for equivalent noise levels from railways (OECD 1988, Nelson et al 1989). According to an OECD report (1990a) approximately 119 million people in all OECD countries are exposed to levels of over 65 dB(A) from road traffic. Some other research shows that 25% of the European Community's population is exposed to unacceptably high levels of noise and for thirteen European countries, road transport is the dominant noise source, heard by 89% of the population at homes (Nelson et al 1989, TEST 1991). Table 8.2 shows the magnitude of exposure to road and rail noise for the UK population. As can be seen from the table, 11% of the UK population are exposed to a road traffic noise level more than 65 dB(A) compared to only 0.3 for equivalent noise levels from railways.
According to OECD (1990a), there are 6 million people in Britain exposed to road traffic noise levels of more than 65 dB(A). This figure refers to 1987 estimates. If the average household size is 2.5 persons (Social Trends 1992), this means that a total of 2.4 million house are exposed to noise level from road traffic of more than 65 dB(A). The corresponding length of road network open to traffic was 352700 km (DTp, 1993). Thus the number of houses per km exposed to a noise level of more than 65 dB(A) was about 6.8 per km.
These estimates can be used to make a very approximate estimate of the number of houses exposed to road traffic noise from the new roads, and then the figure for 1987 can be updated to more recent years. The necessary assumptions, which may well not be valid, are that the distribution of houses along the new roads is, on average, the same as that along the existing roads in 1987, and that the noise characteristics of new roads will be the same as those of existing roads in 1987.
Fields and Walker (1982) estimated the number of houses in Great Britain exposed to different noise levels from railways. They estimated the number exposed to more than 60 dB(A) to be 178,474; to more than 65 dB(A), 59,667; and to more than 70 dB(A), 17,834. The corresponding length of railway routes was 18,166 km. Thus the number of houses per km exposed to different noise levels from existing railways was about 9.8 per km exposed to more than 60 dB(A), 3.3 to more than 65 dB(A) and 1 to more than 70 dB(A). These estimates may be used to update the exposure to railway noise for the more recent years. This will require two assumptions. The first, is that the

distribution of houses along the new railway lines are the same as the old ones. Second, that the noise characteristics of the new railway lines are the same as the 1982. These assumptions might not hold, and then the resultant estimates will be very approximate ones.

Throughout the OECD, there are more reported evidence of exposure of the population to road traffic noise than to rail (DTp, 1991). This is explained by and reflects two main characteristics. First, due to the differing density of the two modes networks, a larger proportion of people live closer to potential road traffic noise than to rail noise sources. Therefore more people will be exposed to road traffic noise than to rail noise. According to OECD (1986), 25 times as many people in the USA are exposed to road noise as compared to rail noise. The corresponding figure for Norway is 45 times. Second, the higher reporting of exposure of population to road rather than rail noise reflects the nature of the noise produced. This is the result of the design characteristics of road and rail as well as the differences between the nature of service provided. Some studies show that for a given amount of passengers or goods carried at the same speed, rail is on average about 5 to 10 decibels quieter than road (Linkerhagner and Amann 1987)

### 9.6 Comparison of the Annoyance Caused by Road and Railway Noise

Extensive research has been carried out into people's response to road and rail noise in the last thirty years (DTp, 1991). It is usually quantified in terms of the population who suffer, are bothered, disturbed, annoyed, or dissatisfied by the noise. The main results of the earlier studies confirm that a higher percentage of the population heard road traffic noise than rail noise and proportionally more people were affected by noise from road traffic sources (British Railway Board 1976; Williams, et al 1978; Flindell 1983).

The concept of a threshold limit for annoyance due to noise has long been the subject of debate. A detailed literature review of 26 reports relating to noise with reference to the annoyance threshold (the theorized critical level when people became annoyed at the noise source) has been carried out by Flindell (1983). He stated that according to Gilbert (1973) in the Paris Area Railway Noise Survey, the estimated values for threshold were:

| | |
|---|---|
| Motorways and road traffic noise | 65 $LA_{eq}$ |
| Railway noise | 70 $LA_{eq}$ |

This means that for noise levels less than 65 dB(A) from road and 70 dB(A) for rail, minimal annoyance is caused by either road or rail. The general conclusion of Flindell study is that there is an estimated higher annoyance threshold for rail than road.

Other surveys investigating threshold levels have given slightly different results. Walker (1988) concluded that at less than 60 dB(A), minimal annoyance is caused by both road and rail. But for a 5 dB(A) increase in rail and a 10 dB increase in road noise, will double the proportion of population annoyed. Anderson, et al (1988) stated that about 39% of people in Denmark are annoyed at railway noise levels of 55 dB(A) $LA_{eq}$, 24h, and research by Peeters et al (1983) found that annoyance is roused at noise ranges between 50-53 dB(A) $LA_{eq}$. Heintz et al (1980) suggested that road noise is more annoying than rail noise for equivalent $LA_{eq}$ levels (cited from Moheler 1988).

As can be seen, on one hand, most of the studies agrees in that the threshold level for railway is higher than for road. On the other hand, the research results contradict in the theorized critical level when people become annoyed at the noise source. This contradiction may be attributed to different cultures and public perceptions, attitudes and reactions at different times in different countries. It also may reflect different survey methodologies, sample sizes, interpretation of results.

In addition to the differences between road and rail noise with regard to the threshold, some studies confirm that annoyance from railway noise increases less rapidly than annoyance from road noise, as noise levels increase. Fields and Walker (1982) confirm that at higher noise levels road traffic noise is between 4 and 20 dB more annoying than rail. Other studies by Peeters et al (1983) and Heintz et al (1980) support this conclusions. This observation suggests that people are more tolerant of railway noise than of road noise.

## 9.7 Techniques of Measuring Transport Noise Cost

Kanafani (1983) has set out the economic impacts of transport noise to be:

**1. Damage costs. This includes**

a) productivity losses due to inability to concentrate, communication difficulties at work, or fatigue due to lack of sleep or inadequate rest outside work.

b) health care costs, for example the effects of sleep less or damage to hearing in case of intense exposure to noise.

**2. Expenditure on protection from noise. This includes:**

a) abatement costs at source. Particularly with regard to vehicles.

b) expenditure on protection for the community, e. g. anti-noise screens along roadways, or cuttings and tunnels.

c) also private expenditure against noise, e.g. double glazing, double windows in dwellings.

**3. The effects on property values, which are driven down by nearby noise.**

It follows that the social cost of transport noise can be looked at and quantified in three ways, these are:

1. The sum of productivity losses and health care costs
2. Expenditure on noise abatement
3. The reduction on property values as a result of exposure to noise

It should be noted that these three ways are not independent of one another. And if both individuals and governments are perfectly informed and rational, and if markets are perfect, one would expect that the sum of marginal productivity losses and marginal health care costs is equal to the marginal expenditure on noise abatement, and is also equal to the marginal reduction in property values.

It is quiet difficult to assess health care costs and productivity losses. This is due to the fact that noise as a cause cannot be isolated from other causes and factors. The only figures available in the literature are the evaluation of sleep loss due to noise in Norway (Ringheim, 1983) and that was equivalent to 0.05% of GDP. The other evidence comes from an evaluation of productivity losses in Germany (Wicke, 1987) which amounted 0.2% of GDP.

Extensive research studies have been undertaken measuring the expenditure on noise abatement and the cost of noise protection. A very detailed review of these studies is given in (Verhoef, 1994 and OECD 1990b).

The third and commonly used method of measuring social costs of transport noise is by measuring the effects on the value of property. The principle behind this method is that it measures people's willingness to pay to eliminate or reduce transport noise. The result of measurement is usually identified in terms of a percent change in house prices for a unit change in the level of noise. The technique used in this process is called Hedonic Pricing. The following section highlights this technique in brief.

### *9.7.1 Hedonic Pricing*

The Hedonic Pricing technique (HP) uses information revealed by the decisions of purchasers to measure the money value of environmental attributes that have no market prices (TRRL, 1992). The most widely used case is that of house prices. House prices vary in accordance with the quality of environment, so they can be used to estimate the money value of environmental attributes. HP is based on the assumption that house prices reflect people willingness to pay for better environment, which is in turn based on the assumption that individuals are rational and aware of the real impact of the quality of environment on them. Pearce and Markyanda (1989) point out that individuals may undervalue the benefits of reducing pollution because they are not fully aware of its impact upon their health.

The relationship between house prices and environmental attributes is usually identified using multiple regression analysis. Most of HP studies have only considered the effect of a single environmental factor on house prices (usually noise levels or air pollution). Environmental values are usually expressed in terms of percentage change in house prices as a result of a single unit change of the concerned environmental attribute.

Extensive research studies have been undertaken both in the USA and in Europe to establish the relationship between house prices and the level of transport noise. Most of the studies are concerned with the aircraft noise impact. However, some research concerned with road traffic noise has been carried out. Table 9.3 shows the results of some empirical work in the USA and Europe.

Table 9.3 The impact of traffic noise on house prices (% of house prices)

| Location | Impact of one unit change in $L_{eq}$ |
|---|---|
| 1. USA | |
| •North Virginia | 0.15 |
| •Tidewater | 0.14 |
| •North Springfield | 0.18-0.50 |
| •Towson | 0.54 |
| •Washington DC | 0.88 |
| •Kingsgate | 0.48 |
| •North King Country | 0.40 |
| •Spokane | 0.08 |
| •Chicago | 0.65 |
| 2. Canada | |
| •Toronto | 1.05 |
| 3. Switzerland | |
| •Basel | 1.26 |

Source: Pearce and Turner (1990)

Note: $L_{eq}$ (equivalent continuos sound level)= a level of constant sound in dBA which would have the same sound energy over a given period as the measured fluctuating sound under consideration.

According to table 9.3, a unit change in noise level would lead to a change in house prices ranging from 0.08 percent in Spokane to 1.26 percent in Basel.

In France, the Institute de Recherché Des Transports (IRT) quotes several studies giving depreciation indices of between 0.15 and 0.71 percent (OECD, 1990b). Kanafani (1983) stated that the fall in house values are estimated at between 1 percent and 10 percent according to the level of noise in dB(A), and may be as low as 0.5 per cent. A study in Norway also gives a figure of 0.4 percent (Ringheim, 1983). Overall, according to OECD (1990b), the most recent assessments of loss of property value and that is also quoted from (Nelson et al 1989), is around 0.4 percent. The threshold from which cost is counted is located between 50 dB, below which no disturbance is perceived, and 65 dB, a legal limit in some countries. The figure of 0.4

percent is used by this study to indicate the change in house prices with a change of one unit of noise level in dB(A).

A study by Pearce, Barde and Lambert (1984) calculated the value of the social cost of traffic noise impact for the housing stock in France in 1980. Taking a depreciation in property value of 0.4% per unit of noise and applying this factor to the number of dwellings exposed to noise levels between 55 and 80 dB(A) on the $L_{eq}$ scale, it was found that the total depreciation obtained was 61.4 billion French Francs. The study assumed that the level of noise after which people start to be annoyed is 55 dB(A) on the $L_{eq}$ scale and the maximum level people may be exposed to is 80 dBA.

## 9.8 Estimating the Cost of Road Traffic Noise for the British Road Network

### *9.8.1 Introduction*

This section explains the method used in estimating the social cost of road traffic noise for the UK road network. The estimation process aims to measure the total social noise cost and to allocate this cost for different types of roads. The break down of roads is the same as that used for measuring congestion time cost in the previous chapter. The process is divided into two main stages, these are:

1. Measuring the noise level for each road type
2. Using the measured noise level to estimate the social noise cost for each road type at the margin

### *9.8.2 Measuring Noise Level for Different Types of Roads*

The method of measuring the noise level for different road types is based on the noise prediction method developed by the Transport and Road Research Laboratory (Harland, 1978). The model calculates the noise level as a function of the average speed (km/h), total flow of traffic (vehicles/h), and the percentage of heavy vehicles on the traffic flow. Specifically, the model is:

$$L_{10}(1hour) = 10\log_{10} q + 33\log_{10}(V + 40 + \frac{500}{V}) + 10\log_{10}(1 + \frac{5p}{V}) + 0.2G - 27.6 \qquad (9.1)$$

Where:

$L_{10}$ (1 hour) = is the level of noise in dBA exceeded 10 percent of the time for any one hour.

q = is the total traffic flow in the hour considered (pcu/h)

V = is the mean traffic speed (km/h)

p = is the percentage of vehicles, other than motorcars, whose unladen weight exceeds 1525 kg.

G = is the gradient of the road expressed as a percentage.

#### 9.8.2.1 Methodology Framework and Steps of the Process

As figure 9.1 demonstrates, the methodology incorporates the distribution of traffic into the measurement of the average noise level of roads. Calculating the hourly traffic flow and speed for the measurement of noise level for each road type is carried out on the same basis as that for the measurement of congestion cost externality. The four distributions of traffic are incorporated to calculate the hourly traffic flow and speed, which in turn is used to calculate the noise level for each hour for the concerned road type.

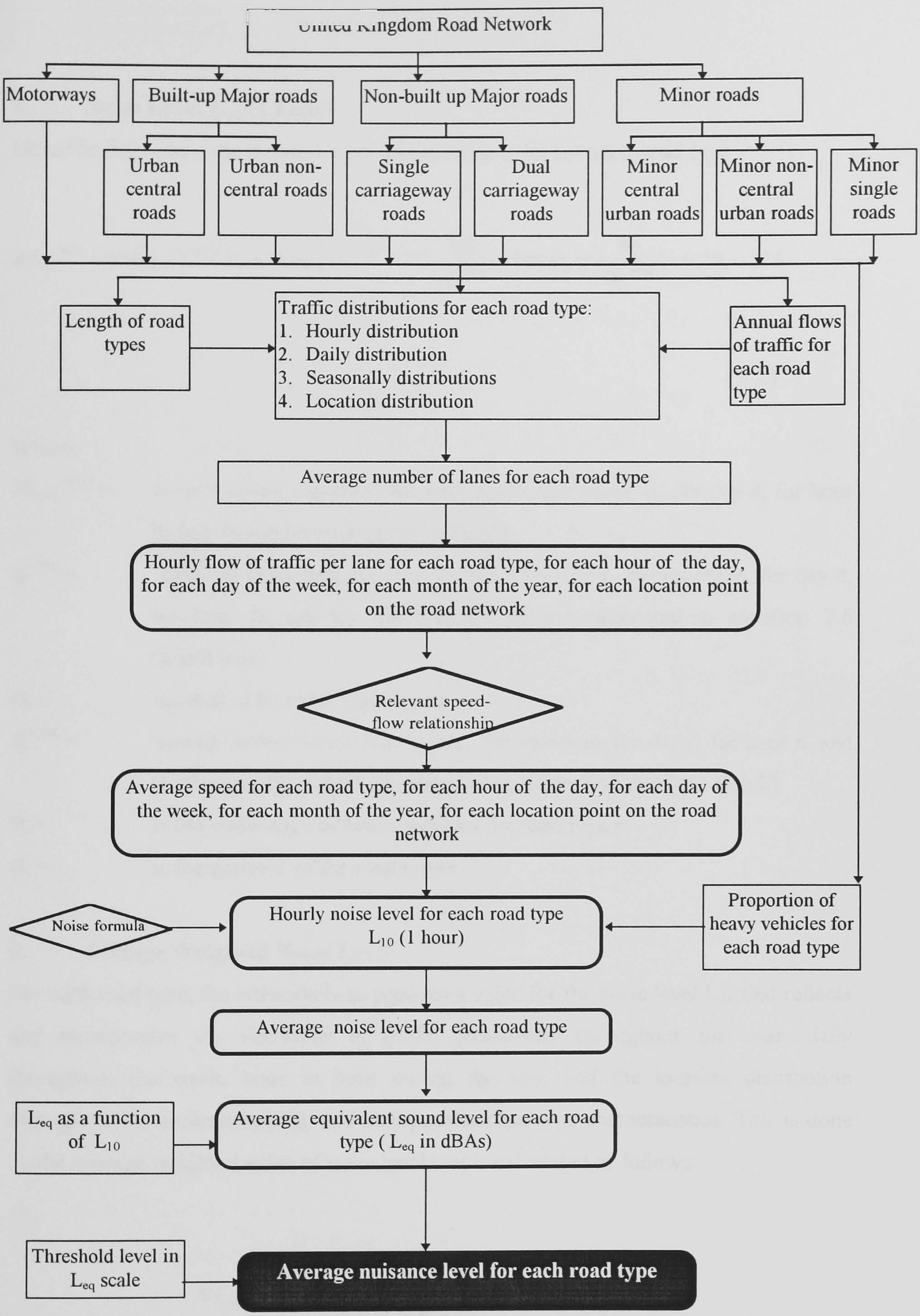



Figure 9.1 Methodology framework of calculating the noise level and nuisance level for roads

## 1. Noise Level $L_{10}$ (1 hour)

Equation 9.2 shows the measurement of the noise level for each road type.

$$NL_{10r}^{mdhl} = 10\log_{10} q_r^{mdhl} N_r + 33\log_{10}(S_r^{mdhl} + 40 + \frac{500}{S_r^{mdhl}}) + 10\log_{10}(1 + \frac{5p_r}{S_r^{mdhl}}) + 0.2G_r - 27.6$$

(9.2)

Where:

$NL_{10r}^{mdhl}$ = is the $L_{10}$ noise level for the road type r, for month m, for day d, for hour h, and for the location point l (dB(A))

$q_r^{mdhl}$ = traffic flow per lane per hour for the road type r, for month m, for day d, for hour h, and for the location point l calculated in equation 7.6 (pcu/h/lane)

$N_r$ = number of lanes for road type r

$S_r^{mdhl}$ = average speed for the road type r, for month m, for day d, for hour h, and for the location point l calculated in equation 7.10 and 7.11 (km/h)

$P_r$ = is the percentage of heavy vehicles for road type r

$G_r$ = is the gradient of the road type r

## 2. Average Weighted Noise Level

For each road type, the intention is to produce a value for the noise level $L_{10}$ that reflects and incorporates the variations in traffic (seasonally throughout the year, daily throughout the week, hour to hour during the day, and the location distribution throughout the entire network), and incorporates road type characteristics. This is done by the average weighted value of noise level that is calculated as follows:

$$NL_{10r} = \frac{\sum_{m=1}^{12}\sum_{d=1}^{7}\sum_{h=1}^{24}\sum_{l=1}^{l} NL_{10r}^{mdhl}}{m \times d \times h \times l} \qquad (9.3)$$

Where:

$NL_{10r}$ = average weighted noise level for the road type r (dB(A))

m, h, d, l = are referring to month of year, day of week, hour of day, and location point on the road network

**3. Energy Mean Sound Level ($L_{eq}$)**

This measure of noise accounts for the magnitude and duration of all the sounds occurring during a given period and, by definition, is equal to the steady-state continuous sound level having the same energy content as the actual time-varying noise (Nelson, 1978). The energy mean sound level is also referred to as the equivalent sound level, and denoted by $L_{eq}$. According to Nelson (1978), the noise level $L_{10}$ and $L_{eq}$ are highly correlated with a correlation coefficient equal to 0.95, and the formula relates $L_{eq}$ to $L_{10}$ is as follows:

$$L_{eq} = L_{10} - 3dB \pm 2dB \qquad (9.4)$$

This formula is used to calculate the equivalent sound level for each road type as described in the following equation:

$$ESL_r = NL_{10r} - 3dB \qquad (9.5)$$

Where:

$ESL_r$ = value of the equivalent sound level ($L_{eq}$) for road type r (dB(A))

**4. Average Nuisance Level**

If people start to be annoyed from traffic noise when the noise level in $L_{eq}$ scale became more than 55 dB, then the nuisance level is the number of dB in excess of 55. The study assumes that the annoyance is aroused at a noise level on the $L_{eq}$ scale >55 dB(A). This is based on the empirical research studies undertaken to investigate human response to road noise. Some of the evidence is discussed above in section 9.6 . The nuisance level is estimated for each road type as follows:

$$ANL_r = ESL_r - 55dB(A) \qquad (9.6)$$

Where:

$ANL_r$ = is the average nuisance level for road type r (dB(A)) and which any household living adjacent to road r is facing.

**5. Marginal Nuisance Level**

In order to estimate the social noise benefits of a railway scheme that attracts people off the road, it is required to estimate the marginal nuisance level. The word marginal refers to the change in nuisance level for an additional pcu km using the road. The marginal nuisance level (MNL) is estimated by adding one pcu km to the traffic flow and measuring the impact on the average noise level ($NL_{10r}$) and average nuisance level ($ANL_r$) explained above. This is carried out for the 8 road types identified for the study. The calculations are undertaken by a BASIC computer program that is developed and mentioned in chapter 7. A flowchart of the program is given in detail in appendix 1.

### *9.8.3 Estimating Social Road Noise Costs*

In this stage, the aim is to use the average and marginal nuisance level for different road types estimated above and the information of exposure to road traffic noise in the UK, in a process to measure the total social cost of road traffic noise and to allocate the cost for different road types in order to measure the average and marginal noise cost. The following steps along with figure 9.2 show how this is carried out.

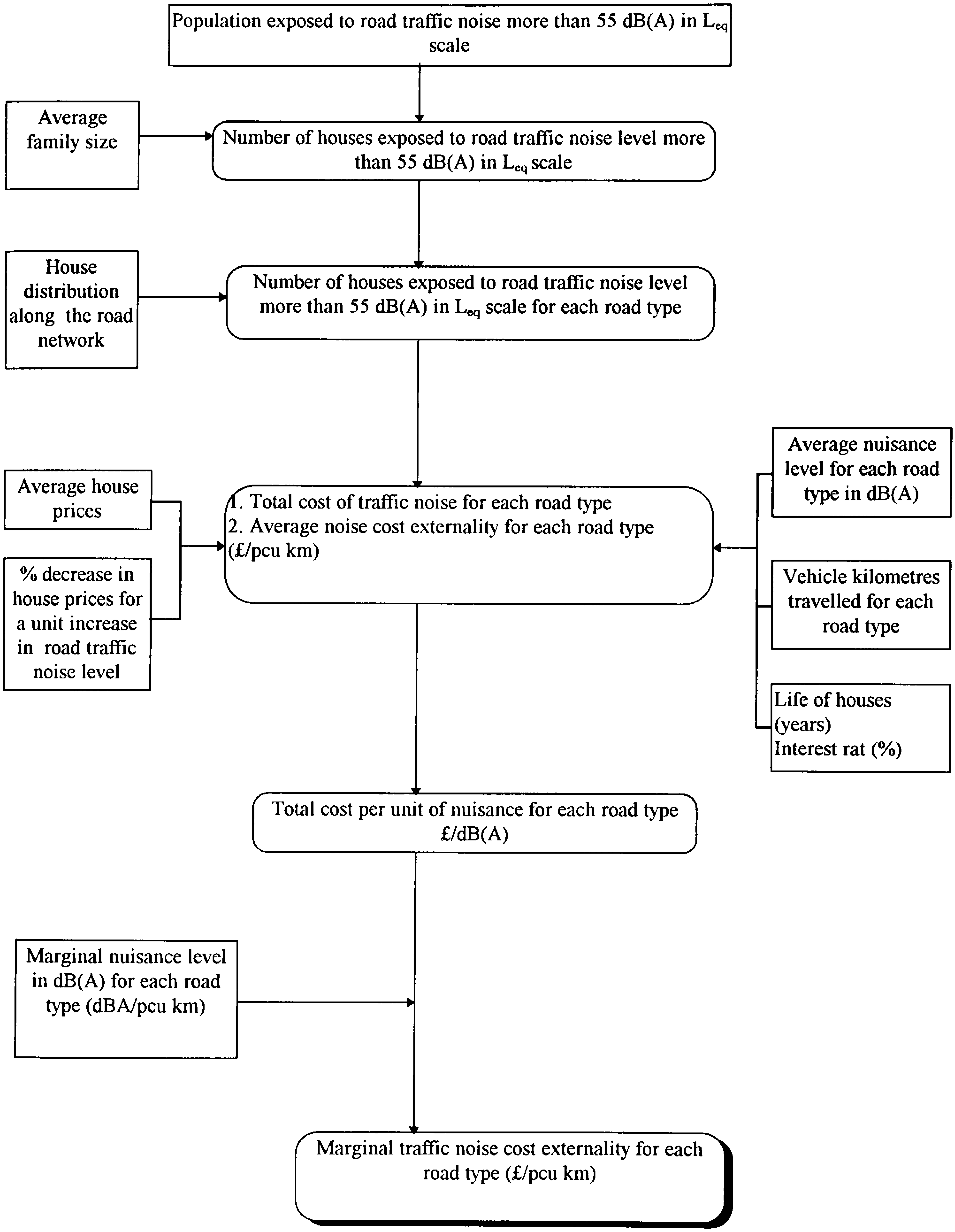



Figure 9.2 Estimating average and marginal traffic noise cost externality

#### 9.8.3.1 Step One: Identify the Exposure to Road Traffic Noise

As shown in table 9.2, according to the OECD (1990a), in 1972, 50% of the UK population are exposed to noise level from road traffic of >55 dB(A) $L_{eq}$ scale. Based on this and information on road network length and average family size for 1972, that means an average of about 28.4 house per km of the road network. This value is used to estimate the number of houses exposed to noise level more than 55 dB(A) for 1993 multiplying by the road network length in 1993. The necessary assumption made is that the distribution of houses along the new roads is, on average, the same as that for 1972.

#### 9.8.3.2 Step Two: House Distribution between Roads

In order to disaggragate the cost of traffic noise by different road types, it is required to identify the number of houses exposed to traffic noise from each road type. This will require information of the distribution of houses along different road types within the entire road network. Some assumptions are made to allocate the total number of houses exposed to road traffic noise >55 dB(A) between the 8 road types, these are:

1. 15 % of the houses are in rural areas, of which 1% are exposed to motorways, 10% exposed to single carriageways, 4% exposed to dual carriageways.
2. The rest of the houses (85% ) are in urban areas, of which 10% are exposed to major urban central roads, 75% exposed to major urban non-central roads.

#### 9.8.3.3 Step Three: Identify the Average House Prices

House prices vary according to the type of the house (detached, semi-detached, terraced or any other types), and also vary with the condition of the house (new, modern, or old). In addition, the prices vary from region to another throughout the county.

The calculation of noise cost in this study is based on the average prices of houses given by the building society Nationwide (Nationwide, 1994). Average house prices for the UK are £61168, £56659, and £52052 for new, modern and older houses respectively. The average for all houses from all types is £54216.

#### 9.8.3.4 Step Four : Identify the Relationship between House Price and Noise Level

The study is based on the assumption that a straight line relationship exists between traffic noise level and house prices. In other words, an increase of noise level by one unit will lead to a reduction of 0.4% of house prices. This is regardless of the noise level itself. In fact this may be an approximate assumption, and one may argue that the reduction of house prices will depend on the noise level. Then the relationship may take other form rather than a straight line. Kanafani (1983) reports that falls in property value are estimated at between 1 percent and 10 percent according to the dB level.

#### 9.8.3.5 Step Five: Total Noise Cost

The noise cost for each road type is measured as follows:

$$TNC_r = ANL_r \times PR_r \times HP_r \times NH_r \qquad (9.7)$$

Where:

$TNC_r$ = total noise cost for road type r (£)

$ANL_r$ = average nuisance level for road type r (dB(A))

$PR_r$ = percentage of house price reduction as a result of a one unit of increase in road traffic noise for road type r (%/dB)

$HP_r$ = the average price of houses for road type r (£/house)

$NH_r$ = number of houses exposed to road traffic noise from road type r

Equation 9.7 gives the total capital cost of noise for each road type. This total is used to estimate the annual noise cost for each road type. The calculation of the annual cost is based on the following assumptions:

1. The life of the house is 25 years
2. Interest rat is 10%

Then the annual noise cost is used to estimate the average noise cost per pcu km, for each road type basing on the number of pcu km travelled on each road type.

#### 9.8.3.6 Step Six: Average Cost per Nuisance Unit

The total noise cost per year and the average nuisance level for each road type estimated by equation 9.6 are used to calculate the average cost per nuisance unit for each road type as follows:

$$CNU_r = \frac{ANC_r}{ANL_r} \qquad (9.8)$$

Where:

$ANC_r$ = annual noise cost for road type r

$CNU_r$ = average cost per unit of nuisance for road type r (£/dB)

#### 9.8.3.7 Step Seven: Marginal Noise Cost Externality

Marginal noise cost (MNC) is measured as follows:

$$MNC_r = MNL_r \times CNU_r \qquad (9.9)$$

Where:

$MNC_r$ = marginal noise cost externality for road type r, the extra noise cost imposed on the society as a result of an extra pcu km using the road type r (£/pcu km)

$MNL_r$ = marginal nuisance level for road type r measured above reflecting the extra nuisance level as a result of an extra pcu km using the road r (dB/pcu km)

### *9.8.4 Results*

#### 9.8.4.1 Average Noise and Nuisance Level by Road Type

Table 9.4 presents the estimated average noise and nuisance levels by road type.

Table 9.4 Average noise and nuisance levels by road class

| Road type | Average noise level $L_{10}$ (dB(A)) | Equivalent sound level $L_{eq}$ (dB(A)) | Nuisance level (dB(A)) |
|---|---|---|---|
| 1. Motorways | 75.05 | 72.05 | 17.05 |
| 2. Major urban central | 70.53 | 67.53 | 12.53 |
| 3. Major urban non-central | 68.63 | 65.63 | 10.63 |
| 4. Single carriageways | 68.55 | 65.55 | 10.55 |
| 5. Dual carriageways | 72.57 | 69.57 | 14.57 |
| 6. Minor urban central | 52.10 | 49.10 | 0 |
| 7. Minor urban non-central | 51.69 | 48.69 | 0 |
| 8. Minor rural single | 55.18 | 52.18 | 0 |

As can be seen from the table, motorways cause the highest level of noise, followed by dual and single carriageways. Minor roads have the lowest noise level. This is mainly explained by the varying levels of traffic flows, speeds and proportions of heavy vehicles between road types.

As can be noticed, for rural roads, speed is the dominant determinant of noise and nuisance levels. In other words, roads with higher speeds have higher levels of noise e.g. motorways, and vice versa. On the other hand, in urban roads, where average speeds are lower compared with rural roads, the flow and density of traffic is the main determinant of noise levels. Road with higher traffic flows per hour have the highest noise level.

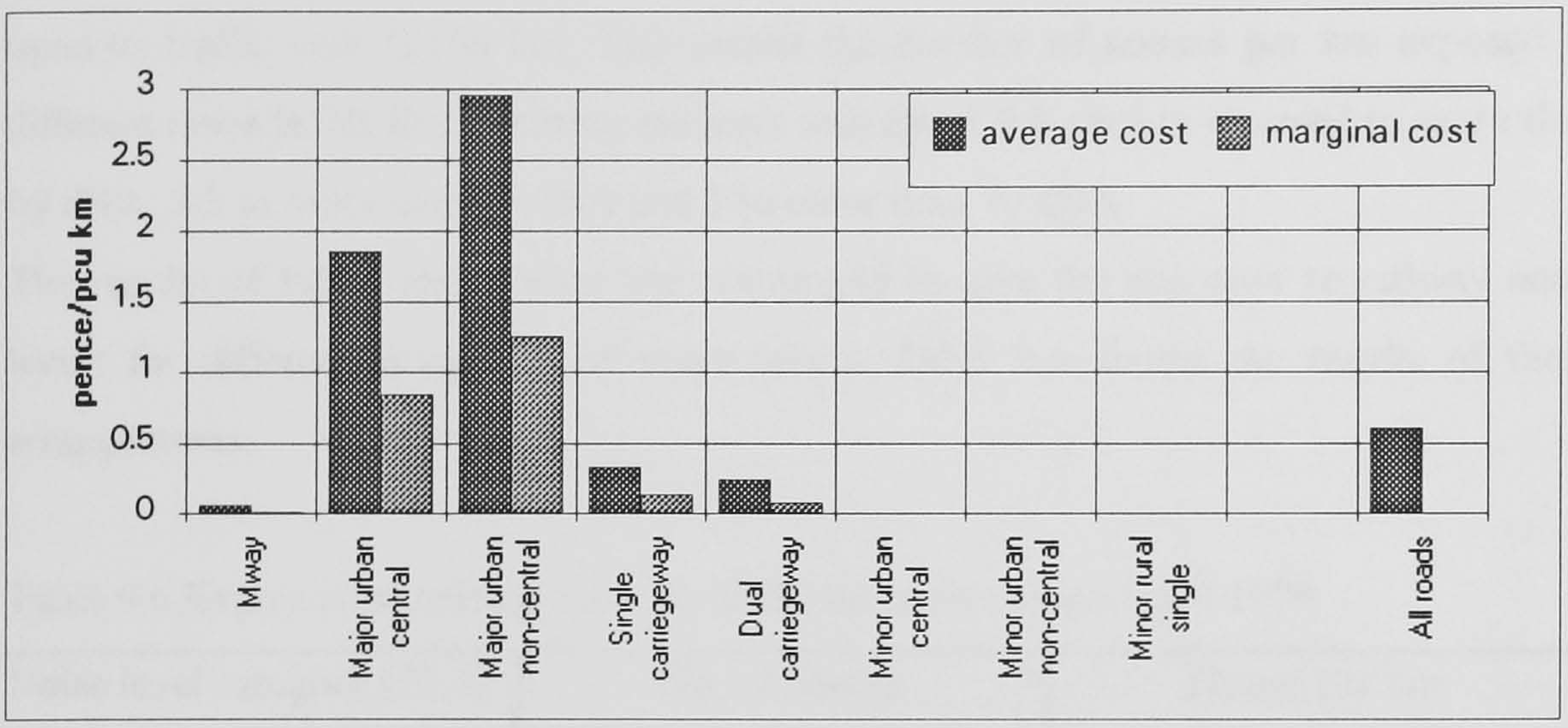
#### 9.8.4.2 Average and Marginal Noise Cost by Road Class

Based on the methodology framework for measuring marginal nuisance levels for different road types and using the distribution of houses between the roads, and using the 0.4 percent depreciation in house values, average and marginal noise cost are estimated for different road types. The results are shown in table 9.5.

Table 9.5 Average and marginal noise cost by road class for 1993

| Road types | Total noise cost per year £ billions | Average noise cost (pence/pcu km) | Marginal noise cost (pence/pcu km) |
|---|---|---|---|
| 1. Motorways | 0.042 | 0.06 | 0.011 |
| 2. Major urban central | 0.308 | 1.86 | 0.846 |
| 3. Major urban non-central | 1.96 | 2.96 | 1.253 |
| 4. Single carriageways | 0.234 | 0.33 | 0.138 |
| 5. Dual carriageways | 0.143 | 0.24 | 0.076 |
| 6. Minor urban central | 0 | 0 | 0 |
| 7. Minor urban non-central | 0 | 0 | 0 |
| 8. Minor single | 0 | 0 | 0 |
| • Total all roads | 2.69 | 0.61 | 0.25 |

Figure 9.3 Average and marginal noise cost by road class for 1993




The figures in table 9.5 show that, although motorways and other major rural roads have higher noise levels compared with urban roads, their estimated average and marginal cost are much lower than those of urban roads. This is explained by the fact that houses are much dense in urban areas and although the traffic noise of urban roads is lower, it is received by much more people. On the other hand, the high noise level of motorways and dual carriageways is received by fewer houses. This in turn affects the estimated marginal noise cost. For an extra pcu km joining a motorway, a cost of only 0.011 pence occurs to the society, however if this pcu km were to join an urban road, the cost would be between 0.85 to more than 1 pence depending on the type of the road.

## 9.9 The Cost of Noise from Railways

### *9.9.1 Introduction*

The methodology of measuring railways noise cost is similar to that of measuring the noise cost of road traffic. The reduction in property values is taken to reflect people's willingness to pay for noise reduction (the Hedonic Pricing Approach).

### *9.9.2 Exposure to Railway Noise*

The number of houses in Great Britain exposed to various noise levels from railways are estimated for 1982 by Fields and Walker (1982). They reported that for 1979, the number exposed to more than 60 dBA in $L_{eq}$ scale was 178474; to more than 65 dBA, 59667; and to more than 70 dBA, 17834. The corresponding length of railway routes open to traffic was 18166 km. This means the number of houses per km exposed to different noise levels from existing railways was about 9.8 per km exposed to more than 60 dBA, 3.3 to more than 65 dBA and 1 to more than 70 dBA.

The results of Fields and Walker are rearranged to give the exposure to railway noise levels for different categories of noise levels. Table 9.6 shows the results of these arrangements.

Table 9.6 Exposure to railway noise for different noise categories in 1979

| Noise level category (dBA) | No. of houses | House per km |
|---|---|---|
| more than 60 - 65 | 118807 | 6.5 |
| more than 65 - 70 | 41833 | 2.3 |
| more than 70 | 17834 | 0.98 |

Source: Adapted from Fields and Walker (1982)

The results of table 9.6 are updated for 1993 to make approximate estimate of the number of houses exposed to different noise level categories from the railways. The necessary assumptions made are:

1. The distribution of houses along the railway lines is, on average, the same as 1979.
2. The noise characteristics of railway are the same as those of existing lines in 1979.

Based on these assumptions and on the length of railway routes open to passengers and freight traffic in 1993 (DTp, 1994), table 9.7 presents the updated exposure to railway noise.

Table 9.7 Exposure to railway noise for different noise categories in 1993

| Noise level category (dBA) | No. of houses | |
|---|---|---|
| | Passenger | Freight |
| more than 60 - 65 | 93060.5 | 14371.5 |
| more than 65 - 70 | 32929.1 | 5085.3 |
| more than 70 | 14030.7 | 2166.78 |

### *9.9.3 Nuisance Level for Railways*

As discussed in section 9.6, most of the research studies suggested that there is an estimated higher annoyance threshold for rail than for road (Flindell 1983). In other words, the noise level after which people start to become annoyed from rail noise is higher than that for road noise. Based on some empirical research investigating the human response to road traffic noise, the study assumed that people's annoyance from road traffic noise started at a noise level of 55 dBA ($L_{eq}$ scale). Despite the difficulties of identifying the response of humans to noise, several authors have attempted to compare the annoyance caused by road and railway noise. Table 9.8 compares the results of different studies reviewed.

Table 9.8 Differences between levels of road and railway noise for equal general annoyance

| Study | Noise level deferential, dBA $L_{eq}$, 24 | | |
|---|---|---|---|
| | 50 to 60 dBA | 60 to 70 dBA | overall range of levels |
| Studies known to use large samples over a wide area | | | |
| Fields &Walker (1982) PBO(1983) | +1 | +5 | +4 to +15 |
| Knall et all(1983) | +2 | +6 | |
| Moheler et al(1986) | +1 | +7 | |
| Other studies(not necessarily less reliable) | | | |
| Berry(1983) | | | -ve |
| Flindell(1983) | | | +10 |
| Holzmann(1978) | +7 to +11 | | +5 to +9 |
| Kastka et al (1983) | | | +ve |
| Heintz et al(1980) | 0 to +4 | | +5 to +9 |
| Ohrstrom et al(1980) | | | -ve |
| Peeters et al(1983) | | | +3 to +5 |
| Kumagai et al(19750 | -3 (convential train)<br>+1 (high speed train) | | |

Source: DTp (1991)

+ ve = people more tolerant of railway noise than road noise

- ve = people less tolerant of railway noise than road noise

Table 9.8 shows that the majority of study surveys found that railway noise is less annoying compared to road noise. The differential in favour of rail varies between studies within the range of 3 to 15 dBA at levels of 60 to 70 dBA, though most found values are between 4 and 9 dBA. At noise levels of 50 to 60 dBA, the differential is small, and sometimes zero. Two studies produced the result that railway noise is more annoying than road noise. According to DTp (1991), these two studies are considered to be relatively insignificant, one relying wholly on secondary analysis of previous survey data and the other wholly on laboratory studies.

Based on these results the study assumes that on average the differential in favour of railway is 5 dBA. In other words, if people's annoyance from road traffic noise starts at a noise level of 55 dBA, for railways that happens at noise level more than 60 dBA. The study assumes that the maximum noise level that people may hear from railways is 80 dBA. This is based on reviewing the noise standards for existing railways in the United Kingdom. The maximum noise levels are found to be in the range 73 dBA for Glasgow and 88 dBA for Warwick in $L_{eq}$ scale. Accordingly, the nuisance level from railways (RNL) is estimated to be the excess in dBA over the 60 dBA (the minimum level over which people become annoyed with railway noise), and with a maximum of 80 dBA.

Table 9.9 demonstrates the nuisance level from railway noise for different categories of noise levels.

Table 9.9 Nuisance level from railway noise

| Noise category level (dBA) | Average nuisance (average excess in dB(A)) |
|---|---|
| >60 to 65 | 2.5 |
| >65 to 70 | 7.5 |
| >70 to 80 | 15 |

### 9.9.4 *Total Cost of Railway Noise*

The total cost of railway noise is estimated as follows:

$$RNC = RNL \times PR \times HP \times NH \qquad (9.10)$$

Where:

| | |
|---|---|
| RNC= | total cost of railway noise (£) |
| RNL= | nuisance level for railways (average excess in dBA above 60 dBA with a maximum of 80 dBA) |
| PR= | percentage reduction in house prices for a unit increase in noise level for railways (%/dBA) |
| HP= | average house price (£/house) |
| NH= | number of houses exposed to railway noise level more than 60 dBA |

Equation 9.10 is used to estimate the total noise cost for the three categories of noise levels shown in table 9.9. The results are disaggregated by the type of service (passenger and fright), and are presented in the next section.

### *9.9.5 Results*

The methodology explained above would give a total noise cost for railways of £0.172 billions, of which £0.149 is for passengers and the rest is for freight. Assuming a 10% interest rate and 25 years for the life of houses, this gives annual noise cost of 0.016 and 0.0025 billions for passenger and freight respectively. Using the total number of passenger and tonne kilometre moved by rail in the year 1993, this would give an average noise cost of 0.052 and 0.016 pence per passenger and tonne km respectively.

## 9.10 Chapter Summary

This chapter is devoted to the measurement of noise cost externality for road and rail. The methodology used and the measurement process are explained. Average and marginal road noise cost are disaggregated by road types. Urban roads have higher noise cost compared with rural roads and motorways. This is explained by the fact that houses are much dense in urban areas compared with rural areas, and then urban traffic noise, although lower than noise from rural road, is received by more houses. Rail noise cost is also measured, and the results shows lower cost for rail noise compared with road traffic noise cost.

## References


1. **Anderson T. V. et al** (1988) *Reactions to railway noise in Denmark: A correction.* Journal of Sound and Vibration, Vol. 120, no. 2, pp. 339-340.
2. **British Railway Board**, (1976) *Environmental and social impact study (ENOSIS)*
3. **Department of Transport DTp** (1991) *Railway noise and the insulation of dwellings*. HMSO.
4. **Flindell I. H**. (1983) *Reactions to transportation noise - A Comparative Study with special reference to railway noise*. Contract report 83/10. Institute of Sound and Vibration Research, Southampton University.
5. **Gilbert, P.** (1973) *The effect of train noise on the environment.* Southampton Institute of Acoustics meeting 13-14 November.
6. **Heintz, P. A. et al** (1980) *Zur Begrenzung der larmbelatung. Zurich Soziologisches.* Institute der Univeresitat.
7. **Houtman J. W. and B. H. Immers** (1987) *A Traffic Assignment Model to Reduce Noise Annoyance in urban networks* . Transportation Research Record 1143. pp. 17-21.
8. **Harland D. G.** (1978) *Rural Traffic noise Prediction - an approximation.* Transport and Road Research Laboratory, TRRL-SR 425.
9. **Kanafani, A.** (1983) *The social cost of road transport.* OECD. Paris.
10. **Linkerhagner, W. and H. Amann** (1987) *The general federal railway's construction program - an active contribution to protecting the environment.* Rail International. Oct. PP. 23-27.
11. **Moheler, U.** (1988) *Community response to railway noise: A review of social surveys.* Journal of Sound and Vibration Vol. 120, no. 2, pp. 321-332.
12. **Nelson, P. C. et al** (1989) *Air pollution and noise from road vehicles.* Paris background report for European Conference of the Ministers of Transport.
13. **Nelson, J. P.** (1978) *Economic Analysis of Transportation noise Abatement.* Ballinger Publishing company, Cambridge, Massachusetts.
14. **OECD**, (1990a) *Transport Policy and the environment.* European Conference of Ministers of Transport. OECD, Paris.
15. **OECD** (1988) *Transport and the environment.* Paris

16. **OECD** (1990b) *Environment Monographs no. 32, The social cost of land transport.* Paris.

17. **OECD** (1973) *The effects of traffic and roads on the environment in urban areas.* Paris, OECD, Road Research Group.

18. **OECD** (1986) *Fighting noise: strengthening noise abatement policies.* Paris.

19. **Pearce D**. (1993) *Blueprint 3: measuring sustainable development.* Center for Social and Economic Research on the Global Environment. Earthcan, London.

20. **Pearce, D. W., Barde, J. P. and Lambert, J.** (1984) *Estimating the cost of noise pollution in France.* Ambio, XIII, 27-28.

21. **Peeters A. L. et al** (1983) *Hinder door spooweqqeluid in de woonomgewing.* IMG-TNO report, D60.

22. **Ringheim, J**. (1983) *Semi-economic aspects of reducing the impact of road traffic noise in Norway.*

23. **Sharp. C. and Jennings, T.** (1976) *Transport and the environment.* Leicester University Press.

24. **TEST** (1991) *Wrong side of the tracks? : impacts of road and rail on the environment: a basis for discussion.* London.

25. **Verhoef, E**. (1994) *External effects and social costs of road transport.* Transport Research A, vol. 28A, no. 4, pp. 273-287.

26. **Wicke, L.** (1987) *An environmental damage balance sheet for the FRG. Symposium "the benefits of environmental polices".* Helsinki.

27. **Williams, J. B. et al** (1978) *Road Traffic and the environment.* London Social and Community Planning Research 390.

28. **Walker, J. G.** (1988) *A criterion for the acceptability of railway noise.* Southampton Institute of Sound and Vibration Research. Southampton.

29. **Social Trends** (1994) *Social Trends 24.* Crown Copyright 1994.

30. **Department of Transport** (1993) *Transport Statistics Great Britain.* Report prepared by the Government Statistical Service, HMSO London.

31. **Department of Transport** (1994) *Transport Statistics Great Britain.* Report prepared by the Government Statistical Service, HMSO London.

32. **Fields J. M. and Walker J. H.** (1982) *Comparing the relationships between noise level and annoyance in different surveys.* Journal of Sound and Vibration, vol. 81 no. 1 51-85.

33. **TRRL** (1992) *Environmental appraisal: a review of monetary evaluation and other techniques.* Transport and Road Research Laboratory Contractor Report 290.

34. **Nationwide** (1994) *House prices in 1994*, first quarter for 1994.

35. **Pearce D. W. and Markyanda A.** (1989) *The benefits of environmental policy.* OECD, Paris.

36. **Pearce D. W. and Turner R.** (1990) *Economics of natural resources and the environment.* Harvester Wheatsheaf, Hemel Hempstead.

# Chapter 10

## Externalities (Air Pollution Benefits)

### 10.1 introduction

This chapter is devoted to the third type of non-user benefits of rail investment schemes concerned in the study. This is air pollution. The chapter explains how this type of externality is dealt with in order to identify and estimate the marginal impacts of rail schemes on the air pollution, and then to extract the amount of marginal air pollution benefit that is to be incorporated into the social framework of a rail scheme appraisal.

### 10.2 Why Incorporating Air Pollution?

Air pollution is another clear example of pure pollution, where the user of transport service do abuse the medium - the polluters - while others are relatively passive victims of such abuse - the public. Since, no charge is paid for the air pollution caused by motorists, the action of polluting the air is an externality to road transport.

When a rail scheme attracts some road users off the road, there will be an associated area of benefits equals to the marginal improvement in air quality. The word marginal refers to the measurement of the marginal impact on the air pollution as a result of the rail scheme concerned. This of course considers the air pollution impacts of both rail and road.

It follows, that a policy of incorporating this type of externality into the social assessment of rail investment schemes will help in directing the investment funds towards the most beneficial (on social basis) and more environmentally friendly form of transport, and in turn improves the well-being of individuals and the society at large.

### 10.3 Air Pollution and Rail Investment Appraisal

The current practice of assessing rail investment schemes, as explained in chapter 3, has no formal procedure for evaluating air pollution impacts of railway schemes.

More recently, the introduction of a new legislation on Environmental Impact Assessment (EIA) of rail projects requested that major new rail schemes require an EIA (Nash et al, 1991). A case example is the Manchester Light Rapid Transit. This requirement for EIA for rail schemes follows the same procedures that are laid out in the Manual of Environment Appraisal (MEA) for roads (DTp 1983). Such an assessment considers only the negative impacts of rail schemes on the environment. No considerations are given to comparing the relative air pollution impacts of road and rail, neither does it consider the pollution impacts of users switching from one mode to another.

On a social basis, it is the relative impact of rail vs. road investment that is relevant rather than the negative impacts of rail transport. The air pollution benefits of modal switching at margins have to be incorporated in the appraisal framework so that the investment decision can be based upon and incorporates the relative advantage of both modes.

### 10.4 The Nature of Air Pollution

According to Faiz et al (1990), air pollution may be classified into two categories: primary pollution, which results from the direct emissions into the atmosphere from the polluting source. This includes, Carbon Monoxide (CO), Hydrocarbons (HC), Sulphur Oxides (SOx), Nitrogen Oxides (NOx), particulate matter such as dust and smoke, lead (Pb) compounds, Volatile Organic Compounds (VOCs) and Carbon Dioxide (CO2). Secondary pollution, which results from the creation of new compounds and mixtures from primary pollutants due to the chemical processes that occur in the atmosphere. Acid depositions is a clear example of the secondary pollutants.

Both primary and secondary pollutants have detrimental health impacts. These impacts are function of the concentration of the pollutant and the duration of exposure. The analysis of health impacts associated with air pollution is complex, and then the results vary considerably. According to (TEST 1991)), (cited from The World Health Organisation WHO 1990) millions of people in Europe live in areas with air pollution severe enough to cause thousands of premature deaths and make many more ill each year. In contrast the former UK Department of Health and Social Security considers the health risk from air pollution produced from motor vehicles fairly small (Hickman, 1990).

## 10.5 Air Pollution Impacts

Air pollution impacts may be discussed under two main headings; these are:

1. Impacts on People's Health
2. Impacts on the Natural Environment

### *10.5.1 Health Impacts*

#### 10.5.1.1 Carbon Monoxide (CO)

CO can have detrimental effects on health due to the interference with the absorption of oxygen by red blood cells. This may lead to increased morbidity and adversely affects fertility and there is evidence that it affects people's productivity (Button, 1993). Studies have shown that in North America and Europe, 50% of urban residents are exposed to unacceptable high level of CO (French 1990). Exposure to high concentrations, where the CO haemoglobin compound reaches levels in the blood of 50% may result in death (OECD 1988). Some other studies stated that, at much lower blood levels of 5% and 1.3%, the impact is a reduction in people's reaction speeds and physical performance (TEST 1991).

#### 10.5.1.2 Nitrogen Oxides (NOx)

The exposure to nitrogen dioxide NO2 increase susceptibility to respiratory infections, decrease gaseous exchanges in human blood and affect pulmonary functioning (Walsh 1989; OECD 1988). The exposure to NO2, in the short term, results in respiratory problems in children (OECD 1988). Some recent research has shown that the rise in NOx levels has lead to an increase in hay fever attacks, whose occurrence should had been decreasing due to generally lower pollen levels (TEST 1991 cited from Adams 1990).

#### 10.5.1.3 Sulphur Dioxide (SO2)

Research studies have shown that at high concentrations, SO2 is strong irritant to eyes and can cause cardiovascular problems including bronchitis and others (TEST 1991).

The most serious health effects associated with $SO_2$ are found when exposure occurs in conjunction with elevated levels of particulate. $SO_2$ may be absorbed onto the surface of particulate matter which is then inhaled deep into lungs where sulphuric acid is formed. Holman (1989) stated that both short and long term exposure under these conditions have been associated with increased mortality and morbidity rates.

#### 10.5.1.4 Suspended Particulate Matter

These embrace fine solids or liquid particles found in the air or in emissions such as dust, smoke or smog. The sources include particles stemming from wear and tear of tyres and brakes and matter resulting from engine, and especially diesel engine, combustion. Suspended particulate matter are reported to be a cause of cancer. In addition, a strong correlation has been established between suspended particulate and child mortality and total mortality rates in urban areas (TEST 1991). Another survey from the US has shown that above normal levels of respiratory illnesses among children living in cities with high particulate levels derived from transport vehicles (Dockery et al 1989).

#### 10.5.1.5 Lead (Pb)

Renner (1988), cited by TEST (1991), reported that lead has long been considered as a major threat to human health, especially its harmful effect on intelligence in young children. According to the IUR (1987), over 2 million people in the European Community are reported to suffer from Pb poisoning, and Pb emissions are considered to be a major air pollution problem, especially in densely populated third world cities. A recent study in Mexico City concluded that 7 out of 10 new-born babies have Pb blood levels exceeding the World Health Organisation (WHO) guidelines (French 1990).

## 10.6 Transport Share in Air Pollution

Transport is a source of many harmful gases. Relative to other sectors, transport is considered to be one of the major contributors of the atmospheric pollutants. Table 10.1 presents the share of transport emissions in total emissions for the OECD countries, while table 10.2 shows the case for the UK.

Table 10.1 Share of transport emissions in total emissions (%)

| Pollutant | OECD total | North America | OECD Europe |
|---|---|---|---|
| Nitrogen Oxides (Nox) | 47 | 51 | 48 |
| Carbon Monoxide (CO) | 71 | 81 | 75 |
| Hydrocarbons (HC) | 39 | 45 | 40 |
| Sulphur Oxides (Sox) | 4 | 3 | 3 |
| Particulate | 14 | 8 | 13 |

Source: OECD (1988)

Note: data refers to 1987 or the most recent year available

Table 10.2 Share of Transport Emissions in Total Emissions in the UK in 1992

| Pollutant | All emissions | | Transport | |
|---|---|---|---|---|
| | thousand tonnes | % | thousand tonnes | % |
| Nitrogen Oxides (NOx) | 2750 | 100 | 1670 | 61 |
| Carbon Monoxide (CO) | 6710 | 100 | 6100 | 91 |
| Sulphur Oxides (SOx) | 3100 | 100 | N/A | N/A |
| Particulate | 457 | 100 | 221 | 48 |
| Carbon Dioxide (CO2) | 566600 | 100 | 139400 | 25 |
| Volatile Organic Compounds (VOC) | 2560 | 100 | 1220 | 48 |
| Lead (Pb) | 1.7 | 100 | 1.7 | 100 |

Source: This table is derived from (DTp 1994)

As table 10.1 shows, for most of OECD countries, transport has a significant share in the air pollution emissions and more than 70% of CO emissions are attributable to transport modes. The UK emission data as presented in table 10.2, shows that transport has even greater share in air pollution emissions.

## 10.7 Road and Railways Contribution in Air Pollution Emissions

Table 10.3 demonstrates the contribution of both road and rail in the air pollution emissions.

Table 10.3 Road and rail share in air pollution emissions for 1993 (thousands)

| | All transport | | road | | rail | | other transport | |
|---|---|---|---|---|---|---|---|---|
| | tons | % | tons | % | tons | % | tons | % |
| Nitrogen Oxides (NOx) | 1670 | 100 | 1460 | 87.4 | 50 | 3 | 160 | 9.6 |
| Carbon Monoxide (CO) | 6100 | 100 | 6050 | 99.2 | 10 | 0.14 | 40 | 0.66 |
| Sulphur Oxides (SOx) | N/A | N/A | 62 | 2 | 3 | 0.01 | N/A | N/A |
| Particulate | 221 | 100 | 216 | 98 | 1 | 0.5 | 4 | 1.5 |
| Carbon Dioxide (CO2) | 139400 | 100 | 121200 | 87 | 5800 | 4.1 | 12400 | 8.9 |
| Volatile Organic Compounds (VOC) | 1220 | 100 | 1170 | 96 | 10 | 0.8 | 40 | 3.2 |
| Lead (Pb) | 1.7 | 100 | 1.7 | 100 | 0 | 0 | 0 | 0 |

Source: data in this table are from various sources (DTp 1994, 1993, DOE 1992) )

Having shown that transport modes contribution to air pollution emissions is very significant, table 10.3 shows that most of transport emissions are mainly from road vehicles, while rail and other transport modes share is insignificant compared with road share. Almost all the emissions of lead and CO are from road vehicles and most of particulate emissions are attributable to road.

Rail emissions are very low compared with road. This is partly because of the lower density of railways compared with roads. But the main reason is the polluting characteristics of both modes. This become more clear when comparing the emissions of both modes in terms of emission unit per passenger or tonne km.

Studies that considered the emission efficiencies of road and rail have concluded that road CO2 emissions are 2-7 times higher per km for fright and 1.1 times higher per km for passenger travel. Per passenger km, road transport emits 14 times more CO, 2.4 times more VOC and 1.2 times more NOx than does rail (TEST, 1991).

## 10.8 Polluting Characteristics of Different Vehicles

The following diagram illustrates the emission indicator for different types of vehicles and for different circumstances of operation.

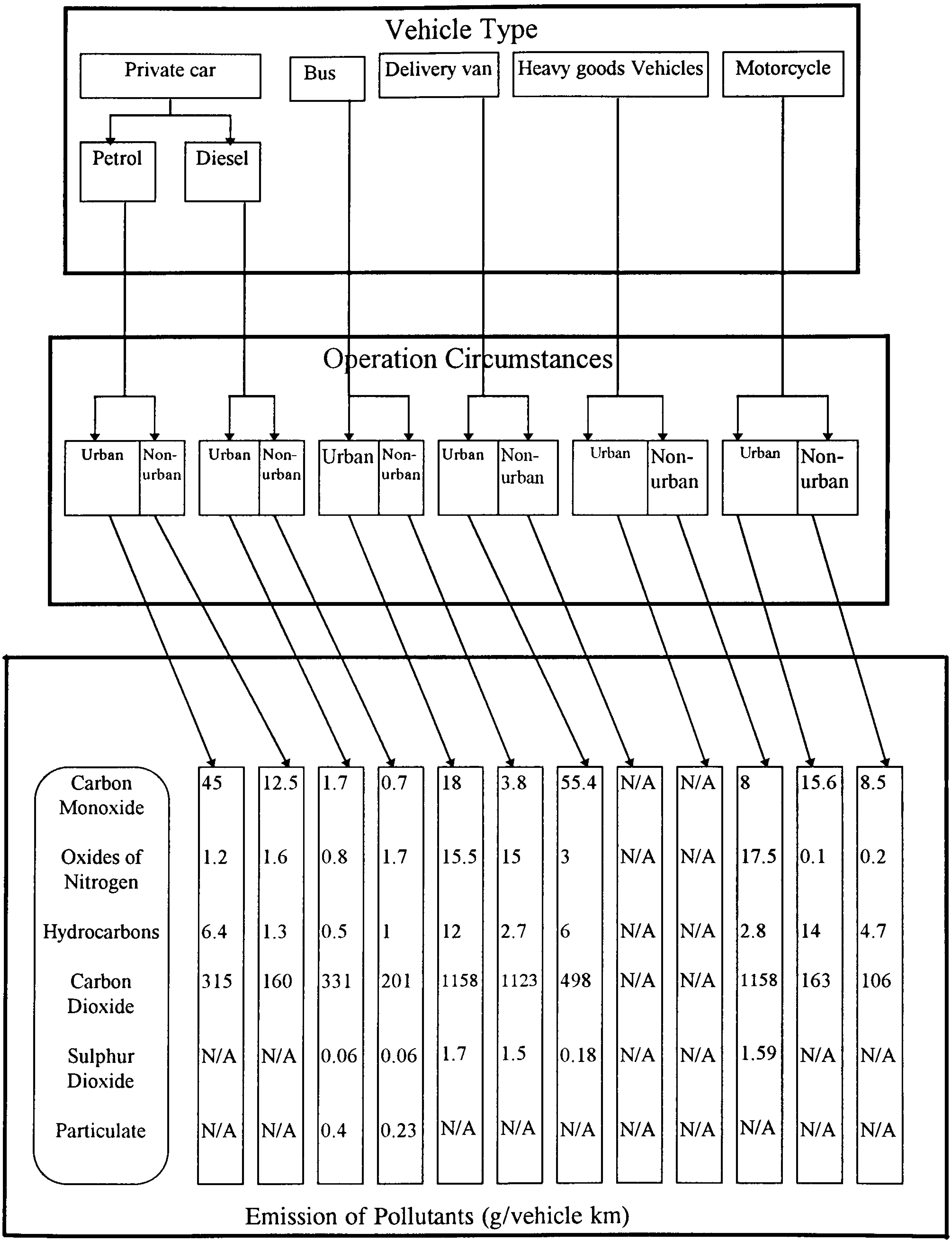



Figure 10.1 Emission Indicators in Road Transport
Source: derived and adapted from Commission of European Communities 1992.

## 10.9 Costing of Air Pollution

### *10.9.1 Introduction*

The costing of air pollution impacts has proved to be a difficult task. This is partly due to the difficulty of isolating the impacts of air pollution from other impacts. The obvious example of this difficulty, is the health impacts of air pollution, though some studies managed to have a rough estimate of air pollution impacts on human health. Other reasons of the difficulty of air pollution costing is related to the poor perception of the extent of air pollution, and its impacts on health in particular restricts the use of some monetary evaluation techniques that may be used to measure people's willingness to pay to reduce air pollution, such as the Hedonic Pricing Technique and the Contingent Valuation Method.

This section outlines the monetary evaluation techniques for air pollution impacts, and review the previous results of costing air pollution of transport modes. After that an explanation of the method used in this study to estimate the air pollution costs for both road and rail is made. This is followed by the results of the estimation.

### *10.9.2 Monetary Valuation Techniques*

In general, the techniques available for deriving private preference monetary values for environmental impacts are (Planning 1992):

1. Indirect methods: these methods mainly used to identify a relationship between the environmental attribute concerned and its impacts. For example, establishing a relationship between the physical or health damage and the level of pollution. The most widespread use of indirect techniques is in obtaining money values of air pollution via dose-response relationships.

2. Direct methods: this method tries to measure the people's willingness to pay for the environmental impacts. The following are the main techniques:

a) Hedonic pricing

b) Travel cost method

c) Contingent valuation method

Each of these techniques has some advantages and disadvantages, and yields different results. Some of the techniques is more relevant for monetising some environmental attributes than the others.

### *10.9.3 Estimating the Social Costs of Air Pollution*

Three main methods may be used to estimate the social costs of air pollution, these are:

1. Quantifying the cost of reducing air pollution. This is by evaluating the costs and expenditure incurred in the car manufacturing and refining industry in order to reduce air pollution emissions. In other words to measure the extra costs of cars (extra equipment to be fitted, impacts on operating costs; especially fuel) and other extra costs incurred for reducing transport emissions.
2. Estimating the cost of the damage caused by air pollution. This is by measuring the damage impacts of air pollution, for example, health damage costs, agriculture damage costs, and the cost of damage to buildings. The most widespread technique used is the dose-response technique. The technique is based on creating a physical damage function relating different levels of air pollution (the dose) to differing levels of damage (the response). Once the physical damage function is identified, the level of air pollution can be fed into it to predict the likely health impacts, for example. Then these can be translated into money values using the value of life estimations. Other impacts upon buildings and materials damage, agriculture losses and forest degradation can be also evaluated the same way.
3. The third method of estimating the social costs of air pollution, is by looking at people's Willingness to Pay (WTP) for reducing air pollution to acceptable levels. The most widespread techniques of identifying the WTP are Hedonic Pricing (HP) and The Contingent Valuation Method (CVM). The poor perception of air pollution impacts may restrict the use of these techniques, or underestimate the social cost of air pollution measured.

It should be noted that in a rational and fully informed economy, the three method of estimating social cost of air pollution should give the same result. In other words, the marginal expenditure for air pollution reduction on the car and refining industries should be equal to the marginal damage cost of air pollution, and should also be equal to the willingness to pay for those who are affected by air pollution. However, it is usually argued (Verhoef 1994) that the marginal expenditure on air pollution reduction (in terms of extra cost of manufacturing transport vehicles) does not reflect the net external cost of air pollution. This is because of the program adapted to reduce vehicle emission is unlikely to reduce the damage cost of air pollution to zero. So Verhoef suggests that in addition to the marginal expenditure on vehicles, there will be an element of air pollution damage cost that has to be included in order to estimate the net external air pollution cost.

### *10.9.4 Recent Empirical Estimates of the External Costs of Road Traffic Air Pollution*

Table 10.4 presents selected estimates of external costs of road traffic air pollution.

Table 10.4 Selected estimates of external costs of road traffic air pollution

| Author | year | country | value | % of GDP | Method |
|---|---|---|---|---|---|
| Shulz | 1987 | FGR | DM 3-6 bln | 0.15-0.30 | 30% of total damage to health, buildings, and forests due to air pollution |
| | | | DM 5-16 bln | 0.25-0.79 | 30 % of total willingness to pay for clean air |
| Perrin | 1984 | EC | $17.5 bln | 0.5 | Cost of complete introduction of catalytic converters |
| Quinet | 1989 | General | | 0.4 | Comparison of studies |
| Kanafani | 1983 | Europe | | 0.16-0.21 | Comparison of studies |
| | | USA | | 0.3 | |
| Bouladon | 1979 | general | | 0.6-1.2 | Vehicle price increase plus unclear extra charge |
| Bleijenberg | 1988 | NL | DFL 1200-1700 | 0.27-0.38 | Prevention at source plus remaining damage |
| V. D. Meijs | 1983 | NL | DFL 100-1200 | 0.03-0.31 | Abatement at source |
| Dietz | 1990 | NL | DFL 619 mln. | 0.14 | Net government costs of abatement of environmental pollution incl. noise; all modes |
| McKinsey | 1986 | NL | DFL 600 mln | 0.14 | Prevention plus damage including noise |
| Dogs | 1991 | FGR | DM 12.1 bln | 0.49 | Roads: damage cost |
| | | | DM 0.2 bln | 0.01 | Rail : damage cost |
| | | | DM 22.3 bln | 0.91 | Roads : WTP |
| | | | DM 0.3 bln | 0.01 | Rail :WTP |
| Grupp | 986 | FGR | DM 4.3-10.3 bln | 0.22-0.53 | Damage cost |

Source: Verhoef (1994)

As can be seen from table 10.4, the external air pollution cost for road traffic ranges between 0.12 and 0.91% of GDP. This wide range is a result of using different methods of the estimation, as well as the way the external costs have been looked at. Some studies looked at the external costs as the expenditure on air pollution prevention at source, while others have considered both the expenditure on prevention and the damage cost together as the external cost of air pollution. One of the studies (Dogs 1991) has looked at the cost of air pollution from railways, and as can be seen the resultant figure for railway cost is much lower than that produced for roads. One reason for that is the differing densities (lengths of road and railways network) for both rail and road. However, the main reason is the difference in polluting characteristics of road and railways.

Pearce et al (1993) has produced an estimate of the cost of air pollution from road transport in the United Kingdom. These estimates are based on the damage cost per unit of pollutants. The results are presented in table 10.5.

Table 10.5 The cost of air pollution from road transport, 1991

| Pollutant | Emissions (thousand tonnes) | Unit value (£/tonne) | Damage costs (£m) |
|---|---|---|---|
| 1. Carbon dioxide (CO2) | 30000 | 13.33 | 400 |
| 2. Methane (CH4) | 10 | 70 | 0.7 |
| 3. Sulphur oxides (SOx) | 58 | 220.69 | 12.8 |
| 4. Nitrogen oxides (NOx) | 1400 | 190 | 266 |
| 5. Carbon monoxide (CO) | 6000 | 10.43 | 62.6 |
| 6. Volatile organic compounds (VOCs) | 970 | N/A | N/A |
| 7. Particulate | 208 | 9778.84 | 2034 |
| 8. Lead (Pb) | 1.8 | N/A | N/A |
| Total | | | 2776 |

Source : Pearce et al (1993)

### 10.9.5 Road Air Pollution Costs

The study method of estimating the costs of air pollution from road transport is based on the damage unit cost produced by Pearce (1993) and shown above. These figures are used to estimate the total damage costs of each emission pollutant for 1993. Then the cost is allocated between the 8 road types identified by the study. Figure 10.2 shows the structure of the cost estimation and allocation process between road types. As can be seen, the allocation method of air pollution costs is based on the polluting characteristics of different vehicles under different circumstances of operation and the flows of traffic for each road type.

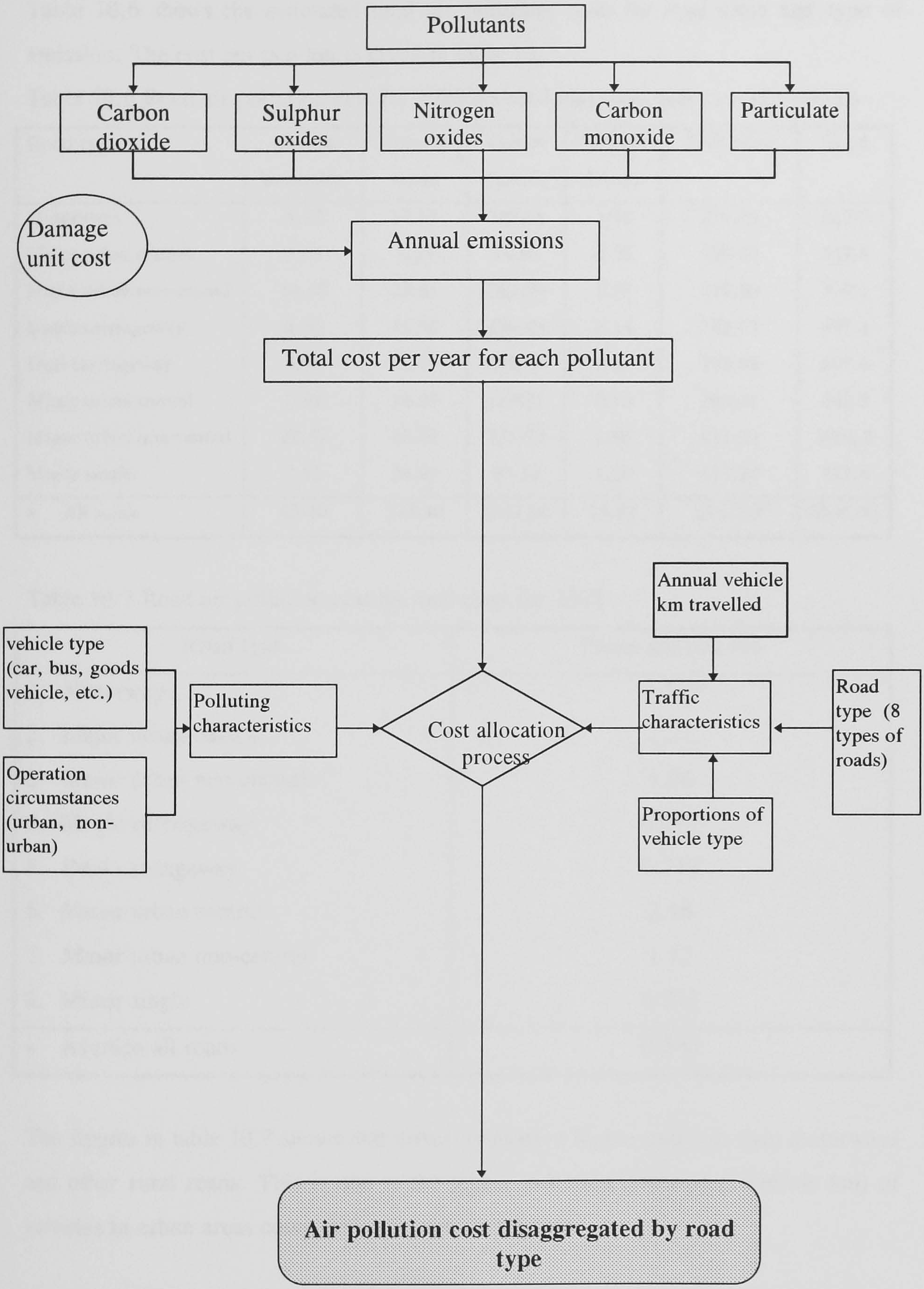



Figure 10.2 Air pollution cost estimates and allocation

Table 10.6 shows the estimated total air pollution costs by road class and type of emission. The cost per pcu km is given in table 10.7.

Table 10.6 Road air pollution cost for 1993 by road class and pollutant (£ million)

| Road type | Carbon monoxide | Nitrogen oxide | Carbon dioxide | Sulphur dioxide | Particulate | Total |
|---|---|---|---|---|---|---|
| Motorways | 5.35 | 57.68 | 228.06 | 3.38 | 216.19 | 510.7 |
| Major urban central | 4.67 | 8.59 | 74.03 | 0.28 | 130.27 | 217.8 |
| Major urban non-central | 14.16 | 38.81 | 263.29 | 1.97 | 390.82 | 709.1 |
| Single carriageway | 5.86 | 45.98 | 196.49 | 2.14 | 242.63 | 493.1 |
| Dual carriageway | 4.98 | 42.21 | 259.34 | 2.45 | 198.52 | 507.4 |
| Minor urban central | 2.98 | 14.07 | 119.71 | 0.45 | 204.11 | 341.3 |
| Minor urban non-central | 22.57 | 46.07 | 373.92 | 1.85 | 612.33 | 1056.8 |
| Minor single | 2.62 | 24.08 | 97.13 | 1.16 | 117.36 | 117.4 |
| • All roads | 63.10 | 277.40 | 1611.96 | 13.68 | 2112.23 | 3836.03 |

Table 10.7 Road air pollution cost by road class for 1993

| Road type | Pence per pcu km |
|---|---|
| 1. Motorways | 0.733 |
| 2. Major urban central | 1.31 |
| 3. Major urban non-central | 1.06 |
| 4. Single carriageway | 0.697 |
| 5. Dual carriageway | 0.718 |
| 6. Minor urban central | 2.16 |
| 7. Minor urban non-central | 1.12 |
| 8. Minor single | 0.513 |
| • Average all roads | 0.866 |

The figures in table 10.7 shows that urban roads have higher unit cost than motorways and other rural roads. This is due to the higher polluting emission (g/vehicle km) of vehicles in urban areas compared with rural conditions.

### *10.9.6 Rail Air Pollution Costs*

Table 10.8 shows the estimated total cost of air pollution from railways. The cost is based on the damage unit cost produced by Pearce and the total emissions from railways.

Table 10.8 Railways air pollution cost for 1993

| Type of pollutant | Total cost (£ millions) |
|---|---|
| 1. Carbon monoxide | 0.10 |
| 2. Oxide of nitrogen | 9.50 |
| 3. Carbon dioxide | 77.14 |
| 4. Particulate | 9.78 |
| 5. Sulphur dioxide | 0.66 |
| Total | 97.00 |

The estimated total cost is distributed between passenger and freight transport according to the total train km travelled for both passenger and freight . In 1993, train km is 348.9 and 39.6 millions for passenger and freight respectively. Accordingly, the allocation of air pollution costs would be 87.1 and 9.9 millions for passenger and fright respectively. Based on the total rail passenger and tonne km in 1993, this gives a cost of 0.27 and 0.063 pence per passenger and tonne km respectively.

## 10.10 Chapter Summary

The chapter is concerned with the air pollution benefits of rail schemes. It starts by discussing why to incorporate air pollution in the assessment of rail schemes and the extent to which air pollution is incorporated in the current practice of rail investment appraisal. Then the nature and health impacts of air pollution are outlined, followed by an outline of the contribution of transport modes in air pollution emissions. The comparison between road and rail shares of air pollution shows that road transport emissions are much higher compared with rail.

The chapter then demonstrates the pollution characteristics of road vehicles. For most of the pollutants, road vehicles' emissions per km are much higher in urban areas compared with non-urban areas. This is followed by identifying the monetary valuation techniques of air pollution costs, which is either indirectly by establishing a relationship between air pollution level and its impacts, or directly by measuring people's willingness to pay for reducing air pollution impacts and the recent empirical estimates of the external costs of road traffic air pollution are reviewed.

After that the study method of estimating air pollution costs for both road and rail is detailed. The cost estimates are based on the air pollution unit damage cost produced by Pearce (1993). The results are disaggregated by the 8 road types identified by the study. Urban roads have higher unit cost compared with rural roads, and this is explained by the differing pollution characteristics of vehicles. Rail costs are disaggregated by freight and passenger. The total estimated cost of road air pollution is more than 38 times as much as that for railways.

**References**


1. **Adams, M.** (1990) *Capital Killer : Air Pollution from Road Vehicles.* London, London Boroughs Association Research Report.
2. **Button, K.** (1993) *Transport Economics.* 2nd Edition. Edward Elgar. England
3. **Department of Transport DTp** (1994) *Transport Statistics Great Britain.* Government Statistical Office, HMSO, London.
4. **Department of Transport DTp** (1993) *Transport Statistics Great Britain.* Government Statistical Office, HMSO, London.
5. **Dockery D. W. et al** (1989) *Effects of Inhalable Particles on Respiratory Health and Disease.* American Review of Respiratory Diseases. Vol. 139 pp. 587-594.
6. **Faiz A. et al** (1990) *Automotive Air Pollution : Issues and Options for developing Countries.* World Bank Working Paper WPS 492, August 1990.
7. **French H. F.** (1990) *Clearing the Air : A Global Agenda.* Worldwatch paper 94. Washington D C Worldwatch Institute.
8. **Hickman A. J.** (1990) *Personal Communication.* Transport and Road Research Laboratory, Vehicles and Environment Division.
9. **Holman C.** (1989) *Air Pollution and Health.* Friends of the Earth, London.
10. **International Union of Railways IUR** (1987) *Railways and the Environment.* Brussels IUR.
11. **OECD** (1988) *Transport and the Environment.* Paris OECD.

12. **Pearce D. et al** (1993) *Blueprint 3: Measuring sustainable development.* Earthcan, London.

13. **Planning R.** (1992) *Environmental Appraisal: A review of monetary evaluation and other techniques.* Transport and Road Research Laboratory, Contractor Report 290.

14. **Renner M.** (1988) *Rethinking the Role of Automobile.* Washington D. C., Worldwatch Institute.

15. **Verhoef E.** (1994) *External Effects and Social Costs of Road Transport.* Transportation Research, Vol. 28A, No. 4, pp. 273-287.

16. **Walsh M.** (1989) *The Global Importance of Motor Vehicles in the Climate Modification Problem.* International Environmental Reporter, pp. 261-275.

17. **World Health Organisation** (1990) *Impact on Human Health of Air Pollution in Europe, Geneva.* Submitted to the Economic Commission for Europe Executive Body for the Convention on Long-range Transport Air Pollution.

18. **Nash C. et al** (1991) *The future of railways and roads.* Institute of Public Policy Research. London.

19. **Department of Transport** (1983) *Manual of Environmental Appraisal.* HMSO, London.

20. **Department of the Environment** (1992) *The UK environment.* HMSO, London.

21. **Commission of the European Communities** (1992) *The impacts of transport on the environment-A community strategy for sustainable mobility.*

22. **TEST** (1991) *Wrong side of the tracks? environmental impacts of road and rail: basis for discussion.* London.

# Chapter 11

## Cost Misperception (Vehicle Operating Costs)

### 11.1 Introduction

This chapter is devoted to the fourth item of non-user benefits of rail investment schemes concerned by the study. This is vehicle operating costs (VOC) of road use.

As shown in chapter 6, VOC of road use is considered by the study to be a case of cost misperception. It follows that, the benefits of a rail scheme with respect to road vehicle operating costs, is only a correction to be made in order to incorporate the misperceived part of vehicle operating costs by motorists. The amount of correction depends, as will be seen in this chapter, on the extent to which road motorists do misperceive VOC, and the existence and magnitude of any price distortions such as taxes and subsidies attached with road vehicle operating cost elements.

The chapter illustrates why the VOC of using roads needs to be incorporated in the appraisal framework of rail investment schemes, and how the incorporation process is made. The chapter also presents the results of the estimation process of vehicle operating cost misperception that are measured for the UK road network and need to be incorporated and corrected for in assessing the benefits of rail investment schemes in the UK. The results are disaggregated by vehicle and road types. The breakdown of roads is the same as for other non-user benefits explained in the previous chapters.

### 11.2 Perception of Road Vehicle Operating Costs

The problem of cost misperception is a common one in transport studies. The reasons behind the misperception, as mentioned in chapter 6, vary from one cost item to another. In the case of vehicle operating costs, the reasons include:

1. The cost item does not vary with the use of the vehicle, such as insurance and licence costs.
2. The costs may be so small and then it does not affect the decision of making a trip.
3. The existence of a tax or subsidy element in vehicle operating costs.

Whatever the reasons behind the failure of a full perception of marginal social VOC, the result is that vehicle operating cost of making a trip on the road will have two values, these are:

1. Value to the motorist, this is the costs that the motorist perceives or considers in his decision of making a road trip and is called perceived or behavioural cost.
2. Value to the society, this is the real cost of the trip that the society scarifies as a result of a road trip. This include all the costs involved in a road trip regardless of who bears the cost and is called marginal social or resource cost.

Resource and behavioural cost of a road trip will be different as far as the motorists do misperceive some of their vehicle operating costs.

Another reason of the divergence between resource and behavioural cost of making a trip on the road is the existence of taxes or subsidies on some of the cost items, such as fuel tax. For a motorist, the tax element is perceived as part of fuel price, and then is considered in his decision of making a road trip. For the society, the tax element is only a transfer payments, and does not reflect a true cost to the society. Then the resource cost of a trip will not include any tax payments.

### 11.3 Why Incorporate Vehicle Operating Cost Misperception?

When assessing investment schemes on a social basis, the target is to identify the costs sacrificed and benefits gained from the society viewpoint. That means costs and benefits that does not reflect a real costs and benefits to the society are not included. It follows, that costs and benefits have to be valued on the basis of their real resource values to the society.

In the context of rail investment schemes, the issue of road vehicle operating costs can be looked at as follows:

1. The existence of a divergence between resource and behavioural vehicle operating costs because road motorists do fail to perceive the full vehicle operating costs of their trips. In this case a rail investment scheme that attracts some road users to use railways instead will result in some benefits to the society equal to the difference between the resource and behavioural vehicle operating costs for those who shift to use railways (Movers). Put differently, a road motorist used to make a trip on the road that costs him £4 in total. But because of misperception of the cost on roads,

the real cost to the society of that trip was £5. After improving railways, the motorist decided to use railways in his travel. That means a savings to the society of £1, which is the extra cost previously (before the railway scheme) imposed on the society and not considered by the trip maker. For more illustration, figure 11.1 (a) presents the case of misperception graphically. As can be seen, $VOC_R$ and $VOC_P$ represent resource and perceived road vehicle operating costs. D1 and D2 are road travel demand curves before and after the rail scheme. Q1Q2 is the number of road trips moved to use rail as a result of the scheme. As a result, an area of benefits emerges equal to ABCD. This is the amount of unperceived VOC by those who moved to rail. In other words, the area ABCD reflects the resource cost released or saved as a result of rail scheme.

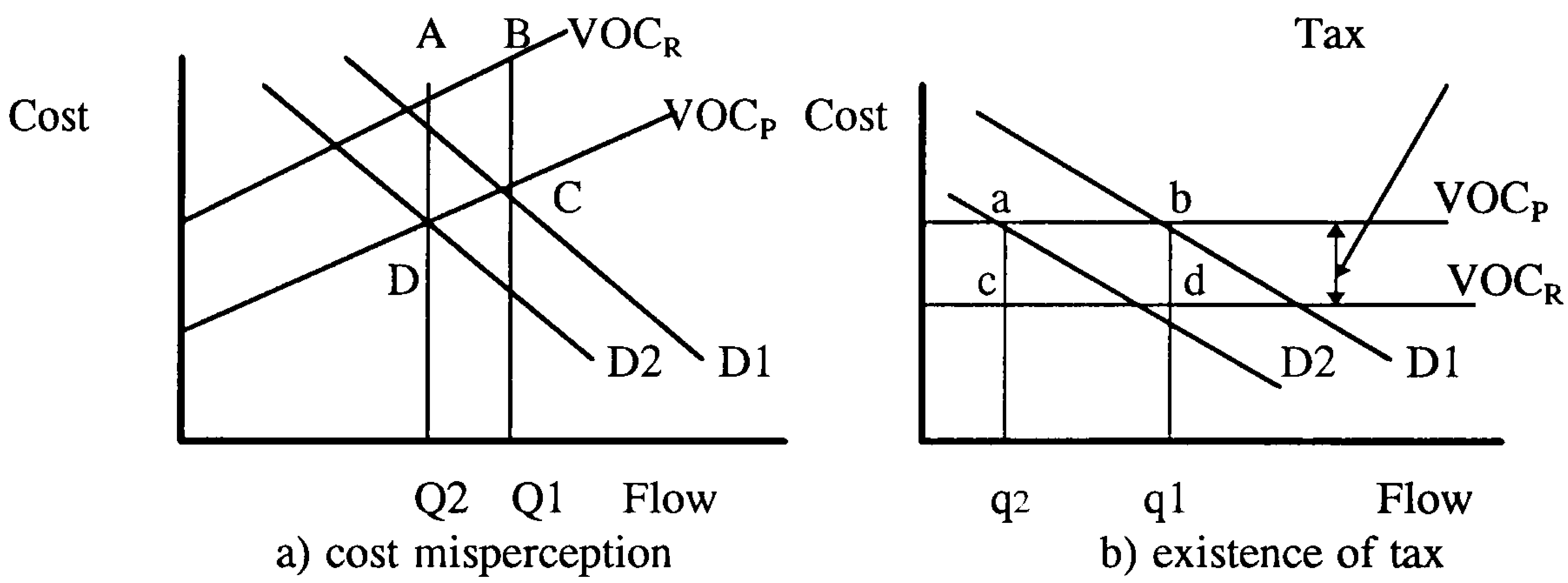



Figure 11.1 Vehicle operating cost misperception

2. An existence of a divergence between resource and behavioural road vehicle operating cost due to an element of tax or subsidy is incorporated in the vehicle operating cost components. A case example of this is the fuel tax and any form of subsidy to public transport users such as fare being lower than the real cost of journeys. In this case when a rail investment scheme is assessed on a social basis, an element of correction has to be made for such difference between resource and behavioural costs of the road journeys that now transferred to railways, and previously made on the road. Figure 11.1 (b) shows the existence of tax on road VOC. This means that the perceived value of VOC ($VOC_P$) is above the resource value ($VOC_R$). When rail scheme lead to shifting the number of trips q1q2 from road

to rail, an amount of tax revenue equal to the area abcd is lost. This amount does not reflect a real resources but rather a transfer payments. So when assessing rail scheme on a social basis, this amount of tax is to be corrected for.

## 11.4 Determinants of Vehicle Operating Costs

The Department of Transport, in planning road construction and maintenance, identifies vehicle operating costs as a function of distance and average speed of travel. The costs involved consist of fuel, oil, tyres, maintenance and depreciation. The depreciation in value of private motor cars is not included. The general formula used is as follows (DTp, 1981):

$$VOC = a + \frac{b}{S} + cS^2 \qquad (11.1)$$

Where:

VOC = vehicle operating cost per kilometre (pence per vehicle km).

a, b, c = are constants.

S = average speed (km/h).

The values of the constants a, b, and c are functions of vehicle type and the cost item. In other words, separate values are calculated for cars, light goods vehicles (under 30 cwt unladen), heavy goods vehicles and buses. In addition, separate values are calculated for fuel and non-fuel operating costs (DTp, 1981).

The manual of the Cost Benefit Analysis program (COBA) identifies the values of those constants for different vehicle and cost categories. Separate values are identified for perceived and resource vehicle operating costs. The values for perceived and resource costs are based on the following assumptions:

1. for non-working cars only fuel costs of VOC are perceived and;
2. for other vehicles the full costs of operation are assumed to be perceived.

In addition, the values takes account of fuel tax, which is perceived for all vehicle categories but does not reflect a real resource costs.

## 11.5 Methodology of Estimating Vehicle Operating Cost Misperception

### *11.5.1 Introduction*

The study objective with respect to vehicle operating cost misperception, is to identify the difference between the perceived and resource costs and then the amount to be incorporated in rail appraisal schemes to correct for road vehicle operating cost misperception. For the consistency with other non-user benefits estimated in this study, this correction is disaggregated by the same road type breakdown.

This section explains the method used to estimate vehicle operating cost misperception for the UK road network.

### *11.5.2 Methodology Framework and the Steps of the Process*

Figure 11.3 demonstrates the framework of the methodology used and the following sections explain the steps of the process.

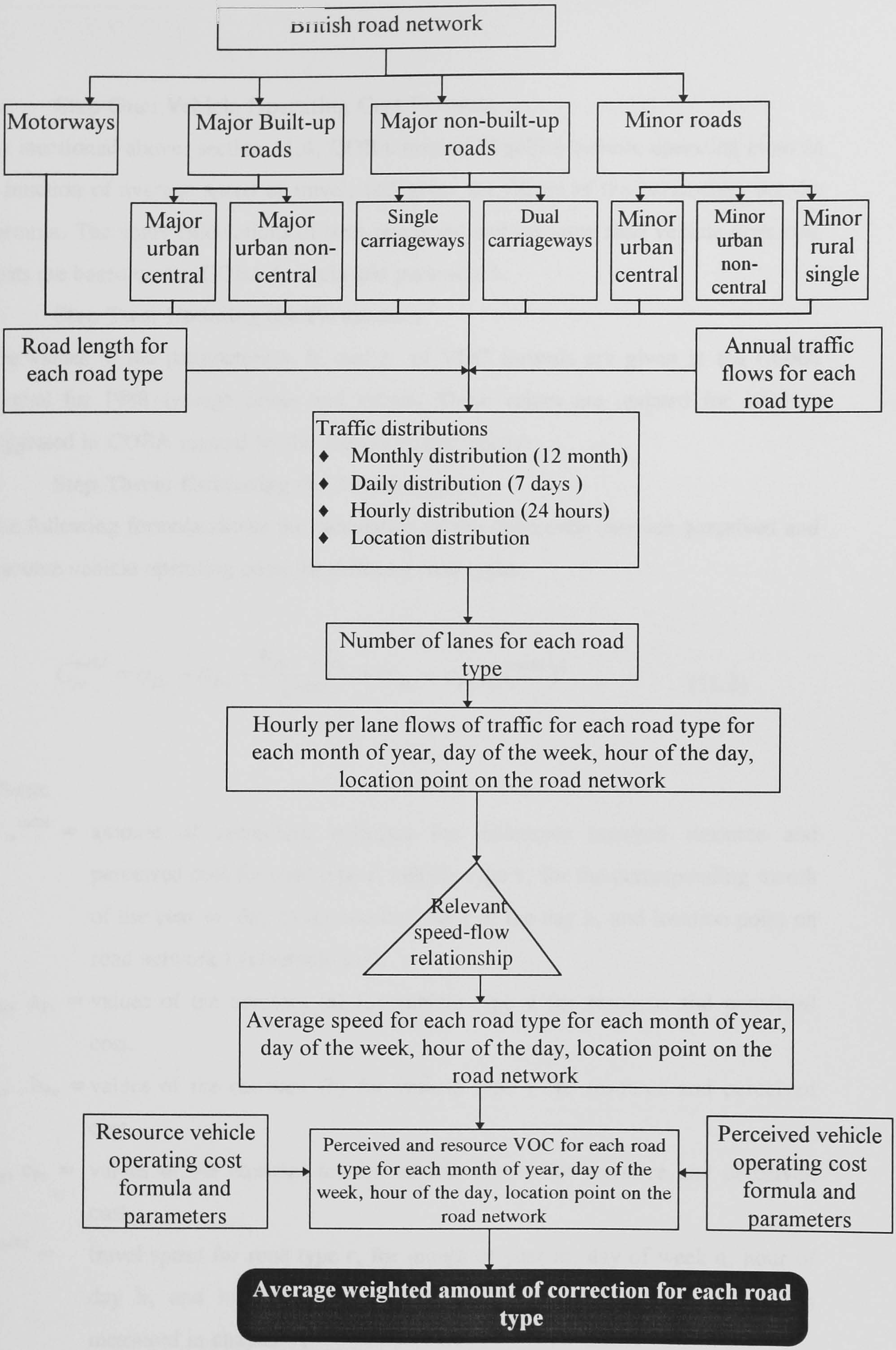



Figure 11.2 Methodology framework of estimating vehicle operating cost misperception for the UK road network

1. **Step One: Vehicle Operating Cost Formula**

As mentioned above, section 11.4, COBA manual identifies vehicle operating costs as a function of average speed of travel, and gives the values of the parameters for the formula. The study calculations of both perceived and resource road vehicle operating costs are based on the COBA formula and parameters.

2 **Step Two: Updating the Parameters**

The values of the parameters a, b, and c of VOC formula are given in the COBA manual for 1988 average prices and values. These values are updated for 1993 as suggested in COBA manual by the growth in fuel prices.

3. **Step Three: Estimating the Misperception**

The following formula shows the calculation of the difference between perceived and resource vehicle operating costs for different road types:

$$C_{rv}^{mdhl} = a_{Rv} - a_{Pv} + \frac{b_{Rv} - b_{Pv}}{S_r^{mdhl}} + (c_{Rv} - c_{Pv})(S_r^{mdhl})^2 \qquad (11.2)$$

Where:

$C_{rv}^{mdhl}$ = amount of correction indicates the difference between resource and perceived cost for road type r, vehicle type v, for the corresponding month of the year m, day of the week d, hour of the day h, and location point on road network l (£/vehicle km).

$a_{Rv}$, $a_{Pv}$ = values of the constant (a) for vehicle type v for resource and perceived cost.

$b_{Rv}$ , $b_{Pv}$ = values of the constant (b) for vehicle type v for resource and perceived cost.

$c_{Rv}$, $c_{Pv}$ = values of the constant (c) for vehicle type v for resource and perceived cost.

$S_r^{mdhl}$ = travel speed for road type r, for month of year m, day of week d, hour of day h, and location point on the road network l (km/h) and that is measured in chapter 7.

It should be noted that the value of travel speed that used for measuring vehicle operating costs is measured on the same basis and assumptions that used for measuring the marginal congestion cost externality and that explained in detail in chapter 7. In other words, vehicle operating costs estimates incorporate the distributions of traffic flows for different types of roads. It is worth mentioning that, according to COBA, the values of a, b, c for cars and light goods vehicles (for fuel element only) are 15% lower on motorways compared with other roads. This has been incorporated in the calculation process that is carried out by a BASIC computer program as shown in appendix 1.

**4. Step Four: Average Weighted Correction.**

For each road and vehicle type, the intention is to produce a value for the amount of correction for road vehicle operating costs, that reflects and incorporates the variations in traffic (seasonally throughout the year, daily throughout the week, hourly throughout the day , and the location distribution on the road network) and incorporates road type and characteristics. This is undertaken by measuring the average weighted value of the difference between resource and perceived vehicle operating costs. This is calculated as follows:

$$C_{rv} = \frac{\sum_{m=1}^{12}\sum_{d=1}^{7}\sum_{h=1}^{24}\sum_{l=1}^{l} C_{rv}^{mdhl} \times q_r^{mdhl} \times S_r^{mdhl}}{\sum_{m=1}^{12}\sum_{d=1}^{7}\sum_{h=1}^{24}\sum_{l=1}^{l} q_r^{mdhl} \times S_r^{mdhl}} \qquad (11.3)$$

Where:

$q_r^{mdhl}$ = hourly per lane traffic flow for road type r, for month of year m, day of week d, hour of day h, and location point l (pcu/h/lane).

$C_{rv}$ = average weighted amount of correction indicates the difference between resource and perceived cost for road type r, vehicle type v (£/vehicle km).

**5. Step 5: Depreciation Cost of Private Cars**

As mentioned above, COBA formula for resource and behavioural vehicle operating costs does not include the cost of depreciation of private cars. This is a resource cost, and need also to be incorporated in the appraisal framework of rail investment schemes.

Automobile Association (AA 1994) gives the figures for standing and running costs for private cars for different engine capacities. Depreciation cost is given per annum for each engine size capacity assuming 10000 miles a year. These figures with the number of cars for each engine size for 1993 as supplied in the Department of Transport Statistics (DTp, 1993) are used to estimate depreciation per km for each engine size. An average weighted depreciation for all cars is produced, which is considered to be a resource cost and to be added to the difference between resource and perceived costs estimated in the previous step to give total amount of correction to be made for private cars.

## 11.6 Results

### *11.6.1 Amount of Correction by Vehicle Type and Road Class*

Table 11.1 shows the amount of VOC correction disaggregated by vehicle and road type.

Table 11.1 Resource minus perceived VOC by vehicle and road type for 1993 (p/vehicle km)

| | Vehicle Type | | | |
|---|---|---|---|---|
| Road Type | Car | Light goods vehicle | Heavy goods vehicle | Buses and Coaches |
| 1. Motorway | 2.91 | -2.29 | -6.80 | -7.55 |
| 2. Major urban central | 2.22 | -3.01 | -6.36 | -7.83 |
| 3. Major urban non-central | 2.65 | -2.41 | -5.75 | -6.91 |
| 4. Single carriageway | 2.68 | -2.39 | -6.00 | -6.94 |
| 5. Dual carriageway | 2.50 | -2.65 | -6.73 | -7.47 |
| 6. Minor urban central | 2.44 | -2.70 | -5.99 | -7.34 |
| 7. Minor urban non-central | 2.68 | -2.37 | -5.71 | -6.84 |
| 8. Minor rural single | 2.65 | -2.43 | -6.16 | -7.04 |
| • Average all roads | 2.66 | -2.45 | -6.36 | -7.12 |

As can be seen, for cars the value of the difference between resource and perceived VOC is positive. This reflects the amount of non-fuel VOC that is not perceived by car users for non-working trips. For other types of vehicles, the difference is negative reflecting the amount of fuel tax.

### *11.6.2 Amount of Correction by Personal Car Unit*

For the consistency of other non-user benefits measured in the previous chapters, the figures in table 11.1 are used to estimate the amount of VOC correction per personal car unit km (pcu km) based on the proportions of vehicle types for each road class. The results are shown in the following table.

Table 11.2 Amount of VOC correction by road class for 1993

| Road Type | pence/pcu km |
|---|---|
| 1. Motorway | 1.05 |
| 2. Major urban central | 1.43 |
| 3. Major urban non-central | 1.49 |
| 4. Single carriageway | 1.45 |
| 5. Dual carriageway | 1.06 |
| 6. Minor urban central | 1.61 |
| 7. Minor urban non-central | 1.79 |
| 8. Minor rural single | 1.63 |
| • Average all roads | 1.43 |

### *11.6.3 Depreciation of Private Cars by Road Class*

As mentioned before, the depreciation of private cars is estimated based on the annual depreciation for each engine size. This gives a 10.23 pence per car km. This figure is used along with the number of car km and personal car unit for each road type to estimate the amount of depreciation per personal car unit km (pcu km). The results are shown in table 11.3.

Table 11.3 Depreciation cost by road class for 1993

| Road Type | Pence/pcu km |
|---|---|
| 1. Motorway | 7.88 |
| 2. Major urban central | 8.69 |
| 3. Major urban non-central | 8.18 |
| 4. Single carriageway | 8.28 |
| 5. Dual carriageway | 8.18 |
| 6. Minor urban central | 8.80 |
| 7. Minor urban non-central | 8.59 |
| 8. Minor rural single | 8.49 |
| • Average all roads | 8.31 |

## 11.7 Chapter Summary

The chapter is concerned with the incorporation of VOC misperception in the social appraisal of rail schemes. It shows that when assessing rail schemes on a social basis, a correction is to be made for the misperceived part of road VOC. The methodology of measuring the amount of correction is based on the use of VOC formula that is used by the Department of Transport in assessing road scheme benefits. The methodology incorporates the variations in traffic over time and place. For all road types, an average correction of 1.43 pence per pcu km is estimated. In addition to that, an average correction of 8.31 pence per pcu km is estimated for the depreciation of private cars.

## References


1. **AA, The Automobile Association** (1994) *Motoring Costs 1994: A general guide to the costs of owning and running a car.* Basingstoke, Hampshire.
2. **Department of Transport DTp** (1981) *COBA 9.* HMSO, London.
3. **Department of Transport DTp** (1993) *Transport Statistics Great Britain.* A Publication of the Government Statistical Service. HMSO, London.

# Chapter 12

## Cost Misperception (Accidents)

### 12.1 Introduction

This chapter is devoted to the last item of rail investment non-user benefits concerned by the study. This is the safety benefits of rail schemes.

The chapter, demonstrates in section 12.2, that road accidents do not reflect any external effects, and then unlike congestion and pollution effects, when considering rail investment non-user benefits, road accident externality can be safely ignored. However, section 12.3, shows how accident costs present a case of cost misperception, and then this misperception has to be corrected for and incorporated in a social framework of rail scheme appraisal.

The chapter then explains the method used to derive the resource and perceived accident costs for road and rail. This includes the types of accident costs that considered by the study to be unperceived for both road and rail, and the valuation of accident costs. For the consistency with other non-user benefits considered in the previous chapters, the results of road accident costs are disaggergated by the same 8 road types identified by the study.

### 12.2 Accident Costs and Justifying the Investment in Road and Rail

#### *12.2.1 Magnitude of Road and Rail Accident Risk and Costs*

From their nature, road and railways have different implications for safety of humans. This is due to the very different characteristics of both modes in terms of the control of the vehicle, interaction between vehicles, and the number of travellers on board. Despite the fall in fatal accidents on Britain's roads, according to TEST (1991), the risk of being killed on the road is over five times that for rail per passenger kilometre. The chance of being injured on the road is seven times as high as railways.

The Department of Transport estimated the financial cost of road accidents to be £5.5 billion in 1988 . On the basis of unit costs, death and injury costs for road are £4.9

and £2 per billion passenger kilometre, respectively, while for rail they are £0.5 and £0.2 respectively (TEST, 1991)

However, the direct comparison between road and rail on the basis of total accident costs may under or overestimate the true resource costs. This is for reasons, such as: first, the underreporting of accidents which is probably associated with road accidents, that makes rail accident statistics more accurate than road. Second the definition of accident for both modes might differ slightly, especially the definition of the level of injury to passengers. For example, in the UK a road death is defined as one reported within 30 days of the accident, but for rail the death has to occur before publication of the British Rail end of year accident report. The third reason is the time loss cost. If accident costs are to be compared, the difference in travel time should to be included.

### *12.2.2 Justifying Road and Rail Investment*

Road investment decisions, being based on the Cost Benefit Analysis (COBA) incorporates the estimated savings in road accident costs from the schemes. Bearing in mind the higher accident risk of roads than that for railways, the inclusion of accident cost savings in road investment decision is therefore an advantage towards and in favour of the justification of road investment. On the other hand, rail investment schemes are assessed on a financial basis. Financial appraisal only considers the financial impacts of the scheme on the British Rail, hence accident cost savings are not incorporated. This might be seen as a disadvantage against rail investment justification. Neither COBA for roads nor the commercial appraisal for rail incorporate the implications of mode switching on the accident costs of road and rail.

The fact that road accident magnitude is higher than that for rail, raise the issue of the potential rail investment opportunities that would be justified if the effects of rail schemes on road accidents were to be incorporated in the rail investment scheme appraisals, and that otherwise, are not justified because rail schemes are being assessed on a commercial basis. This commercial appraisal practice of rail schemes does not allow for wider impacts of schemes, such as scheme implications on road accidents, to be incorporated. The higher the values placed on human lives, damage and police and administration accident costs, the higher the missing opportunities for rail investment schemes, due to the current rail appraisal practice.

As mentioned above, the CBA practice used for justifying road projects does not allow any effects of the road schemes on rail accidents. However, realising that rail accidents are of much lower magnitude than roads, this defect may not be very significant and may bring much less bias than its counterpart defect that is associated with rail scheme appraisal practice, that does not incorporate the scheme implications on road accidents.

## 12.3 Road Accident External Effects

Some activities are sources of external effects of the road system. As has been shown in the previous chapters, congestion and pollution costs are the most obvious examples and widely studied. Road accidents may also, even if of less magnitude, engender negative or positive external effects which, if not properly priced or otherwise internalised, can lead to resource misallocation. This section discusses the relationship between road accidents and the volume of traffic and whether road accident are an external effect or not.

### *12.3.1 Road Accidents and the Volume of Traffic*

The key element in determining road accident external effects is the relationship between number of accidents and the flow of traffic. As in the case of road congestion, developed in chapter 7, the source of the external effect is the difference between the marginal and the average cost of an accident. If the number of accidents rise more than proportionately with the volume of traffic, then the marginal and average rate of accidents are not equal, (the marginal is above the average). It follows that, an extra vehicle journey increases the accident rate of other road users, causing an external effect.

The issue of marginal and average rate of accidents has long been debated. The existing empirical evidence about the relationship between accidents and traffic flow is sparse. Vickrey (1969) used 1960-62 data for California freeways to investigate the relationship between average and marginal accident rates. He concluded that the ratio of marginal to average accident rate is 1.5. Vickrey results suggests a significant negative externality exists. Bailey (1970) criticised Vickrey (1969) for failing to allow for the existence of a positive externality to road accidents. Bailey suggests that the number of accidents might grow less than proportionally with the flow of traffic.

The 1982 Highway Cost Allocation Study ignored the issue of the relationship between accidents and traffic volume. This is on the grounds that no clear relationship between traffic and accidents are found (Vitaliano and Held 1991).

According to Newbery (1988), the UK Department of Transport in its planning manuals, assumes that the relationship between accidents and traffic volume is proportional. He stated that this is analogous to the position of the US Federal Highway Administration of assuming a zero external effect. In estimating optimal road user charges for Great Britain, Newbery (1988) used a marginal to average accident rate ratio of 1.25. This figure is a compromise between Vickrey's figure of 1.5 and the official figure assumed by the Department of Transport of 1.

In considering the external road accident costs, Pearce (1993) concluded that evidence regarding whether there exists a link between the accident rate per PCU kilometre and traffic flow is ambiguous.

The evidence analysed here offers little support for the notion that an important road accident externality exists and then supports the view of no significant external effects of road accidents exists.

This view of no significant externality regarding accidents is supported by the findings of Vitaliano and Held (1991). They estimated the relationship between the number of accidents and traffic volume. Their analysis were based on a random sample of 399 road segments covering urban and rural roads in New York State (USA) in 1985. No significant externality was detected by their research. They concluded that on very high volume of traffic on urban roads, the marginal to average accident rate ratio is 1.06. On all other types of roads, a ratio of 0.98 was found. These findings contrast sharply with those of Vickrey, who estimated a ratio of 1.5 for California freeways in 1962. The conclusions of the research are, however, consistent with the official view of both the UK Department of Transport and the US highway authority that no significant accident externality exists.

Based on the results of the empirical research discussed above, it is probably safe to assume that the average and marginal accident rate are approximately equal, and then the external effects of accidents are very insignificant. It follows that for those who are concerned with assessing non-user benefits of rail investment schemes, considering road accidents as a source of external effects of road transport and then a source of external benefits to the rail scheme is not relevant.

However, this conclusion should not negate the fact that rail investment schemes do imply some road accident benefits. The accident benefits associated with rail investment schemes will be generated as a result of the fact that accident costs are not fully perceived by trip makers, and then there is some costs borne by the society. Put differently, the accident benefits of rail schemes will be in this case on the basis and a result of the misperception of the risks involved.

## 12.4 Road Accident Cost Misperception

### *12.4.1 Costs of Accidents*

A road accident will incur some or all of the following consequences:

1. Peoples killed, this include vehicle users and pedestrians
2. People seriously injured, vehicle users or pedestrians
3. People slightly injured, again this includes users or pedestrians
4. Damage to vehicles involved in the accident
5. Damage to buildings, or any other property damage.
6. Policing and administration work
7. Medical treatment work to those injured
8. Pain, suffering and grief for the relatives of the accident victims

These are the direct consequences of an accident. There will be some other indirect impacts such as clearing the road after an accident.

Both the direct and indirect consequences of an accident imply costs to individuals and the society at large. The term social accident costs is sometimes used to indicate the total costs of accidents. Quinet has estimated the social costs of road accidents in the UK to be 1.5 percent of GDP in 1986.

### *12.4.2 Who Bears the Accident Costs*

The crucial question to be asked is who bears the costs of accidents. Put differently, does the road user consider all these types of costs in his decision to make a trip on the road. And if not how much of the costs is considered in his decision. In fact, if the answer was that road users, in their decision of making a trip on the road, do consider all the implied costs of a potential road accident, that will mean resource and perceived accident cost are the same, and no consideration needed to be taken to account for road accident benefits when assessing rail projects on a social basis. However, this might not be the case.

A road user may be very much concerned about himself being injured or killed in an accident, but he might not be bothered by the implied policing and administration costs of the accident.

Another road user may not be fully aware of the real accident rate on the road, and hence he may underestimate the potential risk of being involved in an accident.

It follows that, misperceiving the accident risk and costs involved by road users is not irrelevant in this case. Before proceeding to investigate which of the accident costs are perceived by users and which is not, an illustration of why and how the misperception of road accident costs is relevant and need to be corrected for in the social appraisal framework of rail schemes.

### *12.4.3 Why Incorporate Road Accident Misperception in the Appraisal Framework of Rail Schemes?*

Regardless of the reasons, when road users misperceive the true accident risk and then the true accident costs, their decisions of using roads are based on a false risk and cost indicators. Their behaviour regarding travel on roads will be based on what they believe to be the accident risk or the accident costs. This situation results in a number of trips made on the road more or less than the optimal number of trips that would have happen if users had perceived the true risk rate or the true costs involved in road accident. Consequently, in addition to the costs borne by the users of roads, there will be an additional accident costs borne by the society equals to that amount of accident costs which (for some reasons) users fail to consider or to take account of when making a decision of a road trip.

It follows that, when a rail investment scheme attracts some road users, the society at large will benefit. The benefit comes from the savings of accident costs that road users (movers to rail) would otherwise have imposed on the society as a result of their misperception of the true road accident costs. Put differently, the transfer of some road users to rail will result in some resource costs saved, and that is to be considered as a social benefit to the rail investment project in question.

### *12.4.4 How to Incorporate the Misperception?*

The process of incorporation of road accident cost misperception into the assessment framework of rail schemes requires knowledge of the amount of the costs that are not perceived or considered by road users. Discussing and investigating the perceived and unperceived road accident costs is shown in details in the following sections. In this section, with the help of figure 12.1, an illustration is made to show how this misperception of accident costs distorts the travel behaviour and then creates extra costs to the society. Then how a rail project may result in savings in the accident costs.

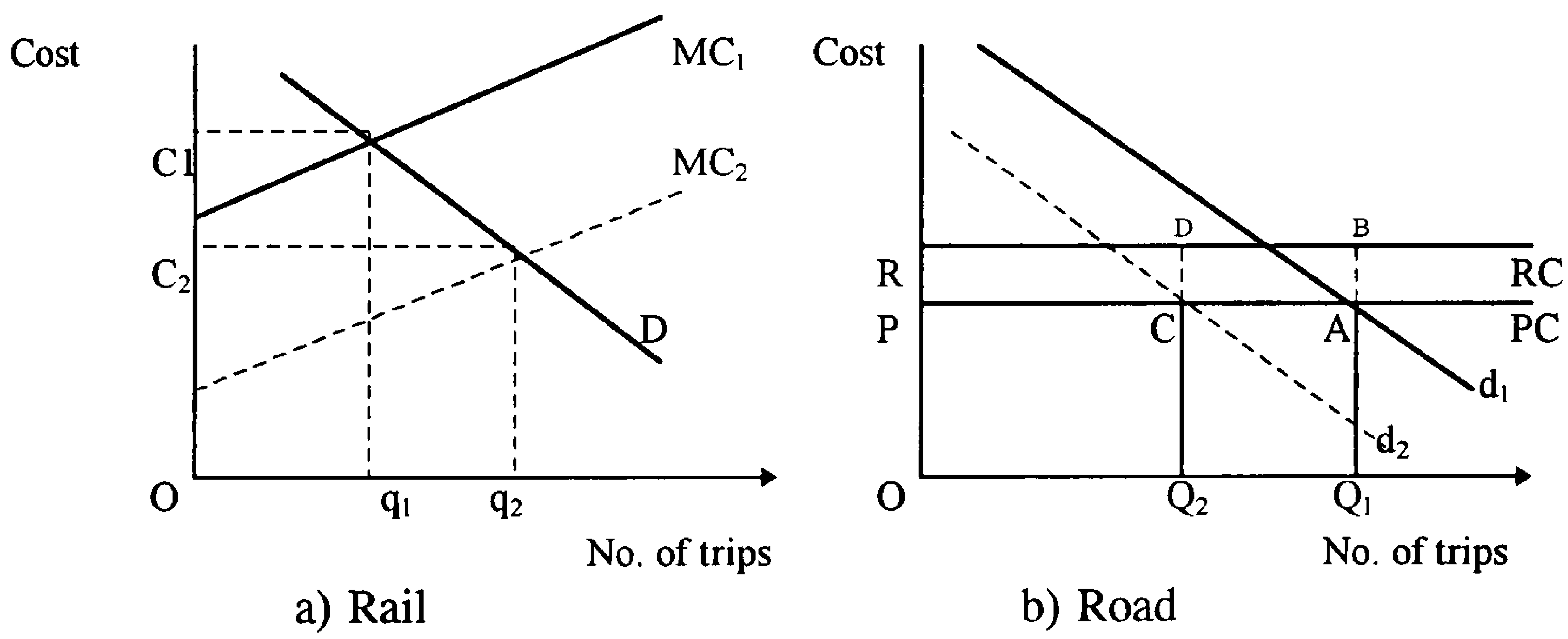



Figure 12.1 Road accident cost misperception

Figure 12.1 shows the case of a rail scheme that leads to a transfer of some road users to use the scheme. In (b), $d_1$ presents the demand curve for road use before the investment in rail takes place. PC is the perceived road accident costs, and RC is the resource road accident costs. The difference between RC and PC indicates to the amount of accident costs that road users fail to perceive. Before rail investment, road users adjust their travel behaviour to the point A, where the costs they perceive is equal to the benefit they derive from the trip with a travel volume of $OQ_1$. This behaviour will result in an amount of extra resource cost equal to the area RBAP.

This area reflects the difference between the total cost of road accidents to the society and the total costs borne by the users of roads.

When the rail scheme takes place, an amount of road trips equal to $Q_1Q_2$ will move to use rail instead. The new demand curve for road use will now be $d_2$, and road users adjust their travel behaviour to the point C. The new situation of travel on roads will mean that the amount of extra resource cost that borne by the society is reduced to be RDCP. In other words, an amount of resource cost saved equal to DBAC. This reflects the amount of unperceived cost by those road users who now moved to use rail. This amount of cost could be measured mathematically as follows:

$$ERCR = (RC_R - PC_R)(Q_1 - Q_2) \qquad (12.1)$$

Where:

ERCR = extra resource cost released as a result of the rail scheme due to the misperception of accident cost in road use (£)

$RC_R$ = resource cost of accidents in roads (£/trip or passenger km)

$PC_R$ = user perceived accident costs in roads (£/trip or passenger km)

$Q_1$-$Q_2$ = movers from road to rail as a result of the rail scheme (trips or passenger km)

It should be noted that in the case example above, figure 12.1, it is assumed that accident cost misperception prevails only on road. In reality, rail users may as well fail to perceive the full cost of the potential accidents in railways. In such a case, it is also relevant to correct for the misperceived rail accident costs. In fact, the intention of the study is to consider the issue of misperception with regard to rail accidents, as well as the road accidents. This will be demonstrated in a latter sections of this chapter.

### *12.4.5 What are the Perceived and unperceived Costs of Road Accidents?*

A motor vehicle accident on the road would probably inflict all or some of the following costs to the society:

**1. User casualties**

This include driver of the vehicle and other occupants. An accident may result in users killed, seriously injured or slightly injured. In 1992, 2882, 36375, 219664 road users were killed, seriously injured, and slightly injured respectively in the United Kingdom. Those killed or injured of course inflict a social cost to the society. The cost will be a function of so many factors such as the age group and the level of injury. The cost of those killed or injured will be discussed latter.

**2. Pedestrian casualties**

When a road accident involves pedestrians, the result may be people killed, seriously injured or slightly injured. In 1992, about 1347 pedestrians were killed in road accidents in the UK, while the number of pedestrians seriously and slightly injured amounted 12837 and 37391 respectively.

**3. Cyclist casualties**

The number of pedal cycle casualties for 1992 are 204 killed, 3787 serious injury, and 20764 slight injuries.

**4. Policing and administration costs of dealing with and sorting out accidents.**

**5. Cost of the potential damage to buildings or any other property when accidents involve damages and injuries at the same time.**

**6. Damage costs in damage only accidents**

The key question now is, which of these costs is considered in the user's decision of making a road trip and which is borne by the community. The answer to this question is not a straight-forward one. Fowkes et al (1990) in a study about track and external costs of road transport produced some figures of the percentage of accident costs borne by the user based on information produced in the Highway Economic Note (HEN 1). These figures are shown in table 12.1

Table 12.1. Percentage of accident costs borne by road user

| Type of accident | Cost element | | | | |
|---|---|---|---|---|---|
| | lost output | medical costs | pain and suffering | police costs | damage to property |
| Fatal | 50 | 0 | 20 | 0 | 100 |
| Serious | 50 | 0 | 80 | 0 | 100 |
| Slight | 50 | 0 | 100 | 0 | 100 |
| Damage only | | | | | 100 |

Source : Fowkes et al (1990)

The figures in table 12.1 suggest that users bear the whole cost of the property damage, while the whole costs of medical treatment and police costs are borne by the community. In the case of lost output, road users bear half of the cost, while for pain and suffering costs the percentage born by the user vary from 20% for fatal causality to 100% for the slight injury.

The dividends of accident costs between user and the community in table 12.1 does not allow for different types of casualties. In other words, it suggests that half of the output lost and some percentage of suffering and pain are borne by the road user regardless of the type of casualty, user casualty or pedestrian, cyclist casualty. The user, in his decision of making a road trip, may consider the full risk and the full cost of himself or others with him in the vehicle, being killed or injured on a road accident, but he probably does not do the same for a pedestrian or cyclist casualty. In this case the dividends in table 12.1 may not be taken to indicate the magnitude of accident cost perception by the user of the road.

The following sections illustrate and discuss the dividends of perceived and unperceived road accident costs pursued by the study in order to work out and estimate the resource and perceived road accident costs. The results of the estimation are disaggregated by road type alternatives, and will be presented and discussed in latter sections of this chapter.

#### 12.4.5.1 Perceived Costs

When a road user decides to make a trip on the road, he probably has two worries, these are:

1. His vehicle being damaged, if he is involved in an accident
2. Himself and his dependants (people with him in the vehicle) being killed or injured, if he is involved in a road accident

Assuming that the user has a full knowledge of the accident rate and risk on the road he uses, these in fact would be the determinants of his decision. Based on that, the perceived accident costs by the user would be the user casualty costs and the damage costs (including damage only accidents).

**1. User casualty costs**

As mentioned above, a person when deciding to travel by road, will consider the full risk of being injured or killed, provided he is fully aware of the accident rate or risk on the road. The person's perception may depend on his age, sex, job, wealth, his own personality and character etc. When a motorist is accompanied by other travelling with him, those dependants will probably perceive the full risk of being involved in an accident.

**2. Costs of Vehicle Damage**

Provided that all vehicle users insure against accidents, this costs are probably perceived through insurance payments. But an argument might be raised that the whole idea and purpose of insurance is mainly to avoid paying the full cost of what is insured against. In this case, a person might not perceive the full cost of damage to his vehicle, and the difference between the total damage cost and what he pays for insurance will be unperceived.

On the other hand, a user knows that his insurance premiums are an increasing function of the number of accidents he probably involved in. In addition, the person may consider the disappointment of having his decent car damaged or probably loosing it, beside the inconvenience of waiting few weeks for his car to be mended. This all support the study assumption that motorists may perceive the full damage cost.

### 12.4.5.2 The Unperceived Costs of Road Accidents?

The unperceived accident costs assumed by the study are:

1. Police and administration costs
2. Pedestrian casualty costs
3. Cyclist casualty costs

In discussing the external road accident costs, Pearce (1993) stated that:

"Evidence regarding whether there exists a link between the accident rate per PCU kilometre and traffic flow is ambiguous. There are however two definite external costs of accidents. In the first place it is clear that the costs of clearing up the aftermath of an accident is a cost not borne directly by the motorist and neither is the cost of his medical treatment. Secondly, the deaths and injuries of pedestrians and cyclists is external since it is not borne by the motorists responsible."

Based on this argument Pearce considered the external costs of road accident to amount to between £4.7 and £7.5 billion in 1991. This comprises the value of deaths and injuries to pedestrians and cyclists.

As can be seen the nature of accident externalities identified by Pearce is that it is costs not borne by the motorist directly, and then not considered in his decision of making a road trip. This is consistent with the study dividends of accident costs between users and the community summarised in table 11.2 below

**1. Police and Administration Costs**

For a person travelling on the road one should not expect him to concern himself with the resultant policing and administration costs of his road accident. These costs will be fully borne by the state.

**2. Pedestrian Casualty Costs**

Road travellers, in their decision of travel, probably do not concern themselves with a possibility of killing or injuring a pedestrian on the road. Even if they may have much sympathy and sorry afterwards for those who injured or killed, the travel decision may hardly bear any attention to the pedestrian casualties.

In addition, insurance companies do not, whoever, charge for the full costs of accidents to pedestrians, and it is logically so difficult to compensate a pedestrian who has been killed or injured in an accident. So the hazard to pedestrians and then the costs are not reflected in the insurance payments, and then are not perceived by the road users.

**3. Cyclist Casualty Costs**

This group of costs have the same characteristics as with pedestrian casualty costs. Cyclist casualty costs will also fall outside the traveller decision function, and they could be considered fully unperceived.

### *12.4.6 Conclusions*

Based on the above discussion, the study dividends of road accident perception are summarised in table 12.2.

Table 12.2 Study dividends of road accident cost perception

| User Perceived costs | Costs unperceived |
|---|---|
| • User casualty costs | • Pedestrian casualty costs |
| • Damage to property costs | • Police and administration |
| • Damage only accidents costs | • Cyclist casualty costs |

The dividends on table 12.2 are based on the following assumptions:

1. That road travellers are well aware of the true accident risk of different modes of transport.
2. The perception of the risk is the same for everybody.
3. The accuracy of accident data. In other words, a full reporting of road accident data is made.

However an argument might be raised about the magnitude of the validity of these assumptions. For example, one may expect that the perception of a person who never been involved in a road accident, despite having travelled by the road all of his life, different from a traveller who has been involved in one or two road accidents. In this case the outlined assumptions above will not hold.

In addition, the reporting of road accidents may not be fully guaranteed. According to TEST (1991), cited from Davis (1989), road accidents in the UK are under-reported. Adams (1987), stated that, an examination of hospital data for the number of road accidents, revealed that approximately 30% of accident victims are not reported to the police. The findings of Ploweden and Hillman (1984) are that all cases of road fatality were fully reported, but only 18 % of serious road casualties treated in hospital were reported. The degree of under reporting differed by road type and user and was most noticeable for cyclists, where 70 % of the cases were not reported (Adams 1987).

## 12.5 Railway Accident Cost Misperception

For the purpose of a comprehensive social appraisal framework for rail investment schemes, which is the main purpose and concern of this research, the misperception prevails in railway accident costs is also relevant to that comprehensive framework. The study considers also railway accident cost misperception in order to work out and estimate the difference between resource and perceived rail accident costs, and then to work out the correction factor to be incorporated in the appraisal framework along side with the correction factor for road accident cost misperception. The following sections outlines the reason of incorporating rail cost misperception, and the dividends pursued by the study in identifying the perceived and non-perceived rail accident costs.

### *12.5.1 Why Incorporating Rail Accident Cost Misperception?*

For similar reason and explanation made in sections 12.4.3 and 12.4.4, the misperception of railway accident cost is relevant to be incorporated when assessing rail investment schemes on social basis. Figure 12.2 is similar to figure 12.1, the only difference is that in figure 12.2, it is assumed that accident cost misperception prevails in rail as well as in road.

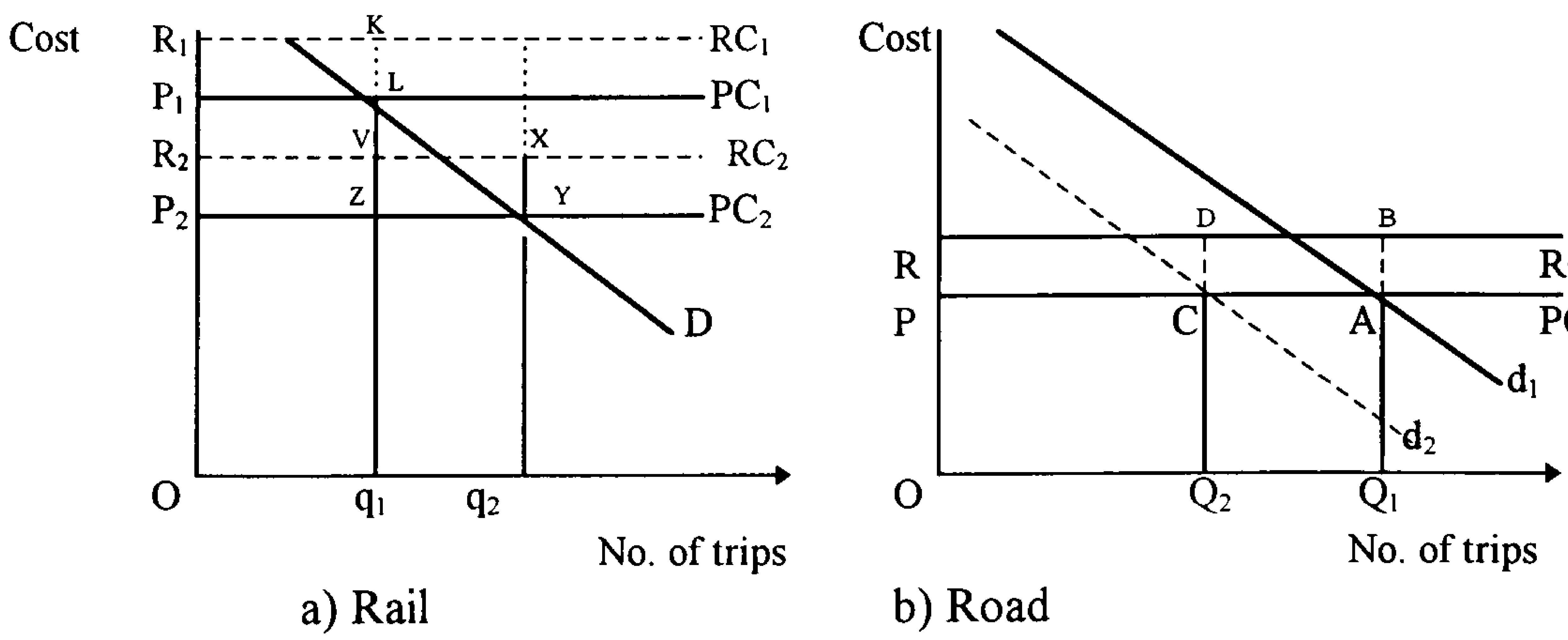



Figure 12.2 Accident cost misperception in both road and rail

As can be seen in figure 12.2 (a), $PC_1$ and $RC_1$ are the perceived and resource rail accident costs before the investment. For after the investment in rail, this is represented by $PC_2$ and $RC_2$. Before the investment takes place in rail, the area $R_1KLP_1$ ( also equal to the area $R_2VZP_2$) represents the extra resource costs of rail accidents that is born by the society and not reflected upon or perceived by the rail users. When rail gets improved this extra resource cost borne by the society is increased to be $R_2XYP_2$, comprising the old area $R_2VZP_2$ and an extra area equal to VXYZ. This extra area is the result of the new users of rail service (movers) $q_1q_2$, and represents the unperceived accident costs of those movers. So it is an extra resource cost used as a result of the scheme, which has to be included in the cost side of the appraisal framework of rail schemes. Mathematically, this extra resource cost could be measured as follows:

$$ERCU = (RC_r - PC_r)(q_2 - q_1) \qquad (12.2)$$

Where:

ERCU = extra resource cost used as a result of the rail scheme due to the misperception of accident cost in railways (£)

$RC_r$ = resource cost of accidents in railways (£/trip or passenger km)

$PC_r$ = user perceived accident costs in railways (£/trip or passenger km)

$q_2$-$q_1$ = movers from road to rail as a result of the rail scheme (trips or passenger km)

### 12.5.2 Perceived and Unperceived Rail Accident Costs

Rail accident costs could be divided into the three following groups of costs:

First: The costs of passenger casualties, people killed or injured.

Second: Damage costs to the railway operator as a result of train or vehicle movement accidents.

Third : The costs of rail staff casualties, people killed or injured.

Rail travellers would not concern themselves with the second and the third group of costs when deciding to travel by rail. So it may be safely to assume that the damage cost of rail accidents and the injuries to railway staff are not perceived by the rail user.

It is the first group of costs that concerns the rail passenger. Passengers probably adjust their use of rail service according to the potential rate of passenger casualty, and the costs involved (the cost of being injured or killed).

## 12.6 Valuation of the Accident Costs

Since 1968, road accident savings based on a human capital approach developed by Dawson at the Transport Research Laboratory (DTp 1992). In 1988 the valuation of fatal casualty was revised and has since been based on a Willingness To Pay (WTP) approach. This places a value on the avoidance of fatal injuries by estimating what people would be willing to pay for a decrease in the risk of a fatal accident. The WTP approach is consistent with the underlying principles of cost benefit analysis in that decisions should reflect the preferences and attitude to accident risk of individuals to be affected by them.

In addition the Department of Transport (DTp) has set a program of research to review the valuation of non-fatal casualties and accidents (DTp 1992).

The major research studies commissioned were Hopkin and O'Reilly, 1993; Ives et al 1993; and Jones-Lee et al, 1993. The values derived from the WTP study undertaken by Jones-Lee and Loomes have been adapted by the DTp. Table 11.3 gives the revised costs per casualty for 1993.

Table 12.3 Average cost per casualty and per accident in 1993 (£)

| Accident Type | Cost per casualty |
|---|---|
| • Fatal | 744057 |
| • Serious | 84262 |
| • Slight | 6540 |

Source; DTp (1993)

The figures in table 12.3 gives the average costs of casualty for each accident type. This costs are of three components:

1. loss of productivity to the economy
2. human costs that reflect people's pain, suffering and grief
3. related medical costs

These figures are used by the current study to estimate the casualty costs to users, pedestrians and cyclists. Values of damage to property costs and police and administration costs used by the Department of transport and provided in its road appraisal manual (COBA) by different types of roads and accident. These figures are updated by inflation and growth in GDP and used by this study to identify the accident related costs. The updated values for 1993 are shown in table 12.4 disaggregated by road and accident type.

Table 12.4 Values of accident cost components by road class and accident type in 1993 values and prices (£s)

| Accident type | Police and administration | Damage to property | | |
|---|---|---|---|---|
| | | Urban | Rural | Motorway |
| • Fatal accident | 577.00 | 1583.4 | 5112.5 | 4562.3 |
| • Serious accident | 465.23 | 1704.2 | 4562.3 | 4441.6 |
| • Slight accident | 335.47 | 1489.5 | 3072.9 | 3408.3 |

This table is updated from the DTp 1981

For damage only accidents, the figures provided by the department of Transport and that used in this study for 1993 are £940, 1380, and 1330 for built up roads, non-built up roads and motorways respectively (DTp, 1993)

It should be noted that the values placed on human lives are developed to be used in quantifying the costs of road accident casualties. No comparable figures are available for railways. The current study assumed that the cost per casualty is the same for rail. However, given the possibility of variations in the definition of accidents and the level of injury between road and rail, probably more research need to be commissioned to place a value for rail accident casualties.

## 12.7 Road Accident Costs

Based on the study dividends of perceived and unperceived accident costs and using the average cost per casualty and other accident costs, resource and perceived costs of road accidents are estimated for 1993. The cost is disaggregated by road types as shown in table 12.5.

Table 12.5 Resource and perceived road accident costs in 1993 (£)

| Road type | Resource cost | | Perceived cost | | Unperceived cost | |
|---|---|---|---|---|---|---|
| | Billions | p/pcu km | Billions | p/pcu km | Billions | p/pcu km |
| 1. Motorway | 0.415 | 0.572 | 0.41 | 0.57 | 0.002 | 0.003 |
| 2. Major urban central | 0.998 | 6.003 | 0.49 | 2.94 | 0.51 | 3.06 |
| 3. Major urban non-central | 2.535 | 3.809 | 1.74 | 2.62 | 0.79 | 1.19 |
| 4. Single carriageway | 1.472 | 2.082 | 1.41 | 1.99 | 0.06 | 0.09 |
| 5. Dual carriageway | 1.197 | 2.020 | 1.17 | 1.97 | 0.03 | 0.05 |
| 6. Minor urban central | 0.946 | 6.016 | 0.47 | 2.97 | 0.48 | 3.04 |
| 7. Minor urban non-central | 3.191 | 3.382 | 2.42 | 2.57 | 0.77 | 0.82 |
| 8. Minor rural single | 1.313 | 2.783 | 0.94 | 2.00 | 0.37 | 0.79 |
| 9. Total all roads | 12.06 | 2.73 | 9.04 | 2.04 | 3.02 | 0.68 |

As can be seen from table 12.5, motorways have the lowest accident cost, followed by other rural roads. Urban roads have the highest cost per pcu km. This is explained by the fact that the number of pedestrian and cyclist casualties attributed to urban roads are much more than that for rural roads and no pedestrians or cyclist casualties attributed to motorways. In addition to that, for each accident on urban roads, there are 6.4 damage only accident, while this figure is 4.5 for rural roads and motorways. The results also show that for major rural roads and motorways, only between 1 to 4% of accident cost is unperceived by users. On the other hand, about 24 to more than 50% of accident cost is unperceived in urban roads.

## 12.8 Rail Accident Costs

Based on the number of rail passenger and staff casualties in 1993 (DTp 1994), the estimated perceived and unperceived cost of rail accidents are shown in table 12.6.

Table 12.6 Resource and perceived rail accident costs for 1993 (£)

| | Passenger | | | Freight | | |
|---|---|---|---|---|---|---|
| | Total | Perceived | unperceived | Total | Perceived | unperceived |
| Billions | 0.139 | 0.081 | 0.058 | 0.006 | 0 | 0.006 |
| pence/pass km | 0.371 | 0.215 | 0.155 | | | |
| pence/tone km | | | | 0.042 | 0 | 0.042 |

The figures in table 12.6 above refer to rail passenger and staff casualty costs. All passenger casualties are allocated to the passenger sector. 90% of staff casualties are allocated to the rail passenger sector, the rest 10% is allocated to rail freight sector. This dividend is according to the total train km of passenger and freight in 1993. The perceived and unperceived accident costs are estimated per passenger and tonne km based on the total number or rail passenger and tonne km in 1993. As can be seen, about 40% of rail passenger casualty cost is not perceived by passengers. On the other hand, all freight related casualty cost is unperceived. This is explained by the fact that all freight related cost is staff casualties, and the study considers rail staff casualty cost to be outside the user decision of travelling by rail.

It is worth mentioning that although road accident costs include the damage to vehicles and property, rail accident costs do not. This is due to the difficulty of quantifying the damage cost of rail accidents. In addition, the damage cost depends upon the accident type and varies from one accident to another. There are no figures available for the value of rail accident damage comparable to that for road accidents. However, in the context of this study's aim of estimating the unperceived rail accident cost, the absence of rail accident damage cost does not disturb the comparison. This is because the damage cost of rail accidents are perceived fully by the operator, and a passenger or tonne km transfer from road to rail would not have any implications with respect to the damage cost of a rail accident.

## 12.9 Chapter Summary

The chapter is concerned with the safety benefits of rail investment schemes. It outlined that unlike congestion, noise and air pollution, accidents do not necessary generate any externality. However, accident risk and cost present a case of cost misperception, that need to be corrected for in a comprehensive framework of appraisal for rail schemes. The chapter discuses how the misperception can be incorporated in the assessment process of rail schemes. This is followed by identifying the perceived and unperceived accident costs for road and rail users. The cost of user casualties, damage to property, and damage only accidents are assumed to be perceived by road users. On the other hand, the cost of pedestrian and cyclists casualties and police and administration are assumed to fall outside the users' decision in making a road trip. Rail passenger casualty costs are assumed to be fully perceived by rail users, while casualty cost to rail staff are assumed to be unperceived. The valuation of accident cost for both road and rail are based on the Department of Transport figures used in assessing road schemes. Resource and perceived cost are estimated for both road and rail. The cost is disaggregatd by road type and for rail by passenger and freight transport. The results show that per pcu km, urban roads have much higher accident cost compared with motorways and other rural roads.

**References**


1. **Department of Transport DTp** (1992) *Road Accidents Great Britain 1992.* London HMSO.
2. **Department of Transport DTp** (1993) *Road Accidents Great Britain 1993.* London HMSO.
3. **Department of Transport DTp** (1994) *Road Accidents Great Britain 1994.* London HMSO.
4. **Department of Transport DTp** (1981), *COBA 9.* HMSO, London.
5. **Fowkes A. S. et al** (1990) *The Track and External Costs of Road Transport.* Institute for Transport Studies, Leeds University, Working Paper 312.
6. **Hopkin M. and O'Reilly D.** (1993) *Revaluation of the cost of road accident casualties:* 1992 revision TRL RR 378, Transport Research Laboratory, Growthorne.
7. **Jones-Lee, M. W. et al** (1993) *The value of preventing non-fatal road injuries: findings of a willingness to pay national sample survey.* TRL Contractor Report 330, Transport Research Laboratory, Growthorne.
8. **Newbery D.** (1988) *Road user charges in Britain.* Economic Journal (conference paper), 98, 161-76.
9. **Pearce D.** (1993) *Blueprint 3: Measuring Sustainable Development.* CSERGE, Earthcan, London.
10. **Vickrey, W.** (1969) *Externalities in public facility use: the case of highway accidents, in the analysis of public output.* Margolis, J. (ed.), National Bureau of Economic Research. New York, pp. 317-35.

11. **Vitaliano D. and Held J.** (1991) *Road accident external effects: an empirical assessment.* Applied Economics, 23, 373-378.

12. **TEST** (1991) *Wrong side of the tracks? impacts of road and rail on the environment: a basis for discussion.* London.

13. **Adams J.** (1987) *Road safety as an environmental issue.* Friends of the Earth Conference, New Priorities in Transport.

14. **Plowden, S. and Hillman, M.** (1984) *Danger on the road: the needless scourge.* London Policy Studies Institute.

15. **Davis R.** (1989) *What is road safety?* In radical Community Medicine.

16. **Ives et al** (1993) *Revaluation of non-fatal casualty costs.* TRRL Contractor Report 339, TRRL, Growthorne, UK.

## Chapter 13

## Findings, Implications and Conclusions

### 13.1 Introduction

This chapter summarises the research findings and identifies the implications of these findings for welfare losses and investment bias. It starts by presenting the aims and objectives identified for the study. Then discusses the achievements of the study in the light of the identified purpose and objectives. After that, the main findings are summarised and discussed. Finally the chapter demonstrates the implications of the study findings for welfare losses and investment bias and discusses the policy options that can be used to alleviate these implications. This is followed by some suggestions for further research.

### 13.2 The Idea and Problem of the Study

The idea of this research study is derived from the long ongoing debate about the criteria of allocating investment funds between transport modes, and in particular between road and rail.

An important issue for transport policy is whether more investment should be devoted to road schemes and less to rail schemes and vice versa. This raises the problem of comparing the investment returns of the two modes. The fact that road and rail investment schemes are currently assessed on a different basis (road schemes are assessed on a cost benefit basis, while rail schemes are generally justified financially, though cost benefit sometimes used) has lead many to think of the possibility of unfairness and bias in allocating investment funds between the two modes, and then a chance of resource missallocation and welfare losses might exist.

This issue was considered by the Leitch Committee in 1977 (DTp, 1977) which recommended a single framework of appraisal which it considered would allow greater comparability between road and rail investment appraisals by incorporating wider issues relevant to the overall decisions of resource allocation. Leitch recommendations have long been supported by many. Based on some empirical research, Nash and Preston (1991) have concluded that the use of purely financial criteria for most rail schemes threaten to distort decision-making and that a move to a comprehensive cost benefit analysis for all rail investment schemes is required.

This study is a step in the direction of examining to what extent the unfairness and bias and their implications for welfare losses might exist. In addition, to explore how rail investment schemes can be assessed on a basis comparable with that used for road investment schemes.

## 13.3 The Purpose of the Study

As identified in the introductory chapter, the purpose of this research is to develop a methodology for assessing the investment in railways that could be consistent with the Cost Benefit technique used in assessing road investment projects. The methodology developed identifies, on a social basis, the benefits of rail investment schemes and the method by which this benefits may be incorporated in a comprehensive social appraisal framework.

## 13.4 The Objectives of the Study

In achieving the research purpose outlined above, a set of objectives are identified, these are:

### *13.4.1 Main Objectives*

1. Identify different appraisal techniques used for assessing the investment in transport sector, in particular cost benefit analysis and financial analysis. In addition, a detailed comparison between the two techniques and implications of resource allocation.
2. Identify the difference between cost benefit analysis and financial analysis in the case of rail investment.
3. Demonstrate and examine the factors that influence the difference or divergence between the returns on the investment of the two methods of appraisal.
4. Identify the means by which the difference between the returns may be incorporated into the framework of appraisal.

### *13.4.2 Sub-objectives*

In addition to the main objectives, the following sub-objectives are targeted to achieve some of the identified main objectives.

1. Identify user benefits of rail investment (consumer surplus), and examine to what extent it does exist and investigate how pricing policy and cost and demand elasticity may affect its existence and magnitude.
2. Identify and quantify non-user benefits of rail investment schemes as a function of the road alternative. These benefits are:

- Congestion time benefits
- Noise Benefits
- Air pollution benefits
- Accident benefits
- Vehicle operating cost benefits

Non-user benefits of rail schemes are quantified at the margin. In other words, the process of identifying these benefits considers the implications of mode switching by quantifying the Marginal Social Cost (MSC) of road and rail travel. The value of MSC (identified as the cost that the society scarifies for an extra passenger km) may vary form one road type to another one due to the variations of travel characteristics between different types of roads, and then the implications for congestion delays and environmental impacts will vary from one type of road to another one. Hence, the study identifies the value of MSC as a function of road type. Eight types of road are identified for the study. These are:

- Motorways
- Major urban central roads
- Major urban non-central roads
- Rural single carriageways
- Rural dual carriageways
- Minor urban central roads
- Minor urban non-central roads
- Minor rural single roads

These 8 types of road present the UK entire road network.

## 13.5 Achievements and Findings of the Study

### *13.5.1 Appraisal Techniques: Theory, Practice and Implications of Resource Allocation*

1. The study identified theoretically the main methods of assessing transport investment to be Cost Benefit Analysis (CBA) and Financial Analysis (FA). The detailed comparison between the two techniques (chapter 2) shows that FA is concerned only with the financial effects of schemes in terms of extra net revenue occurring to the agency carrying out the scheme concerned. On the other hand, CBA technique is concerned with a larger framework, all transport users or society as a whole. This has three important consequences;

First as far as the FA is concerned, the issue of resource cost adjustments is irrelevant. In other words, FA accepts prices as it is regardless whether it reflects a real resource cost or not. So pricing distortions or distortions from the misperception of cost or benefit items are all irrelevant issues under the FA appraisal framework. Second, there are elements of consumer benefit which a CBA would include but a FA would not, e.g. those areas of consumer surplus which, because of the relative crudity of most pricing policies, the financially based organisation cannot tap. Third, when there are effects external to the transport sector, these will in principle enter into CBA but not into FA.

2. On theoretical basis, and assuming no externalities, the study has shown that cost benefit returns may exceed the financial returns of an investment. The divergence between the cost benefit and financial returns is a function of demand and cost elasticity.

3. The study examined the interaction between evaluation techniques and pricing policy. The main findings are:

- For the same pricing policy there is a divergence between financial and cost benefit returns. The type of pricing policy operated has a significant impact on the magnitude of that divergence.

- There is a divergence between financial rates of return measured under different assumptions of pricing policy. Similarly, different pricing policies will bring different CBA returns.

These two findings lead to the conclusion that investment balance between road and rail can be distorted not only by using different methods of appraisal but also by the inconsistency of pricing policy applied for the two modes.

4. Examining the current practice of assessing investment in transport modes (chapter 3) shows the following:

- Road schemes are mainly justified on a pragmatic cost benefit technique. The form of cost benefit analysis applied to road schemes measures in money terms the capital cost of the scheme and the benefits that accrue in the form of time saved, accident saved and operating costs saved. Neither the environmental impacts nor the developmental benefits of road projects are quantified in money terms under the current practice of road appraisal. The impacts on the environment, such as noise and air pollution are descriptively incorporated, and the investment decision is dominated by the three quantified types of benefits.
- Rail schemes are usually assessed on a financial basis. The only benefits of projects are the net revenue to be gained by the rail operator. Schemes are required to earn 8% financial rate of return.
- Neither road nor rail appraisal practice incorporates all the implications of mode switching. In other words, both CBA for road and FA for rail do not incorporate the potential benefits of the scheme assessed for non-users as a result of mode switching. This is seen as a major defect in the current appraisal practice. This is because of the fact that the extra social costs (congestion, noise, accident and air pollution) of road travel are much higher than that for railways as shown in chapters 7-12 of this study. The conclusion is if rail appraisal method incorporates the benefits to road users as a result of mode switching, this would improve investment returns for rail schemes which means more rail investment would be justified.

5. The study (chapter 4) shows that the existing mix of appraisal techniques for road and rail has some potential implications; these are:

- Given the fact that cost benefit returns are likely to be higher than financial returns for an investment, rail investments are subject to a time delay. This delay is a function of the difference between cost benefit and financial returns. The time lag of rail investments dynamically result in affecting the total capital investment in road and rail, leading to a relatively higher levels of investment in road and lower levels of investment in rail than it should be. In turn, this misallocation of investment resources results in losses in welfare to the economy as a whole.
- Given that the rail service is subject to a downward sloping cost curve (as discussed in chapter 4), the encouragement of road investment and discouragement of rail investment caused by the use of different appraisal method for both modes depresses the relative competitiveness of rail compared with road. In other words, a rise in rail travel costs and a deterioration of rail travel demand will be inevitable. This in turn worsens the profitability of rail investments leading again to a discouragement of rail investment.

To bring a sustainable balance between road and rail investment, the study discusses some options that are put forward as a solution. These options include applying financial analysis for both modes or using different discount rates for road and rail investment. Each of the alternative solutions has its shortcomings which are discussed in chapter 4. The most appealing option that brings the consistency between the two modes is the use of the same appraisal technique for both road and rail. From the welfare viewpoint, this technique has to be a social cost benefit analysis as suggested in this study. Other options and their applicability are discussed in this chapter.

### *13.5.2 Previous Work*

1. Reviewing the literature (chapter 5) shows that the problem of comparability between investment returns measured on different basis had been considered as early as 1960. This was followed by an attempt to establish a single rate of exchange between the cost benefit and financial returns which was deemed to be unachievable.

2. Examination of some of rail investment studies where both financial and cost benefit analysis were carried out (as discussed in chapter 5) shows the following:

- The task of cost benefit evaluation in these studies covers both user and non-user benefits of the scheme concerned. The measured non-user benefits are road congestion benefits, vehicle operating cost benefits and road accident savings. In all of the studies reviewed, the incorporation of environmental impacts were absent. However, the current study approach of identifying rail scheme benefits incorporates and quantify the environmental impacts (noise and air pollution) at the margin.

- In all of the studies the issue of users' perception was not considered. This is seen to be relevant for both accidents and vehicle operating costs. On a social basis, the relevant costs and benefits of an investment are to be measured on the basis of their resource values. In consequence the distortion of users' misperception to cost and benefit items have to be corrected for. Hence, the current study incorporates users' perception of these two items when measuring the Marginal Social Cost of road and rail travel.
- In all studies, the results of the evaluation process showed cost benefit returns higher than the financial returns. However, the difference between the cost benefit and financial returns varies from one case to another. This is quiet consistent with the discussion and conclusions of chapter 2, that economic returns are likely to be above the financial returns of an investment and one can not establish *a priori* about the difference between the two types of return.

### *13.5.3 The Study Appraisal Framework and the Approach of Measuring Non-user Benefits of Rail Schemes*

1. The study appraisal framework (as detailed in chapter 6) identified rail scheme impacts under four elements. These are:

- Operator impacts (financial benefits to the operator)
- Impacts on rail users (user benefits)
- Impacts on non-users (non-user benefits)
- Other impacts on other bodies in the society (tax adjustments)

2. Non-user benefits concerned and quantified by the study are road congestion time benefits, noise, air pollution, accidents and vehicle operating costs. The first three are considered to be externalities (either external benefits or external costs to rail schemes), while the last two are dealt with as cases of cost misperception.

3. Non-user benefits are measured as a function of the road alternative, where the results are disaggregated by 8 types of road identified for the study and shown above.

4. The measurement process of non-user benefits incorporates the variations of traffic over time and place. The process incorporates four traffic distributions. These are:

- Traffic variation during the day (24 hour distribution)
- Traffic variation during the week (7 days distribution)
- Traffic variation during the year (12 month distribution)
- Traffic variation from location to another on the road network (a sample distribution of 22-24 sites on the network is used)

Incorporating the variations in traffic over time and place results in a more accurate and precise measurement of the extra social costs of road transport, and then the based economic instruments regarding the correction for or the internalising of these extra social costs would be accurate.

### *13.5.4 Non-user Benefits by Road Class*

#### a) Road Externalities

As stated above congestion time, noise and air pollution are considered by the study to be externalities and measured at the margin (as detailed in chapters 7-10). The following table summarises the results.

Table 13.1 Externalities of road transport by road class for 1993 (pence/pcu km)

| Road Type | Congestion time | Noise | Air pollution | Total |
|---|---|---|---|---|
| 1. Motorways | 2.68 | 0.011 | 0.73 | 3.42 |
| 2. Major urban central roads | 27.30 | 0.846 | 1.31 | 29.45 |
| 3. Major urban non-central roads | 5.01 | 1.253 | 1.06 | 7.32 |
| 4. Rural single carriageways | 1.52 | 0.138 | 0.70 | 2.35 |
| 5. Rural dual carriageways | 0.18 | 0.076 | 0.72 | 0.98 |
| 6. Minor urban central roads | 7.55 | 0.00 | 2.16 | 9.70 |
| 7. Minor urban non-central roads | 1.21 | 0.00 | 1.12 | 2.33 |
| 8. Minor rural single roads | 0.32 | 0.00 | 0.51 | 0.83 |
| • Average all roads | 3.04 | 0.254 | 0.87 | 4.16 |

As can be seen from table 13.1, urban roads have higher externalities per pcu km compared with rural roads, with an average total externality of 4.16 pence per pcu km for all roads.

**2. Road User Cost Misperception**

The following table summarises the misperception of road user cost measured by the study (as detailed in chapters 11 and 12).

Table 13.2 Road user cost misperception by road class for 1993

| Road Type | Unperceived costs (pence/pcu km) | | | |
|---|---|---|---|---|
| | Accidents | Vehicle operating cost | Depreciation of private cars | Total |
| 1. Motorways | 0.003 | 1.05 | 7.88 | 8.93 |
| 2. Major urban central roads | 3.06 | 1.43 | 8.69 | 13.18 |
| 3. Major urban non-central roads | 1.19 | 1.49 | 8.18 | 10.86 |
| 4. Rural single carriageways | 0.09 | 1.45 | 8.28 | 9.82 |
| 5. Rural dual carriageways | 0.05 | 1.06 | 8.18 | 9.29 |
| 6. Minor urban central roads | 3.04 | 1.61 | 8.80 | 13.45 |
| 7. Minor urban non-central roads | 0.82 | 1.79 | 8.59 | 11.20 |
| 8. Minor rural single roads | 0.79 | 1.63 | 8.49 | 10.91 |
| • Average all roads | 0.68 | 1.43 | 8.31 | 10.42 |

As table 13.2 shows, total unperceived road user costs are dominated by the depreciation of private cars. An average of 8.3 pence per pcu km is unperceived by road users in terms of the cost of depreciation to their private cars. In addition, for each pcu km about 1.4 pence is unperceived by road users. This reflects the non-fuel car vehicle operating costs for non-working trips after correcting for fuel tax. On the other hand, road users fail to perceive 0.68 pence per pcu km as an accident costs. This amount is more than 4 times as much in cases of urban roads in central areas.

### *13.5.5 Non User Benefits by Unit of Output*

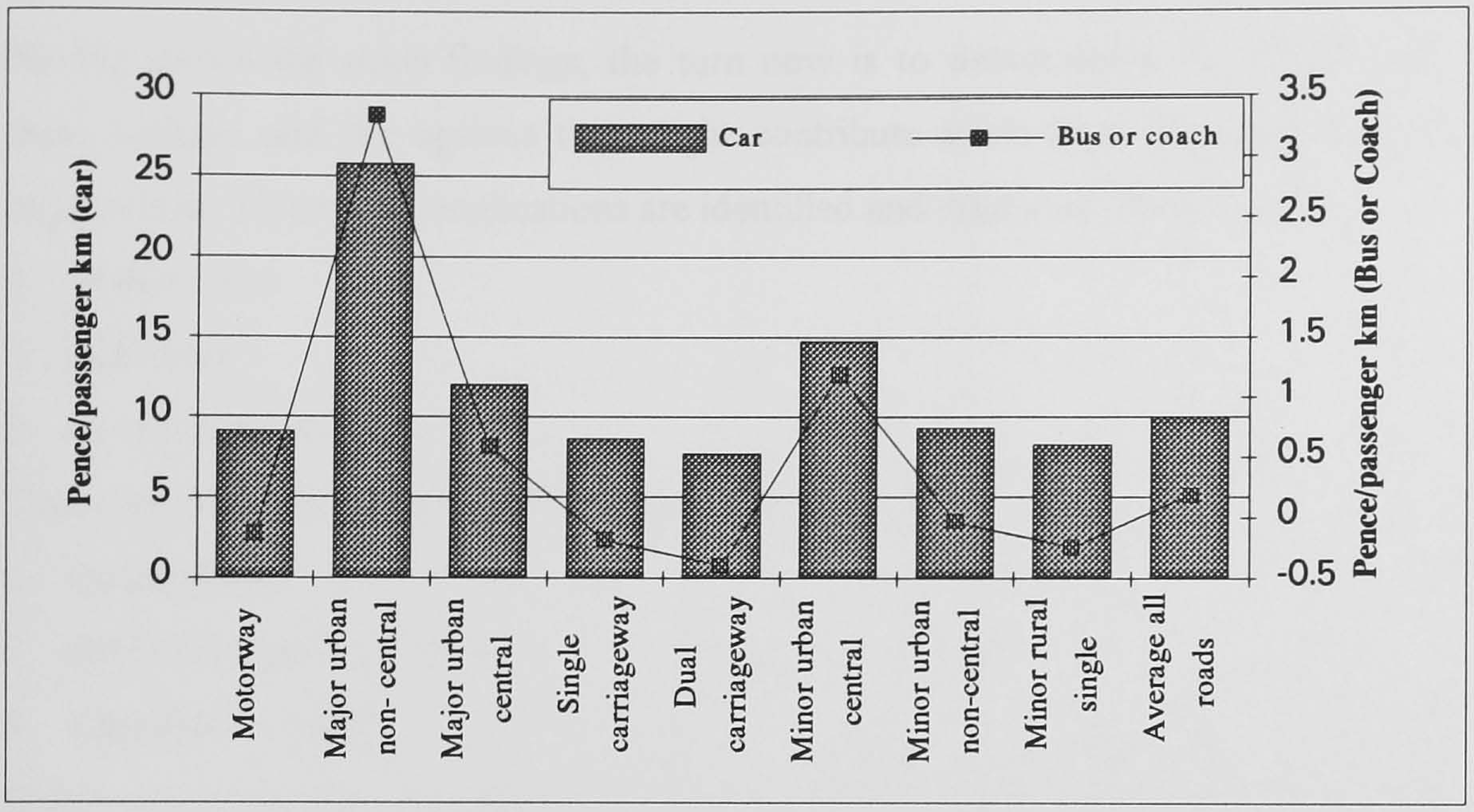
The figures in tables 13.1 and 13.2 are used to estimate non-user benefits per passenger km. Separate values are estimated for car and bus, based on an average vehicle occupancy of 1.2, 1.86 and 13.2 passengers for working car, non-working car and passenger service vehicle (buses and coaches) respectively. These are the vehicle occupancies used in the COBA program for assessing road scheme benefits (DTp 1981). Table 13.3 presents the results.

Table 13.3 Extra social cost of road transport by unit of output and road class for 1993

| Road type | pence/passenger km | |
|---|---|---|
| | Car | Bus and coach |
| 1. Motorways | 9.06 | -0.13 |
| 2. Major urban central roads | 25.80 | 3.34 |
| 3. Major urban non-central roads | 12.01 | 0.58 |
| 4. Rural single carriageways | 8.64 | -0.19 |
| 5. Rural dual carriageways | 7.67 | -0.39 |
| 6. Minor urban central roads | 14.75 | 1.19 |
| 7. Minor urban non-central roads | 9.27 | -0.04 |
| 8. Minor rural single roads | 8.25 | -0.24 |
| • Average all roads | 10.02 | 0.19 |

As can be seen from table 13.3, an extra cost on average of 10.02 pence per car passenger km is either imposed on the society (in a form of time delays, noise and air pollution) or unperceived by users (in a form accident and vehicle operating costs). This extra cost varies from one road type to another one reflecting the characteristics of traffic and speed on each type of road. In general, urban roads have higher social costs than motorways and rural roads. On the other hand, a bus passenger km imposes an extra social cost on average of only 0.19 pence. This also varies between road types. As can be seen from table 13.3 column 3, the extra social cost of buses on rural roads is negative. That means, bus travellers on rural roads have a marginal social cost lower than the marginal private cost of travel. This is due to that buses on rural roads have lower externalities (congestion, noise and air pollution) compared with urban roads, and then the tax on fuel is more than outweigh these externalities leading to a marginal social cost lower than the marginal private cost for buses on rural roads. In fact this conclusion is consistent with a similar conclusions pointed out by Tyson (1972) suggesting that the marginal social cost of bus travel is below the marginal private cost.

Figure 13.1 Extra social cost of road transport by unit of output and road class




### *13.5.6 Rail Externalities and Cost Misperception*

Table 13.4 summarises the externalities and cost misperception estimated for railways.

Table 13.4 Rail externalities and unperceived cost by unit of output for 1993

| | Externalities | | Unperceived cost | Total |
|---|---|---|---|---|
| | Noise | air pollution | Accidents | |
| Pence/passenger km | 0.052 | 0.27 | 0.155 | 0.477 |
| Pence/tonne km | 0.016 | 0.063 | 0.042 | 0.121 |

As can be noticed the extra social cost of car travel per passenger km is much higher than that of rail and bus travel. On average a car passenger km has an extra social cost of more than 20 times as that of rail and more than 40 times that of buses. Given that public transport share in passenger km is only 12% (Houghton 1994), that obviously mean most of passenger journeys in the UK are by private car with the highest extra social costs. This in turn means welfare losses to the society, unless an economic instrument or any form of policy is used to correct for these extra social costs of car travel.

## 13.6 Implication and Solutions

Having shown the study findings, the turn now is to demonstrate the implications of these findings and the options that might contribute towards an elimination of these implications. Three main implications are identified and discussed. These are:

1. Welfare loss
2. Rail share
3. Investment bias

Three options are examined and discussed. These are:

1. Pricing policy
2. Public transport subsidies
3. Appraisal methods

Before discussing the applicability and suitability of these options towards the elimination of the three implications outlined above, an examination of the three undesirable implications is carried out.

### *13.6.1 Undesirable Implications*

**1. Welfare Losses**

The results shown in table 13.3 indicate that the society scarifies an extra cost on average of 10.02 pence for a car passenger km, while if this passenger km travels by rail or bus, the extra cost to the society are only 0.477 and 0.19 pence respectively. Obviously, this means welfare losses to the society. The aim here is to use the study results to estimate the amount of welfare losses to the society.

Assuming that the balance between road and rail travel can be brought in by a form of operating subsidy for railways. The subsidy has to make over and match exactly the difference between the extra costs to the society of a passenger km by road and rail. The study results suggest that a subsidy of 9.5 pence is to be paid for railway. However, considering that the cost per passenger km for rail Inter-City is 7.5 pence (British Rail 1994), the study assumed a subsidy of 3.8p per passenger km. This represents the difference between the extra social cost by road and rail excluding the misperception of the depreciation of private cars. The amount of welfare gains will depend on the shape and the elasticity of rail travel demand curve. The estimates of welfare gains as a result of 3.8p operating subsidy for the Inter-City railways are made for two cases of rail demand curve. These are linear and non-linear demand curve. The following equations show the two rail demand functions used.

$$D = a + bf \qquad (13.1)$$

$$D = af^{\alpha} \qquad (13.2)$$

Where:

D = rail travel demand (passenger km/period of time)

a, b α = constants

f = rail fare (£/passenger km)

The elasticity of demand in both cases are assumed to be -0.8. This is the mode choice elasticity measured for inter-city rail travel (Nash et al 1992). The increase in rail demand is estimated to be 4.9 and 9.1 billions passenger km for the two cases of demand curves respectively. In other words, rail travel demand increases by 40% and 75% for the two cases of demand curves. It is assumed that the new rail demand is all from road (since the elasticity used does not allow for trip generation impacts) and 70% of movers are car users and the rest are bus users. The results are shown in the following table.

Table 13.5 Welfare gains as a result of a subsidy to Inter-City railways

| Road type | £ Millions | |
|---|---|---|
| | Linear demand curve | Non-linear demand curve |
| 1. Motorways | 286.1 | 532.9 |
| 2. Major urban central roads | 912.5 | 1699.8 |
| 3. Major urban non-central roads | 397.9 | 741.2 |
| 4. Rural single carriageways | 270.9 | 504.6 |
| 5. Rural dual carriageways | 234.4 | 436.6 |
| 6. Minor urban central roads | 501.1 | 933.4 |
| 7. Minor urban non-central roads | 294.5 | 548.5 |
| 8. Minor rural single roads | 256.6 | 478.0 |
| • Average all roads | 323.7 | 602.9 |

As table 13.5 shows, welfare gains as a result of 3.8p subsidy to railways are £323.7 millions, and this amount is nearly doubled in case of non-linear demand curve for rail.

The amount of welfare gains are higher when the road alternative is urban one. This is due to the higher marginal social cost of urban roads compared with rural roads. In fact, one may argue that, the new demand for rail travel as a result of operating subsidy would be transferred from a mix of road types. Hence, to be very specific of the amount of welfare gain, one has to identify exactly the types of roads from which the new rail travellers transfer. This will need a knowledge of roads that are used as a substitute to rail inter-city travel.

**2. Rail Share**

As shown in section 13.6.1, when a subsidy of 3.8 pence/passenger km is paid to rail, an estimated extra 4.9 or 9.1 billions passenger km would transfer from road to rail. In other words, rail travel demand increases by 40% and 75% for the two demand curve shapes. That is to say that rail share in passenger transport is far less than it should be if road and rail travellers are charged the full marginal social cost of their trips, or any other form of policy options used to correct for the difference between the extra social cost of road and rail travel.

**3. Investment Bias**

The study results indicates that on a social basis, rail investment schemes yield a significant social benefits in a form of time delays, pollution, noise, accidents and vehicle operating costs. Hence, the economic return of rail schemes is likely to be above the financial return. The implications are, as discussed in chapter 4, rail investments that are assessed only on financial basis are subject to time delay (or probably not made at all), and then dynamically, the result will be relatively lower levels of investment in rail.

To elaborate in this point, the study results are used to re-estimate the Internal Rate of Return (IRR) for one case study of rail investment. This is the electrification of the line from Birmingham to Paddington via Oxford. The project was assessed on both financial and cost benefit basis in 1984 (DTp 1984), and the results were discussed in chapter 5.

The evaluation results of the scheme are given in a form of Net Present Value of costs and benefits. This is used by the current study to estimate the financial and cost benefit IRR. Based on the evaluation results of 1984, the financial and cost benefit rates of return are estimated to be 6% and 7% respectively. However, based on the current study results of rail investment non-user benefits, the value of the cost benefit rate of return is estimated to be 9%.

This case study shows that, cost benefit rate of return is 1.5 times the financial rate of return. However, in general this cannot be taken as a rule. The divergence between cost benefit and financial IRR may vary from case to another, depending on the **type of investment** (pure expansion, replacement, cost reducing investment, etc.) and the extent to which it is attracting travellers off the road. Whether the investment affects the quality of service or not is another important determinant of the divergence. So, one cannot have *a priori* of the exchange rate between economic and financial IRR. However, the study results suggest that, for rail investment that attracts travellers off the road, the economic return is above the financial return. Then, if this is not corrected for, the use of financial assessment for rail schemes will lead to under-investment in railways.

### *13.6.2 What Can be Done?*

Having illustrated the implications of the study results, it is the turn to discuss the options that are put forward to bring a sustainable balance between road and rail travel and investment. Three main options are discussed. These are:

1. **Pricing (Charging the Full Marginal Social Cost of Travel)**

From the economic theory point of view, pricing probably is the first best and optimal solution for internalising the extra social costs of travel. Based on the study results, on average car users are to be charged a levy of 10.02 pence per passenger km, and a tax of 0.191 pence is to be added to the bus or coach fare per passenger km. This amount of tax would vary from one type of road to another. For example car users on central urban areas would be charged 25.8 pence per passenger km, while users of dual carriageways, single carriageways and motorways would be charged between 7 to 9 pence per passenger km. Bus and coach travellers on rural roads would not be charged since their marginal private cost is just equal or even higher than the marginal social cost. However bus users on urban areas would be charged between 0.5 and 3.3 pence per passenger km depending on the type of the road. On the other hand, rail users are to be charged an extra 0.477 pence per passenger km. This in fact, if applied correctly, will eliminate the undesirable implications discussed above. In other words, a sustainable balance between private and public transport will be maintained, and the loss of welfare indicated by table 13.5 will be avoided. However, as discussed in chapter 4, applying such amount of extra charges might not be easy and another options are needed. This is because the imposition of such charges can only generate a social welfare gain if similar pricing policies *in all* other sectors of the economy (marginal cost pricing). If this is not the case, any welfare gain in the transport field may be more than offset by losses elsewhere in the economy. If those wishing to remain on roads pay the congestion charge by withdrawing expenditure from sectors where *prices are above marginal costs*, this will lead to an *excessive underconsumption* of the goods in such sectors. Similarly, those deciding to forego road motoring may spend the money saved on goods produced in a sector where *prices are below marginal cost*, leading to *overproduction* of these goods. Only if marginal cost pricing is universal in the economy is it certain that the imposition of such charges will lead to an aggregate national welfare gain and maintain the balance between private and public transport.

The second problem of charging travellers according to the marginal social cost of their trips is the difficulty of applying such charges in practice. In addition, as discussed on chapter 4, roads have been long considered as a public good that is accessible without any charges or restrictions. These issues are usually restricts the pricing option to be used as a solution to bring the balance between private and public transport.

**2. Public Transport Subsidies**

Again the balance between road and rail travel can be brought into through a form of subsidy to railways. As discussed above, if the misperception of depreciation of private cars is to be included, an average subsidy of 9.5 pence approximately per passenger km is to be paid to railways. However, given the average cost per passenger km (inter-city) of 7.5 pence per passenger km, this seems inapplicable (unless rail travel is made free). Hence, excluding depreciation misperception of private cars, the subsidy would be 3.8 pence per rail passenger km. The form of subsidy employed will affect its impact. A direct service subsidy may be employed to keep fares down or to reduce them, but this does not guarantee any improvements to the service provided. On the other hand, if the subsidy is made in a form of capital grants, this will have less effect on fares than direct subsidies, but will encourage the use of newer and better equipment and then an improved rail service may therefore be expected.

Two traditional criticisms of subsidy are raised. First is where the funds to finance the *optimal subsidy* are to be raised. If the scheme is to be self-financing from within the transport sector, by some form of tax (e.g. petrol duty), this will probably distort private transport costs, and then the welfare implications of that distortion have to be considered to assess the ultimate welfare implications of subsidy. On the other hand, if the finance is to be collected outside the transport sector, this might mean a welfare losses in other parts of the economy which have to be brought into the calculation.

The second criticism of subsidy is its impact on the *internal efficiency* of railways (the amount of resources used to produce given output level). Some argue (Pryke 1977) that subsidy system will seriously damage the incentive to efficient operation, by leading the operator to assume that he will always get support whatever financial difficulties he faces. However, there are some generally agreed conditions that are necessary for a subsidy to be given with a minimum damage to the internal efficiency (Nash 1982). First the amount of the subsidy is to be stipulated in advance. Second the objectives with respect to which subsidy is to be used should be made clear and easily to be monitored.

**3. Investment Appraisal Methods**

The possibility of getting the balance between road and rail investment is by assessing the investment in both modes on a comprehensive social basis as suggested in this study. This will achieve the correct balance of investment between the two modes. However, the impact on rail travel share would probably be minimal. In other words, an increase in rail investment may mean better service but will not automatically lead to an increase in rail travel share. Hence, the amount of welfare loss discussed in section 13.6.1 will not be avoided.

Given the current organisational structure of railways (profit maximisation), using cost benefit analysis for assessing investment schemes might not be possible. Section 56 Grant may be used for rail schemes. However, the Department of Transport guidelines for Section 56 only consider the schemes of £5m and over, beside the evaluation method itself does not include benefits to rail users assuming that this type of benefits is fully recouped through fare box. As discussed in chapter 5, in most of the cases reviewed, user benefits of the schemes evaluated were very significant, and then the full economic benefits of rail schemes may be underestimated under Section 56 evaluation method.

**4. Creating a Sustainable Transport Policy**

Two main conclusions may be drawn from the above argument. These are:

a) Public and private transport differ in attractiveness and convenience, and the differing basis on which users pay towards the costs of public and private transport have an important distorting effect on decisions about which mode to use. The relative private costs of additional journeys therefore favour car use against buses and rail. A smaller proportion of journeys will therefore be made by public transport, (in 1993 only 12% of passenger km is moved by public transport (Houghton 1994)) than if decisions were based on the actual additional resource costs of alternative modes of travel. The term resource cost reefers to both private and society costs of the marginal trip.

b) The use of inconsistent appraisal methods of private and public transport investment distorts the investment balance between them.

The three options discussed above (pricing, subsidy and appraisal methods) have their shortcomings in achieving the balance between private and public transport investment and travel.

So restoring that balance between private and public transport investment and travel will need a package of instruments that **insure an integrated transport policy that minimise the need for transport and increase the proportions of journeys made by environmentally friendly modes.** This may be achieved by a set of targets to be put forward, such as increasing public transport share from 12% to 20% for example in a given period of time, reduce the proportion of urban journeys undertaken by car to a certain level, maintaining a certain level of noise and air pollution and maintaining a certain level of investment in public transport modes. The instruments to be used are to be tailored to suit the targets and to be easily monitored. This may include increase in fuel prices with the exception of public transport, parking charges, operating and grant support to rail and bus, command and control tolls for maintaining a certain level of noise and air pollution, introducing bus lanes and priority in urban areas, make more resource available for new light rail systems, and provide safe pedestrians and cyclists routes.

## 13.7 Further Improvements

### *13.7.1 Value of Time*

The measurement of the marginal congestion time externality in this study is based on the value of time used by the Department of Transport in planning road maintenance and construction. While the variations in traffic flows with time and place (throughout the day, the week, the year and the location on the network) are incorporated and allowed to affect the value of Marginal Congestion Time Externality that vary with time and place, the value of time is assumed to be the same for all times and places.

People may value the time differently from hour to another throughout the day, from day to another throughout the week, and month to another throughout the year. In addition, the value of time may differ from region to another within the country. Then more research is needed to explore whether there is a significant relationship between the value people place on the time and the time of day, week, year, and place.

The consideration of varying the value of time with time and place may have a significant impact on the value of marginal congestion time externality.

### *13.7.2 Congestion Disbenefits of Railways*

By attracting motorists off the roads, rail investment schemes create an area of congestion benefits equal to the number of movers times the marginal congestion cost externality of the road.

However, those movers may affect travel conditions in railways. In other words, if rail is subject to congested and crowded conditions, travel conditions will be worsened as a result of any transfer of passengers from road. Then the congestion impacts of road movers on rail travel conditions need to be incorporated in a full assessment of rail investment benefits and costs. One might expect that the congestion impacts of road movers on rail travel to vary from a rail service to another (regional, or inter-city) and from place to another throughout the rail network. In addition, these impacts may vary according the time of day, week, year. Hence, a full considerations of the possible impacts of passengers transfer (from road to rail) on rail congestion need to be explored and investigated as well as incorporated in the assessment process of rail schemes..

### *13.7.3 Rail User Benefits*

The study identifies the benefits of a rail investment scheme to fall in three categories, these are:

1) Net revenue to rail operator
2) Benefits to rail users
3) Benefits to non-users

The current practice of rail investment appraisal (financial appraisal) only considers the benefits of the investment to be the first category (net revenue to operator), assuming that the second category (user benefits) is recouped through the fare box and then is recouped as net revenue to the project. The study shows that, this is not always the case, unless perfect price discrimination is possible. Then rail users may enjoy some benefits as a result of the investment (consumer surplus).

The study showed that on the theoretical background, there will be a divergence between the economic benefits (measured as net revenue plus user benefits) and the financial benefits (net revenue) of an investment. The divergence is found to be a function of demand elasticity. However, more research is needed to explore and quantify this divergence practically. This would be by exploring practically the relationship between economic and financial benefits and investigating whether an exchange rate can be found between them.

### *13.7.4 Accident Benefits and Perception*

In measuring non-user benefits of rail schemes with respect to accident costs, the study considered accident costs to be a case of misperception that need to be corrected for in a comprehensive social assessment for rail schemes.

The study distinguishes between those costs of accidents that are perceived and not perceived by road and rail users. Then a calculation is made for estimating the correction to be made, and disaggregated by road types.

For road accidents, the costs of damage to vehicles and buildings, and user casualty costs are considered to be perceived, while pedestrians and cyclist casualties and police and administration costs are considered to fall outside the user decision of making a road trip.

More research is needed to explore the issue of accident cost perception. In particular, investigating the extent and magnitude of perceiving the costs of casualties. The study considered user casualties to be fully perceived by users. However one may argue that if this is correct for the driver, it might not be for the accompanied passengers. Also the study considered cyclist and pedestrians casualties are not perceived at all by road motorists. One may argue that this will vary between motorists themselves and the issue then need to be investigated more empirically. The same may be said about the cost of vehicle damage. This is assumed in the study to be fully perceived by motorists. However, assuming that motorists insure their cars, one may argue that damage costs only perceived as an insurance payments and then the full cost of damage is not perceived, especially the whole idea of insurance is to avoid the burden of the full cost of an accident. In this case, vehicle damage is only partly perceived by road users. Furthermore, some may argue that motorists may consider insurance payments as a fixed cost and may not affect their decision of making a road trip. In such a case, the cost of damage to vehicles is not at all perceived.

In conclusion, the issue of accident perception need to be explored and investigated in order to place a value judgements of the true perception of accidents.

### *13.7.5 Traffic Noise and Property Value*

In measuring the noise cost of both road and rail, the study used the figure 0.4 percent to indicate the reduction in house value for a unit increase in noise level ($L_{eq}$). This is the most recent figure used to indicate the impact of noise on the value of properties The calculations are based on the assumption of a straight line relationship between house prices and noise level.

More research is needed for identifying the relationship between house value and noise levels. A consideration of any other form of relationship (non-linear forms) is required. In addition, further work is required to investigate the value of the elasticity of house prices with respect to noise levels. In particular, an investigation of whether the value of the elasticity is changing with the level of noise would be useful. Also whether the depreciation of house values would vary across the regions within the country, and between urban residential and rural areas.

### *13.7.6 Developmental Benefits*

In principle the development and land use effects of rail schemes should be incorporated into the comprehensive social appraisal of that schemes. However, the degree to which transport schemes in general and rail projects in particular may promote economic development remains controversial (Hall and Hass-Klau 1985). A case example, where investment was justified mainly on the basis of developmental benefits is the London Docklands Light Railway scheme (Clarke and Cotton 1983). These benefits do seem to have occurred (Nash and Preston 1991).

Developmental benefits of rail schemes may vary according to the type of the project (new railway line, replacement investment, cost cutting investment etc.) and on the nature of the scheme area (very developed, undeveloped, industrial area, residential area). The issue of developmental benefits of rail schemes becomes more crucial in developing countries, where schemes may lead to industrial or agricultural developments or even reallocation of activities.

Whether rail schemes may have marginal developmental benefits is a case of further research. This may be explored through "after studies" as an assessment of the scheme contributions in developing the area of potential scheme impacts.

## 13.8 Attached Areas of Further Research

### *13.8.1 How to Correct for the Distortion?*

The study shows that the current practice of assessing road and rail investment (the first being based on cost benefit analysis, while the second is commercially assessed) creates a chance of misallocation of resource funds and then missing opportunities for railways. This in turn is translated into welfare losses to the society.

The measurement of non-user benefits of rail investment schemes shows that there is a considerable amount of benefits to non-users emerging from rail schemes. In turn if rail schemes are to be assessed on a social basis, these benefits ought to be incorporated in the appraisal framework.

In order to avoid the distortion created by applying different investment criteria to road and rail, and to bring the balance between the road and rail travel and investment, two routes can be followed:

1. Assessing investment schemes for both modes on the same basis. This can be achieved by using cost benefit analysis for both modes. Then non-user benefits measured in the study can be used as a basis for applying a comprehensive cost benefit analysis to rail schemes. As discussed above this may only achieve the balance between road and rail investment, but does not automatically mean an increase to rail share or avoiding the loss in welfare.
2. Given the organisational structure of railways, applying a comprehensive cost benefit appraisal to rail projects might not be possible. The alternative is to use some other policy options to correct for the distortion of using different appraisal methods. The study results can be used as a basis of designing and making over the difference between the financial and the social returns. The policies to be used have to be designed to match exactly the difference, and more research is required to test and examine some administrative options. As suggested above, a consideration and examination of the suitability of using grants and subsidies as an administrative toll would be very relevant and useful. In addition, more research in identifying and testing other options would be interesting.

### *13.8.2 Rail Privatisation*

With rail privatisation in due course, the amount of investment in railways is a crucial issue. The implications of privatisation on assessing and allocating investment funds for railways is a further area of research.

If rail privatisation is to establish and enforce the commercial incentive for railways, this would mean that investment fund would be justified on a commercial basis. In this case, the reset for some policy options to correct for the distortion become crucial and the two area of research can then be looked at jointly.

## References

1. **Department of Transport, DTp** (1977) *Report of the Advisory Committee on Trunk Road Assessment.* HMSO, London.

2. **Department of Transport** (1984) *Rail investment comparability study.* Final Report.
3. **Department of Transport** (1981) *COBA 9.* HMSO, London.
4. **Nash, C. and J. Preston** (1991) *Appraisal of Rail Investment Projects: recent British experience.* Transport Reviews, Vol. 11, No. 4, pp. 295-309.
5. **Nash, C. A. et al** (1992) *A review of rail research relevant to the case for increased rail investment.* ITS working paper 392, University of Leeds.
6. **Hall, P. and Hass-Klau, C.** (1985) *Can Rail Save the City? The Impacts of Rail Rapid Transit and Pedestrianisation in British and German cities.* Aldershot: Gower.
7. **Clarke, W. and Cotton, A.** (1983) *The choice of a light transit system for London Docklands.* Presented at Electrifying Urban Public Transport Conference, Blackpool.
8. **British Rail** (1994) *British Rail Annual Report 1994.* London.
9. **Tyson, W. J.** (1972) *A critique of road passenger transport subsidy policy.* Manchester School, December, pp. 397-418.
10. **Pryke, R.** (1977) *The case against subsidies*, in A policy for Transport, Nuffield Foundation, Oxford.
11. **Nash C. A.** (1982) *Economics of public transport.* Longman, London and New York.
12. **Houghton, J.** (1994) *Royal Commission on Environmental Pollution.* Eighteenth Report, Transport and the Environment. HMSO, London.

## List of References


1. **AA, The Automobile Association** (1994) *Motoring Costs 1994: A general guide to the costs of owning and running a car.* Basingstoke, Hampshire.
2. **Anderson T. V. et al** (1988) *Reactions to railway noise in Denmark: A correction.* Journal of Sound and Vibration, Vol. 120, no. 2, pp. 339-340.
3. **Adams J.** (1987) *Road safety as an environmental issue.* Friends of the Earth Conference, New Priorities in Transport.
4. **Adams, M.** (1990) *Capital Killer : Air Pollution from Road Vehicles.* London, London Boroughs Association Research Report.
5. **Adler, H. A.** (1987), *Economic Appraisal of Transport Projects*, Washington, World Bank.
6. **Bureau of Public Roads** (1964) *Traffic assignment manual.* US Department of Commerce, Washington, D. C.
7. **Bates J. and Lowe S.** (1989) *Criteria for Public Support in Urban Public Transport.* Presented at Summer Meeting of PTRC.
8. **Button, K. J. and A. D. Pearman** (1983), *The Practice of Transport Investment Appraisal.* Gower, England.
9. **Button K. J.** (1993), *Transport Economics.* 2nd Edition. Edward Elgar, London.
10. **British Railway Board**, (1976) *Environmental and social impact study (ENOSIS)*
11. **Baumol, W. J. and W. E. Oates** (1988). *The Theory on Environmental Policy* (2nd ed.). Cambridge University Press, Cambridge.
12. **British Rail** (1994) *British Rail Annual Report 1994.* London.
13. **Commission of the European Communities** (1992) *The impacts of transport on the environment-A community strategy for sustainable mobility.*
14. **Clarke, W. and Cotton, A.** (1983) *The choice of a light transit system for London Docklands.* Presented at Electrifying Urban Public Transport Conference, Blackpool.
15. **Carr, J. L.** (1967) *Efficiency in Government Spending (Commentary).* Public Finance, pp. 48-60.
16. **Church, A.** (1992) *London's transport system.* Geography, 334(77), part 1, PP. 84-7.

17. **Department of Transport, British Rail, London Regional Transport and London Underground Ltd** (1990*). Central Rail Study - a report on further work 1990.* Working Paper.

18. **Department of Transport DTp**, (1984) *Economic Evaluation Comparability Study : the application of the SACTRA framework and COBA principles to rail investment- Final Report.* Colin Buchanan and Partners, London.

19. **Department of Transport DTp** (1979) *"Report of the Leitch Committee" ACTRA* HMSO, London.

20. **Department of Transport** (1992) *Roads for Prosperity.* HMSO London.

21. **Department of Transport, DTp** (1992) *Road Lengths in Great Britain 1993.* Prepared by the government statistics service.

22. **Department of Transport, DTp** (1993) *Transport Statistics Report: Road Traffic Statistics Great Britain 1993.* Prepared by the government statistics service.

23. **Department of Transport, DTp** (1994a) *Transport Statistics Report: Road Traffic Statistics Great Britain 1994.* Prepared by the government statistics service.

24. **Department of Transport, DTp** (1994b) *Transport Statistics Report: Road Travel Speeds in English Urban Areas.* Prepared by the government statistics service.

25. **Department of Transport** (1991a) *"Transport Policies and Programme Submissions for 1992/93 - Information Required on Individual Major Highway Schemes"* . Highway Policy and Local Roads Division.

26. **Department of Transport** (1981 ) *COBA 9.* HMSO, London.

27. **Department of Transport** (1991b) *3/89 Annex A to Department of Transport Circular.*

28. **Department of Transport** (1983), *Manual of Environmental Appraisal.* HMSO, London.

29. **Department of Transport** (1994) *Transport Statistics Great Britain.* Report prepared by the Government Statistical Service, HMSO London.

30. **Department of Transport** (1989) *Section 56 Grant for Public Transport, circular 3/89*

31. **Department of Transport** (1993) *Road Accidents Great Britain.* HMSO, London.

32. **Department of Transport** (1981b) *Traffic Appraisal Manual.* HMSO, London.

33. **Department of Transport**, (1978), *Report of the Advisory Committee on Trunk Road Assessment* . Leitch Committee, London HMSO.

34. **Department of Transport** (1989), *National Traffic Forecast*. HMSO, London.

35. **Dernburg, T. F. and D. McDougall** (1976) *Macroeconomics: the measurement, analysis and control of aggregate economic activity*. Fifth Edition.

36. **Department of Transport DTp** (1991) *Railway noise and the insulation of dwellings*. HMSO.

37. **Department of Transport DTp** (1992) *Road Accidents Great Britain 1992*. London HMSO.

38. **Department of Transport DTp** (1993) *Road Accidents Great Britain 1993*. London HMSO.

39. **Department of the Environment** (1992) *The UK environment*. HMSO, London.

40. **Downs A.** (1962) *The law of peak-hour expressway congestion*. Traffic Quarterly, 16, 393-409.

41. **Dockery D. W. et al** (1989) *Effects of Inhalable Particles on Respiratory Health and Disease*. American Review of Respiratory Diseases. Vol. 139 pp. 587-594.

42. **Duncan, N. C. et al** (1980) *Traffic speeds in towns - a further analysis of the urban congestion surveys*. Traffic Engineering and Control, December 1980.

43. **Economist** (1992), *Planes, trains and automobiles*. 12 September 1992, pp. 91-2.

44. **Faiz A. et al** (1990) *Automotive Air Pollution : Issues and Options for developing Countries*. World Bank Working Paper WPS 492, August 1990.

45. **Fowkes A. S. et al** (1990) *The Track and External Costs of Road Transport*. Institute for Transport Studies, Leeds University, Working Paper 312.

46. **French H. F.** (1990) *Clearing the Air : A Global Agenda*. Worldwatch paper 94. Washington D C Worldwatch Institute.

47. **Flindell I. H.** (1983) *Reactions to transportation noise - A Comparative Study with special reference to railway noise*. Contract report 83/10. Institute of Sound and Vibration Research, Southampton University.

48. **Foster, C. D.** (1969) *Investment and finance theory and pricing: investment policy and pricing in transport*. Paper presented at the International Symposium on Transportation Pricing held at the American University, Washington, D. C. between June 16 and 20, 1969.

49. **Fields J. M. and Walker J. H.** (1982) *Comparing the relationships between noise level and annoyance in different surveys.* Journal of Sound and Vibration, vol. 81 no. 1 51-85.

50. **Foster, C. A.** (1960). *"Surplus Criteria for Investment".* Bulletin of the Oxford University Institute of Statistics. Vol. XXII . pp. 337-357

51. **Goodwin P. (1994)** *Traffic growth and the dynamics of sustainable transport policies.* Transport Studies Unit, University of Oxford.

52. **Gilbert, P.** (1973) *The effect of train noise on the environment.* Southampton Institute of Acoustics meeting 13-14 November.

53. **Houghton, J.** (1994) *Royal Commission on Environmental Pollution.* Eighteenth Report, Transport and the Environment. HMSO, London.

54. **Heintz, P. A. et al** (1980) *Zur Begrenzung der larmbelatung. Zurich Soziologisches* Institute der Univeresitat.

55. **Houtman J. W. and B. H. Immers** (1987) *A Traffic Assignment Model to Reduce Noise Annoyance in urban networks* . Transportation Research Record 1143. pp. 17-21

56. **Harrison A. J.** (1974), *The Economics of Transport Appraisal.* Croom Helm, London.

57. **Hall, P. and Hass-Klau, C.** (1985) *Can Rail Save the City? The Impacts of Rail Rapid Transit and Pedestrianisation in British and German cities.* Aldershot: Gower.

58. **Hopkin M. and O'Reilly D.** (1993) *Revaluation of the cost of road accident casualties:* 1992 revision TRL RR 378, Transport Research Laboratory, Growthorne.

59. **Harlow K. C. and D. Windsor** (1988), *Integration of Cost Benefit and Financial Analysis in Project Evaluation.* Public Administration Review, Vol. 48, no. 5, Sept./Oct. 1988.

60. **Harrison A. J. and P. J. Mackie** (1973), *The Comparability of Cost Benefit and Financial Rates of Return*, Government Economic Service Occasional Paper no. 5. HMSO, London.

61. **Holzapfel, H.** (1992) *Violence and the car.* Unpublished manuscript, University of Kassel.

62. **Hickman A. J.** (1990) *Personal Communication.* Transport and Road Research Laboratory, Vehicles and Environment Division.

63. **Holman C.** (1989) *Air Pollution and Health.* Friends of the Earth, London.

64. **Harland D. G.** (1978) *Rural Traffic noise Prediction - an approximation.* Transport and Road Research Laboratory, TRRL-SR 425.

65. **Hill, M.** (1968), *A goals Achievement Matrix for Evaluating Alternative Plans*, in Journal of the American Institute for Planners, vol. 34, pp. 19-29.

66. **Independent Commission on Transport** (1974) *Changing Directions.* Coronet, London.

67. **International Union of Railways IUR** (1987) *Railways and the Environment.* Brussels IUR.

68. **Joy, S.** (1973) *The train that ran away: a business history of British railways 1948-1968.* London, Ian Allan.

69. **Joy, S.** (1989) *Railway costs and planning.* Journal of Transport Economics and Policy: 23 pp. 45-54.

70. **Jones-Lee, M. W. et al** (1993) *The value of preventing non-fatal road injuries: findings of a willingness to pay national sample survey.* TRL Contractor Report 330, Transport Research Laboratory, Growthorne.

71. **Kanafani, A.** (1983) *The social cost of road transport.* OECD. Paris.

72. **Linkerhagner, W. and H. Amann** (1987) *The general federal railway's construction program - an active contribution to protecting the environment.* Rail International. Oct. PP. 23-27.

73. **Lang A. S. and R. M. Soberman** (1966) *Urban Rail Transit, its Economics and Technology.* Cambridge, Massachusetts, M.I.T. and Harvard University.

74. **Lardner, D.** (1850) *Railway economy, a Treatise on the New Art of Transport, its Management, Prospects and Relations, Commercial, Financial and Social.* London.

75. **Lichfield N.** (1956), *Cost Benefit Analysis in Town Planning: A case study of Cambridge.*

76. **Leftwich R. H. and R. D. Eckert** (1985), *The Price System and Resource Allocation.* Ninth Edition, The Dryden Press, New York.

77. **Lichfield, N. and Chapman, W.** (1968), *Cost benefit analysis and road proposals for a shopping centre- a case study.* Edgware, Journal of Transport Economics and Policy, 2, pp. 280-320.

78. **Leitch, Sir George (Chairman),** (1977), *Report of the Advisory Committee on Trunk Road Assessment.* HMSO, London.

79. **Marlow, M. et al** (1978) *Urban congestion study 1976: traffic flows and speeds in eight towns and five conurbations.* TRRL SR 438.

80. **Moheler, U.** (1988) *Community response to railway noise: A review of social surveys.* Journal of Sound and Vibration Vol. 120, no. 2, pp. 321-332.

81. **May. A. D. and et al** (1991) *The Development of a Common Investment Appraisal for Urban Transport Projects.* The Institute for Transport Studies, the University of Leeds and the MVA Consultancy, ITS Working Paper 348. December 1991.

82. **McGuire, M. and Gain, H** (1969), *The integration of equity and efficiency criteria in public project selection.* Economic Journal, 79, pp. 882-93

83. **Midland Main Line Consortium**, (1992), *The Role of Investment Appraisal in Road and Rail Transport: A response to the Department of Transport.* Public Transport Unit, Derbyshire County Council.

84. **Mohring, H.** (1972) *Optimization and Scale Economies in Urban Bus Transportation.* American Economic Review: Vol. 62 pp. 591-604.

85. **Mogridge, M.** (1990) *Travel in Towns.* Macmillan, London.

86. **Misham, E. J.** (1971) *The Post-war Literature on Externalities: An interpretative essay.* Journal of Literature, 9: pp. 1-28.

87. **Nelson, P. C. et al** (1989) *Air pollution and noise from road vehicles.* Paris background report for European Conference of the Ministers of Transport.

88. **Nelson, J. P.** (1978) *Economic Analysis of Transportation noise Abatement.* Ballinger Publishing company, Cambridge, Massachusetts.

89. **Nationwide** (1994) *House prices in 1994*, first quarter for 1994.

90. **Nash, C. and J. Preston** (1991) *Appraisal of Rail Investment Projects: recent British experience.* Transport Reviews, Vol. 11, No. 4, pp. 295-309.

91. **Nash C. A. et al** (1991a) *Evaluation of Road and Rail Projects: Issues and New Developments.* ITS, Leeds University.

92. **Nash C. A.** (1982) *Economics of public transport.* Longman, London and New York.

93. **Nash C. A et al** (1991b). *The Future of Railways and Roads.* Institute for Public Policy Research. London.

94. **Nash, C. A. et al** (1992) *A review of rail research relevant to the case for increased rail investment.* ITS working paper 392, University of Leeds.

95. **Newbery D.** (1988) *Road user charges in Britain.* Economic Journal (conference paper), 98, 161-76.

96. **Newbery, D. M. G.** (1987a) *Road user charges and the taxation of road transport.* IMF working paper WP/87/5. Washington D.C.

97. **Newbery, D. M. G.** (1987b) *Cost recovery from optimally designed roads.* Churchill college, Cambridge, England.

98. **Newbery, D. M. G.** (1987c) *Road user charges in Britain.* Discussion paper series, no. 174. Centre for Economic Policy Research.

99. **Newbery, D. M. G.** (1988) *Road user charges in Britain.* The Economic Journal. Vol. 98. pp. 161-176

100. **Newbery, D. M. G.** (1990) *Pricing and congestion: economic principles relevant to pricing roads.* Oxford Review of Economic Policy, vol. 6 no. 2.

101. **Nijkamp, P** (1994), *Roads Toward Environmentally Sustainable Transport.* Transport Research A. Vol. 28A no. 4 pp. 261-271.

102. **OECD** (1988) *Transport and the Environment.* Paris OECD.

103. **OECD**, (1990a) *Transport Policy and the environment: European* Conference of Ministers of Transport. OECD, Paris.

104. **OECD** (1988) *Transport and the environment.* Paris

105. **OECD** (1990b) *Environment Monographs no. 32, The social cost of land transport.* Paris.

106. **OECD** (1973) *The effects of traffic and roads on the environment in urban areas.* Paris, OECD, Road Research Group.

107. **OECD** (1986) *Fighting noise: strengthening noise abatement policies.* Paris.

108. **Pearce D. et al** (1993), *Blueprint measuring sustainable development 3.* Centre for Social and Economic Research in the Global Environment, Earthcan Publication Ltd, London.

109.**Prest A. R. and R Turvey** (1965), *Cost Benefit Analysis: A survey*. Economic Journal, Vol. LXXV, no. 300, December 1965.

110.**Peters, G. H.** (1968), *Cost benefit analysis and public expenditure*. Eaton Paper 8, Institute of Economic Affairs, London.

111.**Pryke, R.** (1977) *The case against subsidies*, in A policy for Transport, Nuffield Foundation, Oxford.

112.**Peaker A.** (1974*). The Allocation of Investment Funds Between Road and Rail: A Conversion Factor Linking Financial and Surplus Rates of Return*. Public Finance, PP. 49-55.

113.**Pearce, D. W., Barde, J. P. and Lambert, J.** (1984) *Estimating the cost of noise pollution in France*. Ambio, XIII, 27-28.

114.**Peeters A. L. et al** (1983) *Hinder door spooweqqeluid in de woonomgewing*. IMG-TNO report, D60.

115.**Pearce D. W. and Turner R**. (1990) *Economics of natural resources and the environment.* Harvester Wheatsheaf, Hemel Hempstead.

116.**Pearman, A. D.** (1978), *An assessment of Multiple Criteria Decision Making Methods and their Potential use in Comparability Studies between Trunk Road and rail investment.* Report prepared for the British Railway Board.

*117.***Ploweden, S. and Hillman, M.** (1984) *Danger on the road: the needless scourge.* London Policy Studies Institute.

118.**Planning R.** (1992) *Environmental Appraisal: A review of monetary evaluation and other techniques*. Transport and Road Research Laboratory, Contractor Report 290.

119.**Pearce D. W. and Markyanda A**. (1989) *The benefits of environmental policy*. OECD, Paris.

120.**Renner M.** (1988) *Rethinking the Role of Automobile*. Washington D. C., Worldwatch Institute.

121.**Ringheim**, J. (1983) *Semi-economic aspects of reducing the impact of road traffic noise in Norway.*

122.**Sadove A. and Fromm G.** (1965) *Transport investment and economic development*. London.

123.**Starkie, D. N. M.** (1979) *Allocation of Investment to Inter-urban Road and Rail.* Regional Studies, Vol. 13 pp. 323-336.

124.**Social Trends** (1994) *Social Trends 24.* Crown Copyright 1994.

125.**Sharp. C. and Jennings, T.** (1976) *Transport and the environment.* Leicester University Press.

126.**TEST** (1991) *Wrong side of the tracks? : impacts of road and rail on the environment: a basis for discussion.* London.

127.**Transportation Planning Associates** (1991) *" A Review of Traffic and Economic Appraisals of Local Authority Highway Schemes"* Final Report to the Department of Transport.

128.**Thomson J. M.** (1977) *Great cities and their traffic.* Gollancz Peregrine Edition, London.

129.**Tyson, W. J.** (1972) *A critique of road passenger transport subsidy policy.* Manchester School, December, pp. 397-418.

130.**Thomas R.** (1991) *Traffic assignment techniques.* Avebury Technical, USA.

131.**TRRL (Transport and Road Research Laboratory),** (1979a) *A study of speed-flow relations on rural motorways and all-purpose dual carriageways.* TRRL LF 779.

132.**TRRL** (1992) *Environmental appraisal: a review of monetary evaluation and other techniques.* Transport and Road Research Laboratory Contractor Report 290.

133.**TRRL (Transport and Road Research Laboratory),** (1979b) *Speed-flow formulae for rural motorways and all-purpose dual carriageways.* TRRL LF 780.

134.**TRRL (Transport and Road Research Laboratory),** (1980a) *A study of speed-flow geometry relations on rural single carriageways.* TRRL LF 923.

135.**TRRL (Transport and Road Research Laboratory),** (1980b) *Speed-flow geometry formulae on rural single carriageways.* TRRL LF 924.

136.**Vickrey, W.** (1969) *Externalities in public facility use: the case of highway accidents, in the analysis of public output.* Margolis, J. (ed.), National Bureau of Economic Research. New York, pp. 317-35.

137.**Vitaliano D. and Held J** (1991) *Road accident external effects: an empirical assessment.* Applied Economics, 23, 373-378.

138. **Verhoef** E. (1994), *External effects and social Costs of Road Transport.* Transportation Research A. Vol. 28A, no. 4 pp. 273-287.

139. **Vaughan B. C. et al** (1992) *"Comparability in Road and Rail Investment Appraisal: The Trans-Pennine Rail Study Example".* PTRC Summer Annual Meeting ,Siminar C, Manchester, September 1992.

140. **Wicke, L.** (1987) *An environmental damage balance sheet for the FRG. Symposium "the benefits of environmental polices".* Helsinki.

141. **Williams, J. B. et al** (1978) *Road Traffic and the environment.* London Social and Community Planning Research 390.

142. **Wohl M. and C. Hendrickson** (1984) *Transportation investment and pricing policy principles.* John Wiley & Sons. New York.

143. **Walker, J. G.** (1988) *A criterion for the acceptability of railway noise.* Southampton institute of Sound and Vibration Research. Southampton.

144. **Walsh M.** (1989) *The Global Importance of Motor Vehicles in the Climate Modification Problem.* International Environmental Reporter, pp. 261-275.

145. **World Health Organisation** (1990) *Impact on Human Health of Air Pollution in Europe, Geneva.* Submitted to the Economic Commission for Europe Executive Body for the Convention on Long-range Transport Air Pollution.

# Appendix 1

The following are the BASIC computer program developed for the measurement of non-user benefits of rail schemes. The program has been used in the measurement of marginal congestion cost, noise cost and vehicle operating cost misperception.

## 1. Flowchart of the Program


Impute: Road type (1 to 8)
Impute: Traffic Characteristics
Imput: Traffic distributions
January to December (12 month distribution)
Monday to Sunday (7 days distribution)
24 hour distribution
22 location point on the network
Speed-flow formula
Noise levele L10 formula
Vehicle operating cost formula
Output:hourly flow per lane and hourly average speed
Output: marginal time cost externality (MCTE)
Output: L10 (1 hour)
Output: VOC perceived and resource
Next location
Next hour
Next day
Next month
Output
: Average weighted MCTE by road class
: Average weighted speed by road class
: Average weighted L10 by road class
: Average weighted VOC by road class
Next road type

## 2. Program

```
1 open"distmc.out" for append as #10  :open"dissp.out" for append as #11
2 print #10," MCC distribution "
3 k=1: rem"motorways program"
8 cls:locate 1,10
10 dim  veh (29,24)
11 open"mway.out" for append as #1
12 print #1,"AMTC h/veh.km     AMCC p/veh.km    ASP noise level"
13  locate 4,1
14 cls: print;k
15 print"        cou        veh/h    speed        Tvehcles      MTC        TMTC"
16 locate 8,1
17 print "          MCC            TMCC"
18 Rem"enter road length and vehicle km traveled"
20 VKT =72.5*1000000000      : RL = 3.1 * 1000: VY = VKT / RL: AM = VY
/ 12
30 DIM MI(12), WI(7), HI(24), LI(20)

35 REM"enter monthly distribution"
40 FOR i = 1 TO 12
50 READ MI(i)
60 NEXT i
70 DATA 90, 87, 98,98,101,103,111,112,106,108,95,91

75 REM"enter weekly distribution"
80 FOR i = 1 TO 7
90 READ WI(i)
100 NEXT i
110 DATA 101.3, 102.3, 103.8, 102.4, 116.3, 85.2, 88.6

115 REM"enter huorly distribution"
120 FOR i = 1 TO 24
```

```
130 READ HI(i)
140 NEXT i
150 DATA 16.2,9.15, 7.4,7.85, 11.2, 27.5, 71.15, 164.5, 195.6, 155.8,144.75
,142.35, 136.2, 139.2, 146.6, 157.75, 184, 199.8 , 165.7, 113.5 ,77.8, 54.75,
39.95,28

151 REM"enter location distribution"
152 FOR i = 1 TO 20
153 READ LI(i)
154 NEXT i
155 DATA
19.5,30.1,40.7,49.2,55.6,62,68.3,74.7,81.1,87.5,94.4,102.7,110.9,119.1,127.3,135
.5,150.4,168,188.6,234.6

156 rem"flows per hour"
157 TMTC=0 :Tveh1=0:Tveh2=0 :cou=0 :TMCC=0 :TSP=0 :D1=0 :D2=0
:D3=0 :D4=0 :D5=0 :D6=0 :D7=0 :D8=0 : D9=0 :D10=0
158 R1=0 :R2=0 :R3=0 :R4=0:R5=0:R6=0:n1=0:n2=0:n3=0 :Tdba=0
:Tuc=0:Tul=0:Tuo=0:Tup=0

160 for m= 1 to 12 : for y= 1 to 7 :for h= 1 to 24 :for l= 1 to 20

167 veh=(vkt*MI(m)*wi(y)*hi(h)*li(l))/(100000000*365*24*RL*5)

168 rem"speed flow slope definition"
169 if veh=<1200 then 170 else 171
170 S=6/1000 : goto 179
171 S=27/1000
```

```
179 rem"speed an marginal time congestion cost calculations"
180 v=104-20/10+8/4-S*veh
181 TSP=TSP+v*veh
185 MTC=(S*veh)/v^2
190  TMTC=TMTC+MTC*veh*v
195 Tveh1=Tveh1+veh :Tveh2=Tveh2+veh*v

196
MCC=MTC*(1.3162)*(1.0195)*(.824*468.8+.088*859+.076*622.5+.011*3213.
7)
197 TMCC=TMCC+MCC*veh*v

198 cou=cou+1
199 locate 5,1


200 print,cou ;:print using"######.##"; veh,v;:print"    ";:print
using"##########.##";Tveh;:print"    ";:print using"##.######";MTC;:print"  "
;:print using"#######.####";TMTC ;:print using"###.##";n1,n2,n3
201 if MCC<=.4 then 202  else 203
202 D1=D1+veh :goto 221
203 if MCC<=.6 then 204 else  205
204 D2=D2+veh :goto 221
205 if MCC<=8 then 206 else 207
206 D3=D3+veh :goto 221
207 if MCC<=1 then 208 else 209
208 D4=D4+veh :goto 221
209  if MCC<=1.2 then 210 else 211
210 D5=D5+veh :goto 221
211  if MCC<=1.4 then 212 else 213
212 D6=D6+veh :goto 221
213  if MCC<=1.6 then 214 else 215
```

```
214 D7=D7+veh: goto 221
215  if MCC<=1.8 then 216 else 217
216 D8=D8+veh :goto 221
217  if MCC<=2 then 218 else 219
218 D9=D9+veh :goto 221
219 if MCC>2 then 220
220 D10=D10+veh :goto 221 :locate 17,1
:print;D1,D2,D3,D4,D5,D6,D7,D8,D9,D10

221 Rem"noise level calculations"
222 dba=10*log10(veh*5)+33*log10(v+40+500/v)+10*log10(1+5*0.145/v)-27.6
223 Tdba=Tdba+dba

224 rem"unpercieved VOC"
225 uc=(4.893-.461*.15)+(51.781-24.019*.15)/v+(.000114-.000059*.15)*v^2-
(1.383-1.383*.15+(72.554-72.554*.15)/v+(.000177-.000177*.15)*v^2)*.86-(5.744-
1.196*.15+(118.716-63.087*.15)/v+(.000209-.000154*.15)*v^2)*.14
226 ul=0.718*.85-1.616*.85+(30.760*.85-69.372*.85)/v+(.000079*.85-
.000178*.85)*v^2
227 uo=2.832-5.966+(35.695-84.240)/v+(.000157-.000371)*v^2
228 up=2.832-6.683+(45.688-107.799)/v+(.000134-.000317)*v^2
229 Tuc=Tuc+uc*veh*v :Tul=Tul+ul*veh*v :Tuo=Tuo+uo*veh*v
:Tup=Tup+up*veh*v

245 locate 9,1
250 print using"##########.####";MCC;TMCC

251 if v<=60 then 252 else 253
252 R1=R1+veh :goto 262
253 if v<=70 then 254 else 255
254 R2=R2+veh :goto 262
```

```
255 if v=<80 then 256 else 257
256 R3=R3+veh: goto 262
257 if v<=90 then 258 else 259
258 R4=R4+veh :goto 262
259 if v<=100 then 260 else 261
260 R5=R5+veh :goto 262
261 if v>100 then R6=R6+veh

262 if veh<1200 then 266 else 263
263 if veh=1200 then 267 else 264
264 if veh>1200 then 268
266 n1=n1+veh*v :goto  269
267 n2=n2+veh*v: goto 269
268 n3=n3+veh*v :goto 269
269 n=n1+n2+n3

275 next:next:next:next
276 print"  average MTC (H/veh.km)      Average MCC(p/veh.km)  average
speed km/h"
277 AMTC=TMTC/Tveh2 : AMCC=TMCC/Tveh2  :ASP=TSP/Tveh1
:Adba=Tdba/40320 :c=Tuc/Tveh2 :l=Tul/Tveh2 :o=Tuo/Tveh2 :p=Tup/Tveh2

278  print using"###.####";AMTC;AMCC;ASP
279 print#1,"mway": write #1, AMTC, AMCC, ASP, Adba,c,l,o,p
280 print#10,"mway": write #10, D1, D2, D3, D4, D5, D6, D7, D8, D9 ,D10
281 print#11,"mway":  write #11, R1,R2,R3,R4,R5,R6


290 end :stop
```